

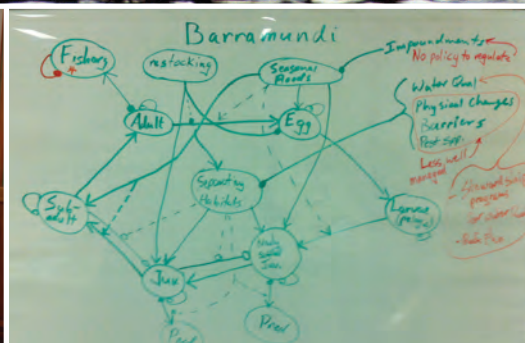


National Environmental
Research Program

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



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

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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 a 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.

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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 Arslan 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 other 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

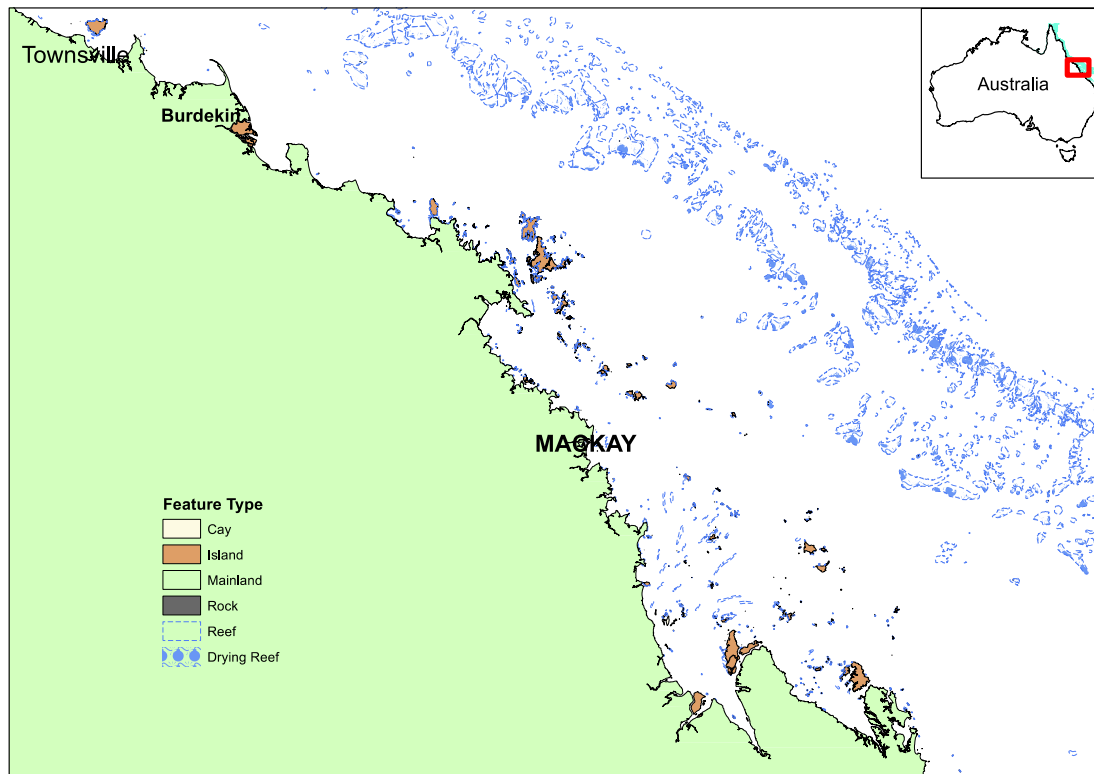


Figure 1. Map showing the area of the two case studies south of Townsville and the Mackay surrounds.

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 Broomsound 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.

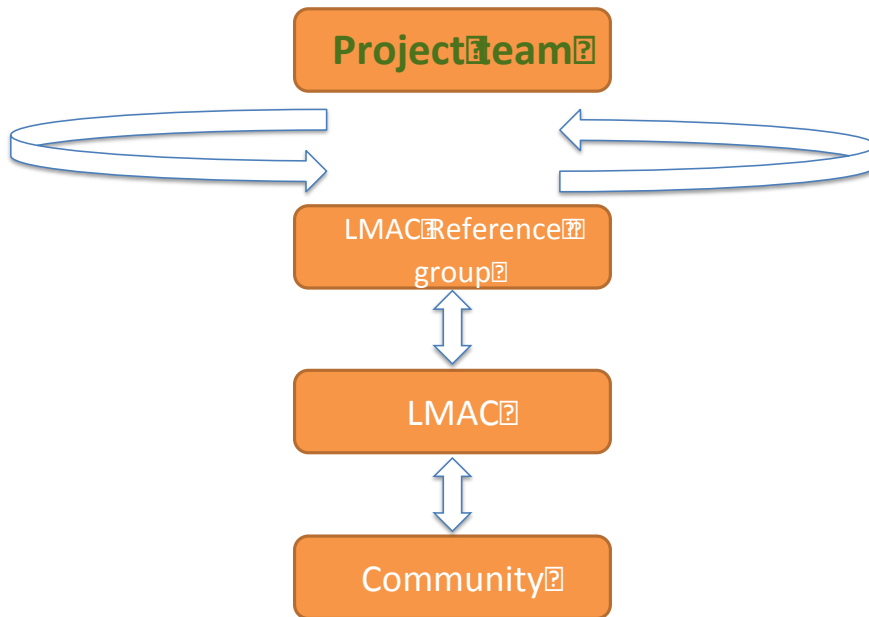


Figure 3. Community engagement process used in Mackay and attempted in Burdekin.

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 LM AC sub-committee and LM AC	LM AC 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	One to one or small group interviews to determine list of objectives
		Sub-committee member awareness and knowledge of each other's responses. Agreement on the set, summarising and rewording	Anonymity of responses between respondents
		(v) of objectives by the stakeholder group at a meeting	Email confirmation and comment on wording and summarising of objectives from stakeholders
4	Weight objectives relative to each other (see Section 7)	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 LM AC.	Researchers to reword and summarise list of objectives into Hierarchical tree with predefined groups of objectives (environmental, socio-economic, and governance)
		Objectives weighted by LM AC and sub-group.	Tentatively planned (<i>weighing of objectives can be implemented at LM AC session if members choose to do so</i>)
		Weighing of objectives by public via survey form and	Not planned at this stage (<i>weighing of objectives by</i>

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	<i>public may be implemented if LMAC or other local organisation choose to do so)</i>
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/EventManager/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 $\min[\max(x); Q3 + 1.5(Q3 - Q1)]$ of the data vector x and the lower whisker is $\max[\min(x); Q1 - 1.5(Q3 - Q1)]$. Any values outside these whiskers are shown as outliers.

Defining stakeholder groups

Additional information was obtained from survey 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)
	Not specified	Agriculture, NRM in general and fisheries (42)
7. Conserve traditional activities, culture and products	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)
	Links to maintaining social capital	Fisheries (42)
9. Maintain/enhance resilience	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)
	Not specified	Mining (42)
10. Enhance quality of life	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	- Number of conflicts [Foresters] and local users of the resource	Fisheries (42)
- Gear conflicts - Interacting fisheries - Recreational / commercial		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	Local Government (43, 50)
	Median Size of new residential lots	
	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	Fisheries (51)
	• Return on investment	
	• Secure levels of living of farmers	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	Compliance costs to industry	Fisheries (42)
- Industry compliance costs - Government costs	- Total management costs (recoverable and non-recoverable) - Infrastructure costs	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
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Objective	Possible Indicator	Sector and references
1. Improve water and stormwater quality to protect environmental values	- 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)
	- Freshwater - Dissolved inorganic Nitrogen (DIN) - Dissolved Inorganic Phosphorous (DIP) - Chl-a - Diuron (herbicide) - Atrazine (herbicide) - Hexazin (herbicide) - Ametryn (herbicide) - Simazine (herbicide) - Thebuthiron (herbicide) - pH - Coliforms - Total Phosphorous (TP) - Ammonia - Temperature - TOC - Al - Fe - Freshwater (event based) - Total suspended solids - PN - DIN - PP - DIP	State Government (53)
	Macroinvertebrates	State Government (54)
	- 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	- Bycatch of threatened, endangered, protected (TEP) species (number) - Total bycatch (number, weight)	Fisheries (42)
- TEP species - All species		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 - DO - pH - Electrical conductivity - Water temperature - 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. Strengthen 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 - Hymenacnae - 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 (<i>Aponogeton queenslandicus</i>))		State Government (55)
17. Control illegal collection of wild plants (e.g. orchid <i>Phaius australis</i>) and animals (e.g. spiders <i>Selenocosmia crassipes</i> and <i>Sele not ypus plum ipes</i>)		State Government (55)

Objective	Possible Indicator	Sector and references
18. Minimise road kills (northern quoll (<i>Dasyurus hallucatus</i>))	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 water flow 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 and 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 water flow regimes (39, 16)	Environmental	Environmental	Comment: already regulated; Comment 2: 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 (<i>Aponogeton queenslandicus</i>))	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 <i>Phaius australis</i>) and animals (e.g. spiders <i>Selenocosmia crassipes</i> and <i>Selenotypus plumipes</i>)	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
	Increased management integration (policy, regulation, implementation) (-)	(31,27)	
		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	

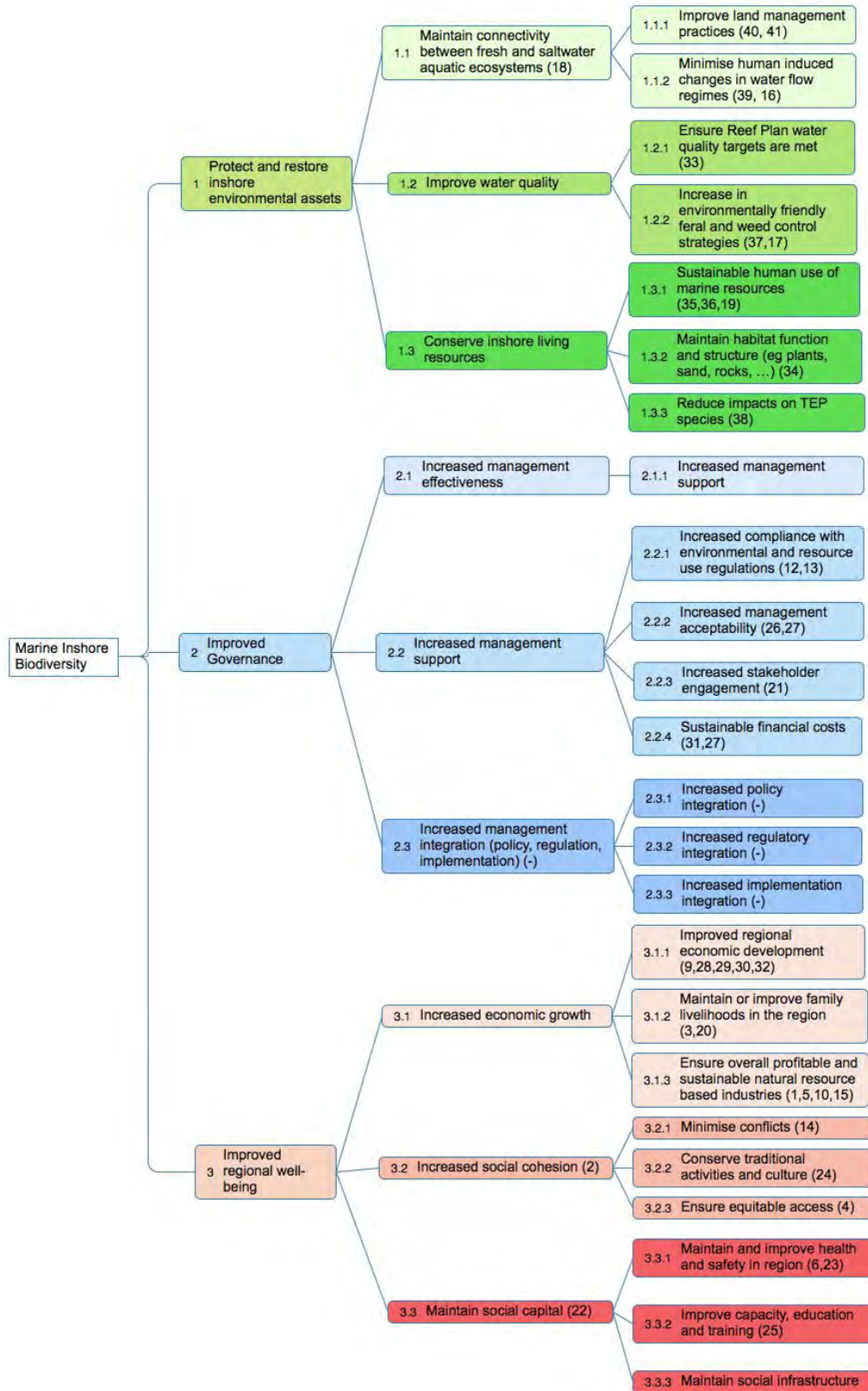


Figure 4. Initial objectives hierarchy discussed with the Mackay reference group on the 1st of March 2013.

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

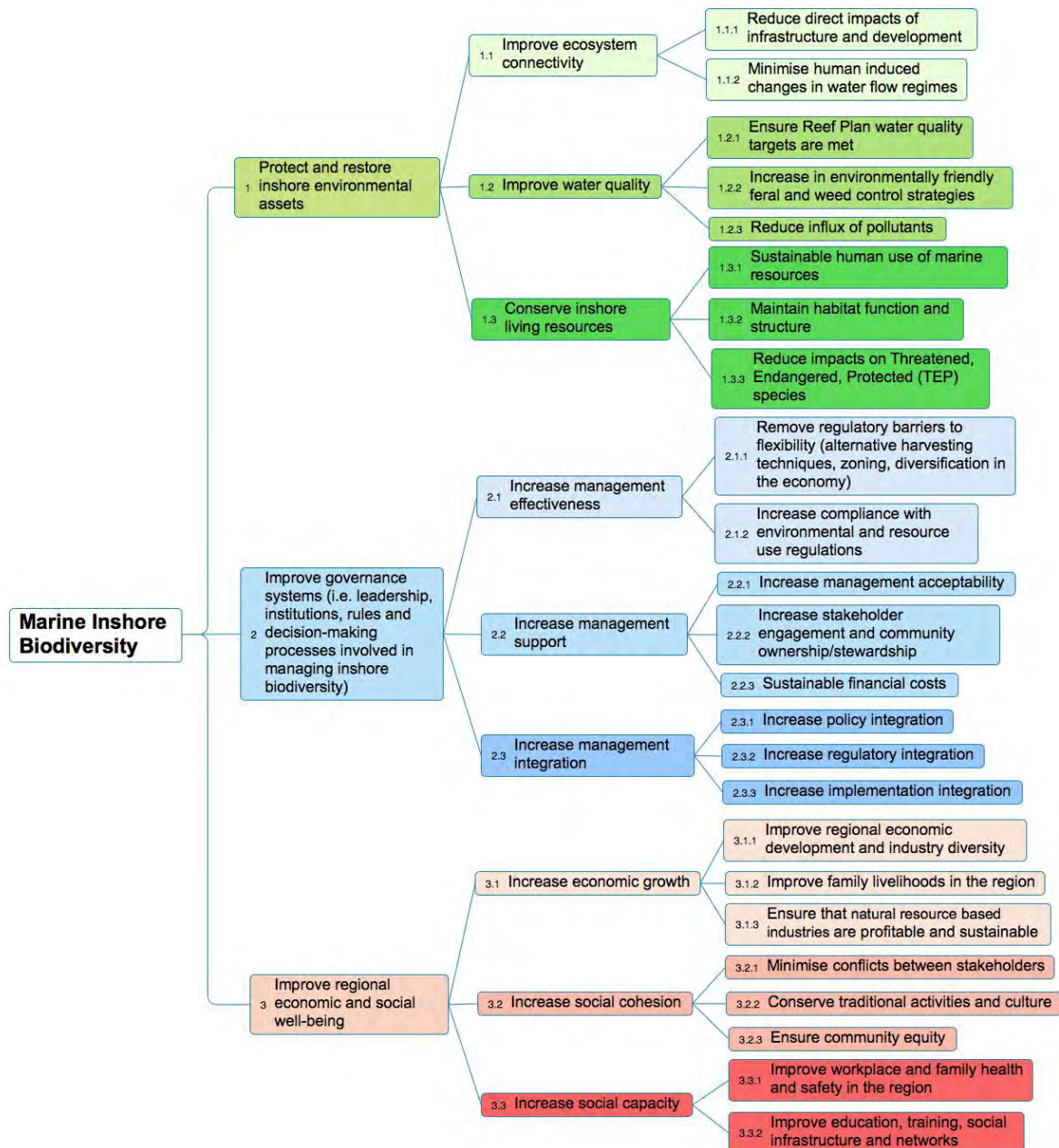


Figure 5. Objective hierarchy for inshore biodiversity management in the Mackay region, based on input from the Mackay Reference Group and LM AC.

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

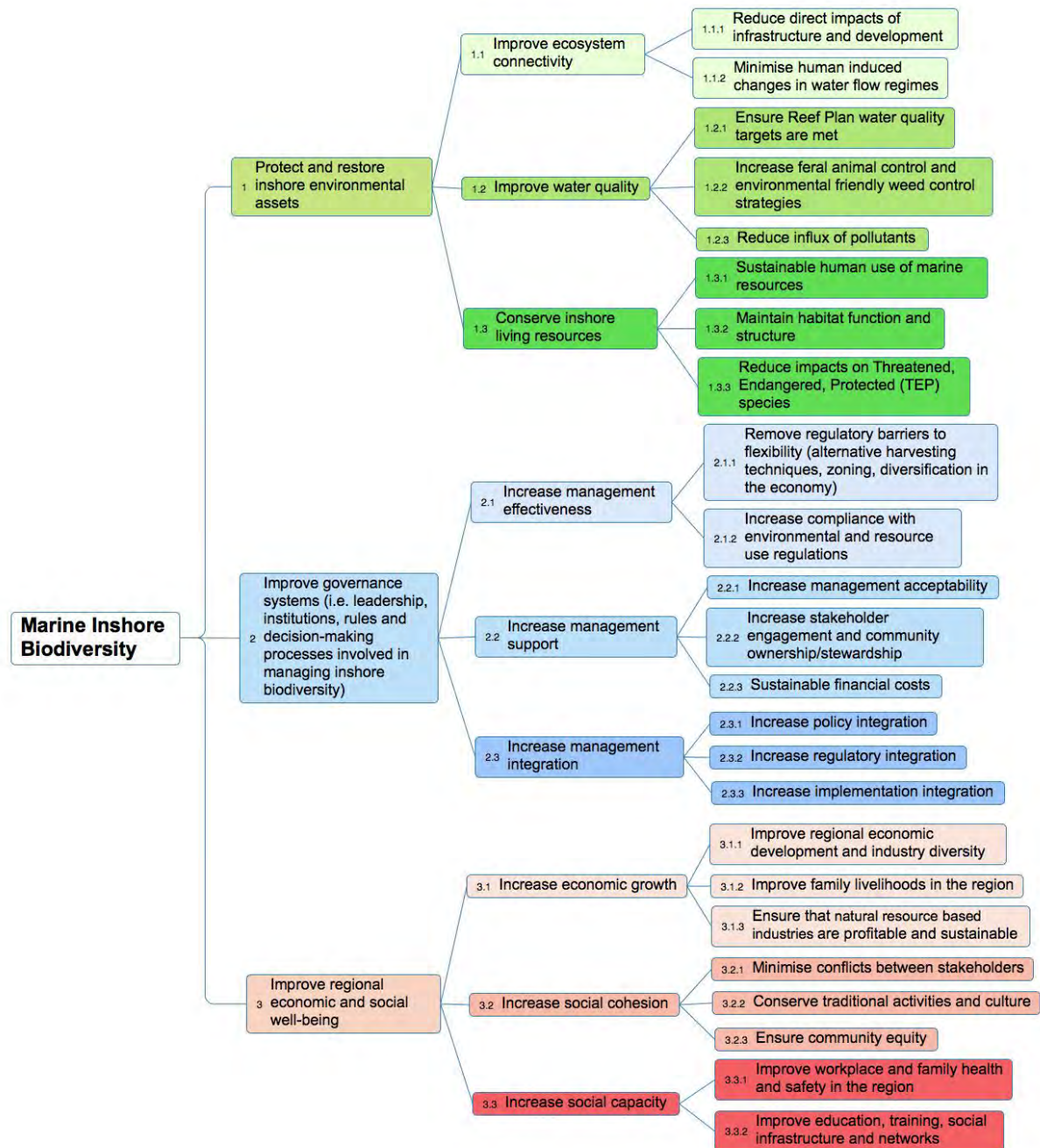


Figure 6. Third and final revised objective hierarchy for inshore biodiversity management in the Mackay region, based on input from the Mackay Reference Group and LM AC.

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 Wales border, which includes

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

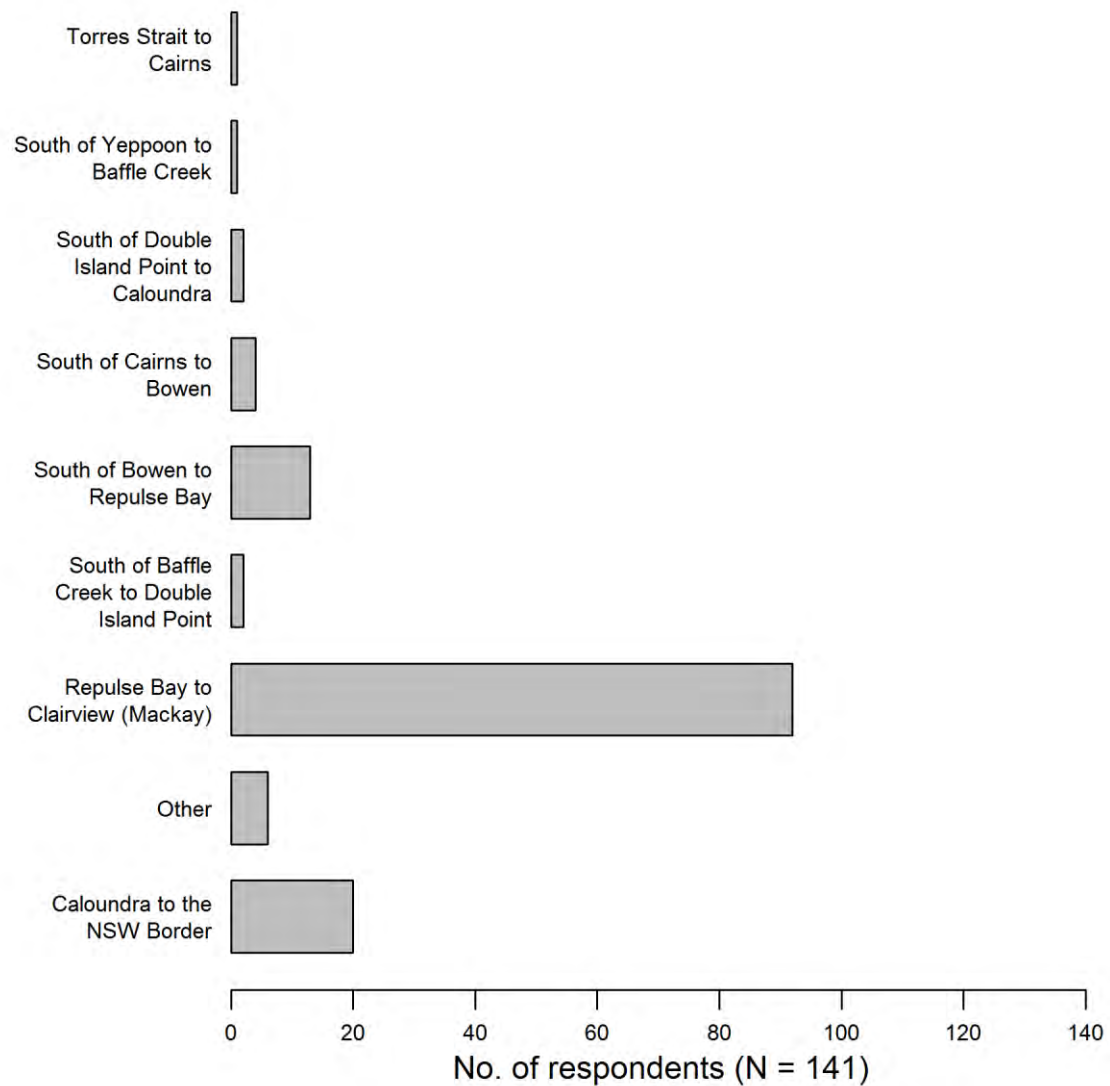
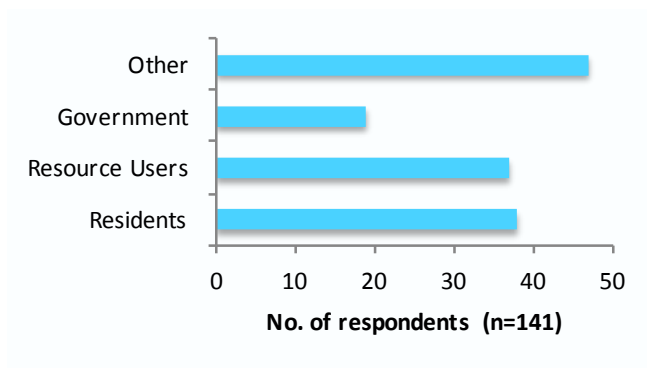
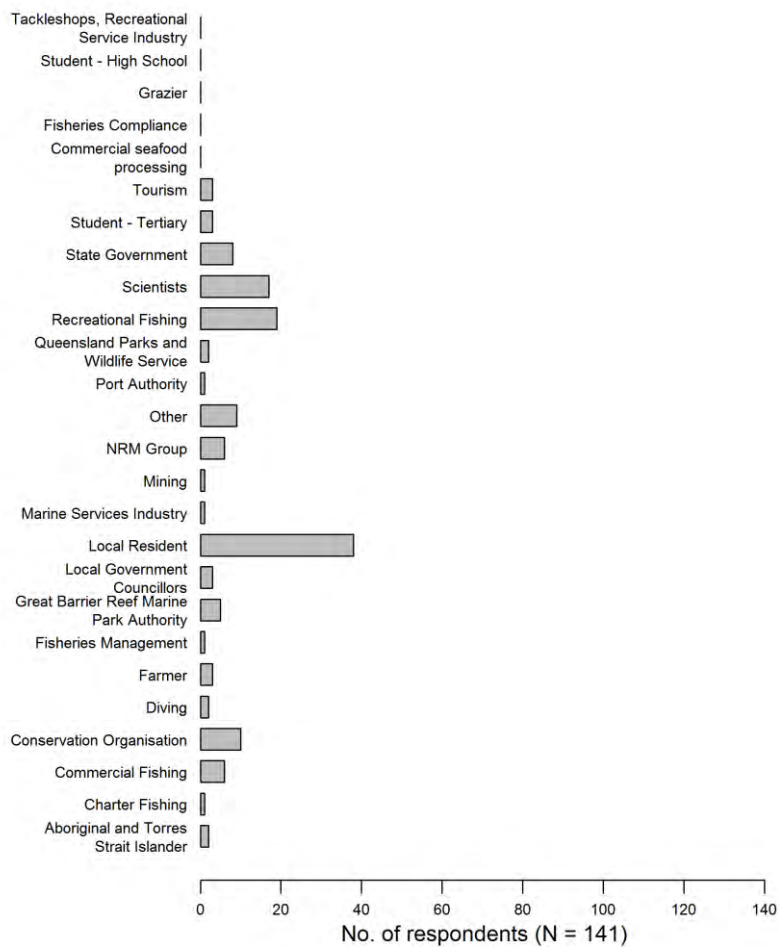


Figure 7: Total number of survey respondents by region.

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).



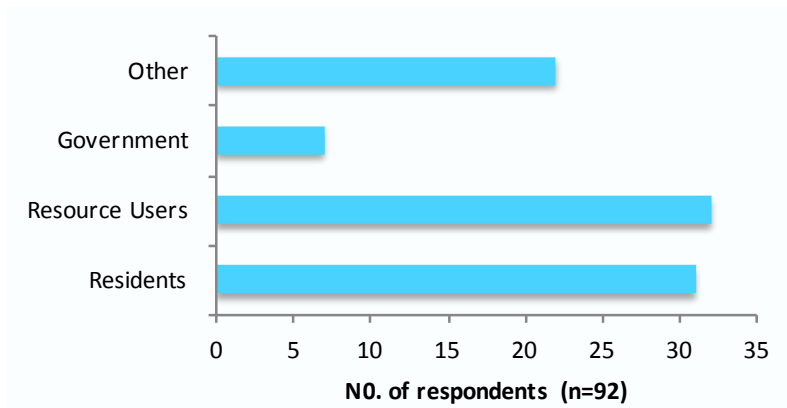
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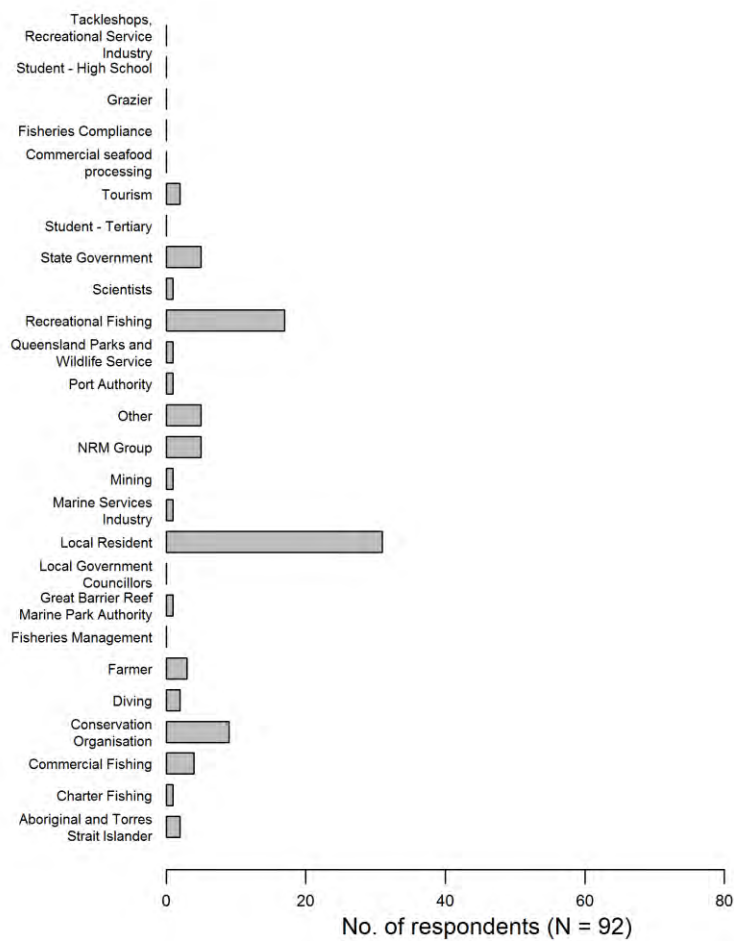
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Figure 8: Total number of respondents for all survey respondents. A) Broader stakeholder categories, B) stakeholder groups as per survey questionnaire.

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).

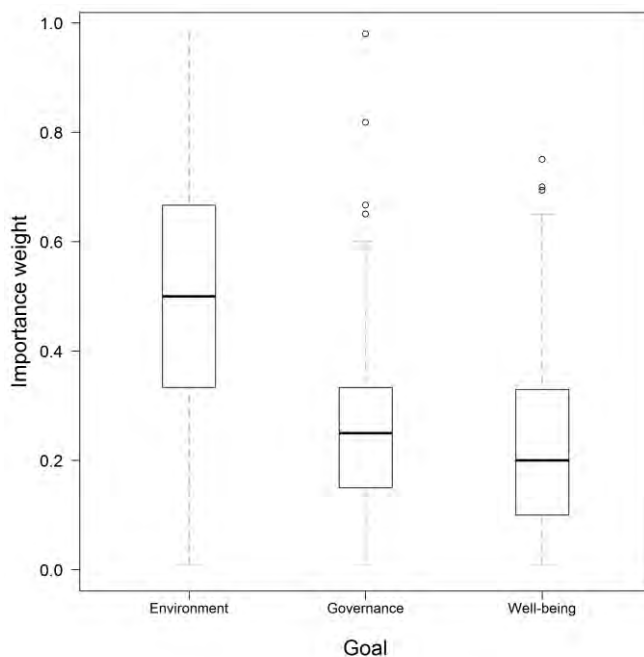


Figure 10: Box and whisker plot of the relative weights of the high order objectives by region.

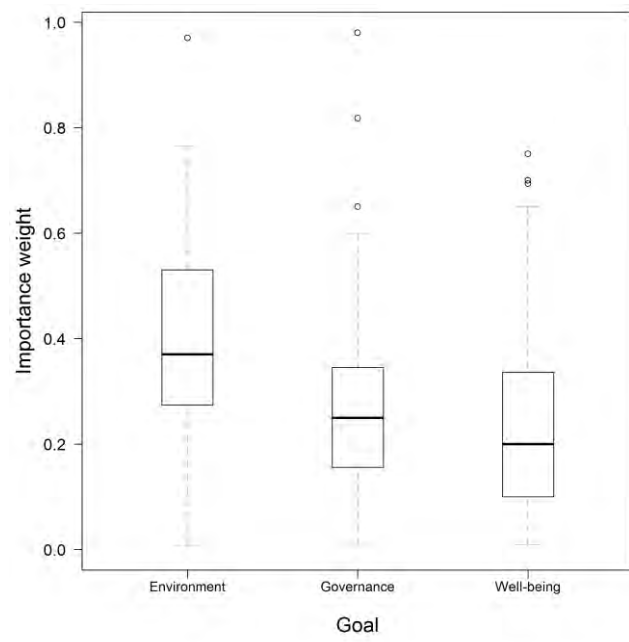


Figure 11: Box and whisker plot of the relative weights of goals for the Mackay region.

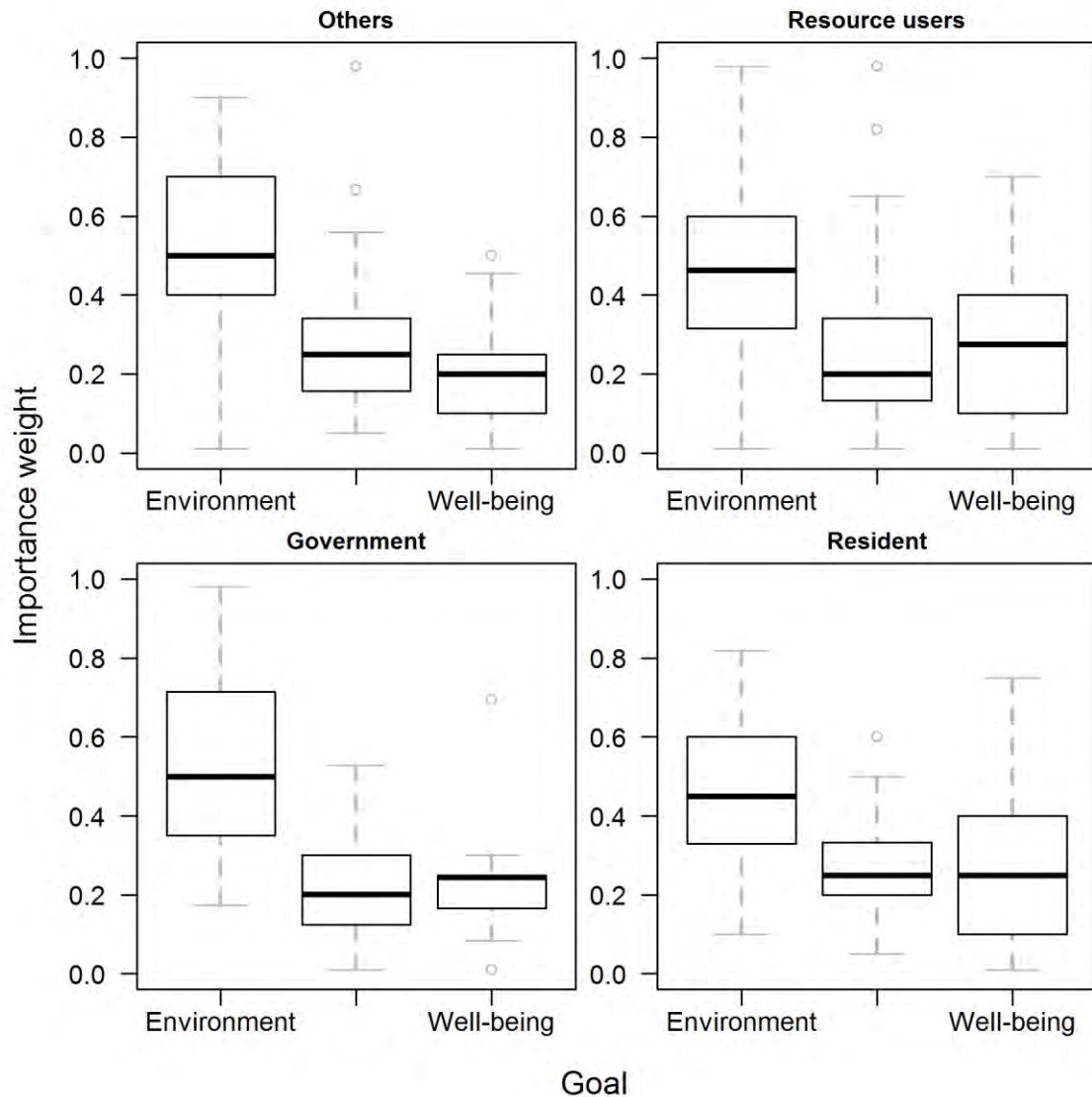


Figure 12: Relative weights of goals per stakeholder group.

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).

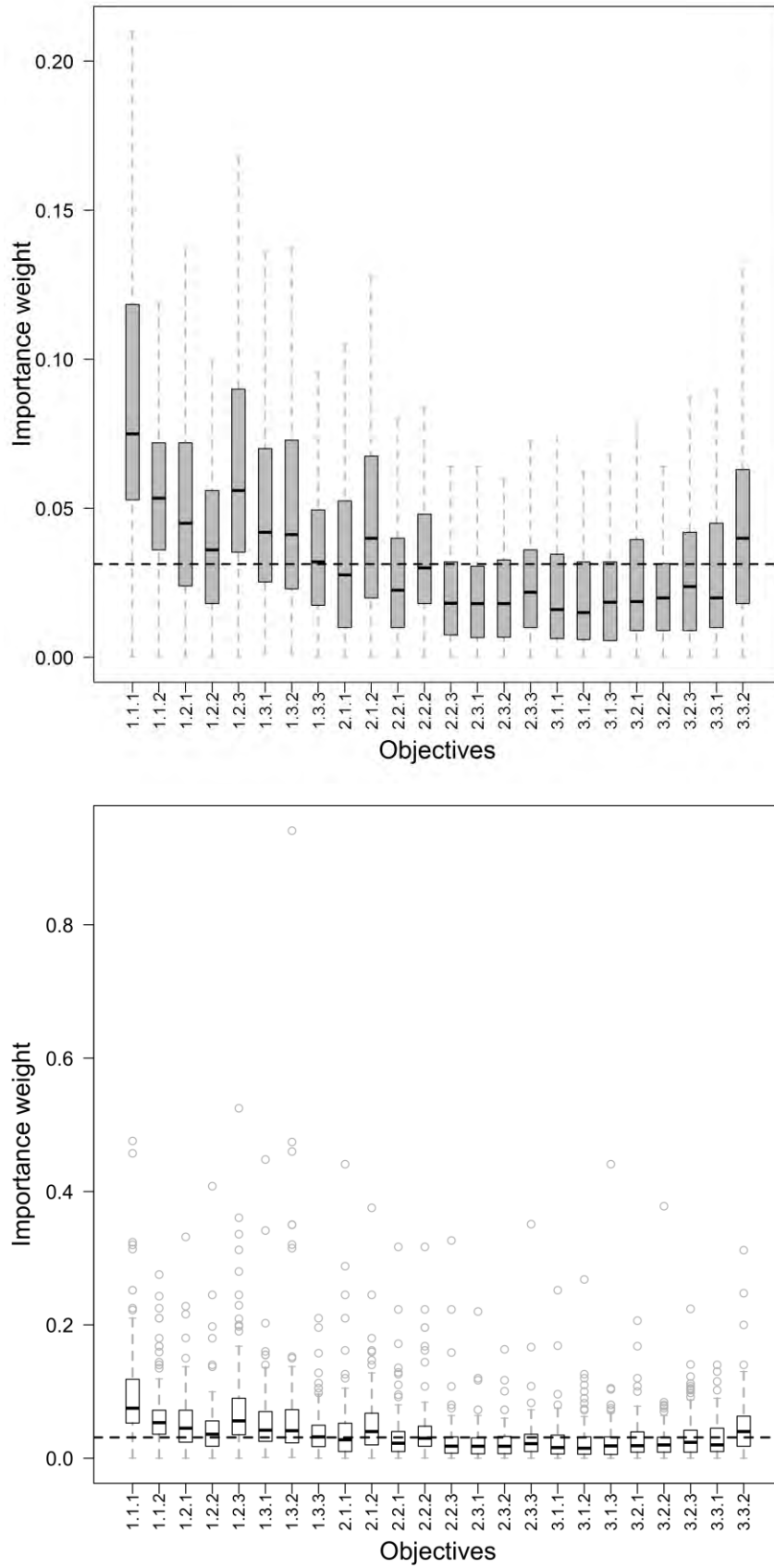


Figure 13: Box and whisker plot of the relative weights of objectives for all regions with (top) and without (bottom) outliers.

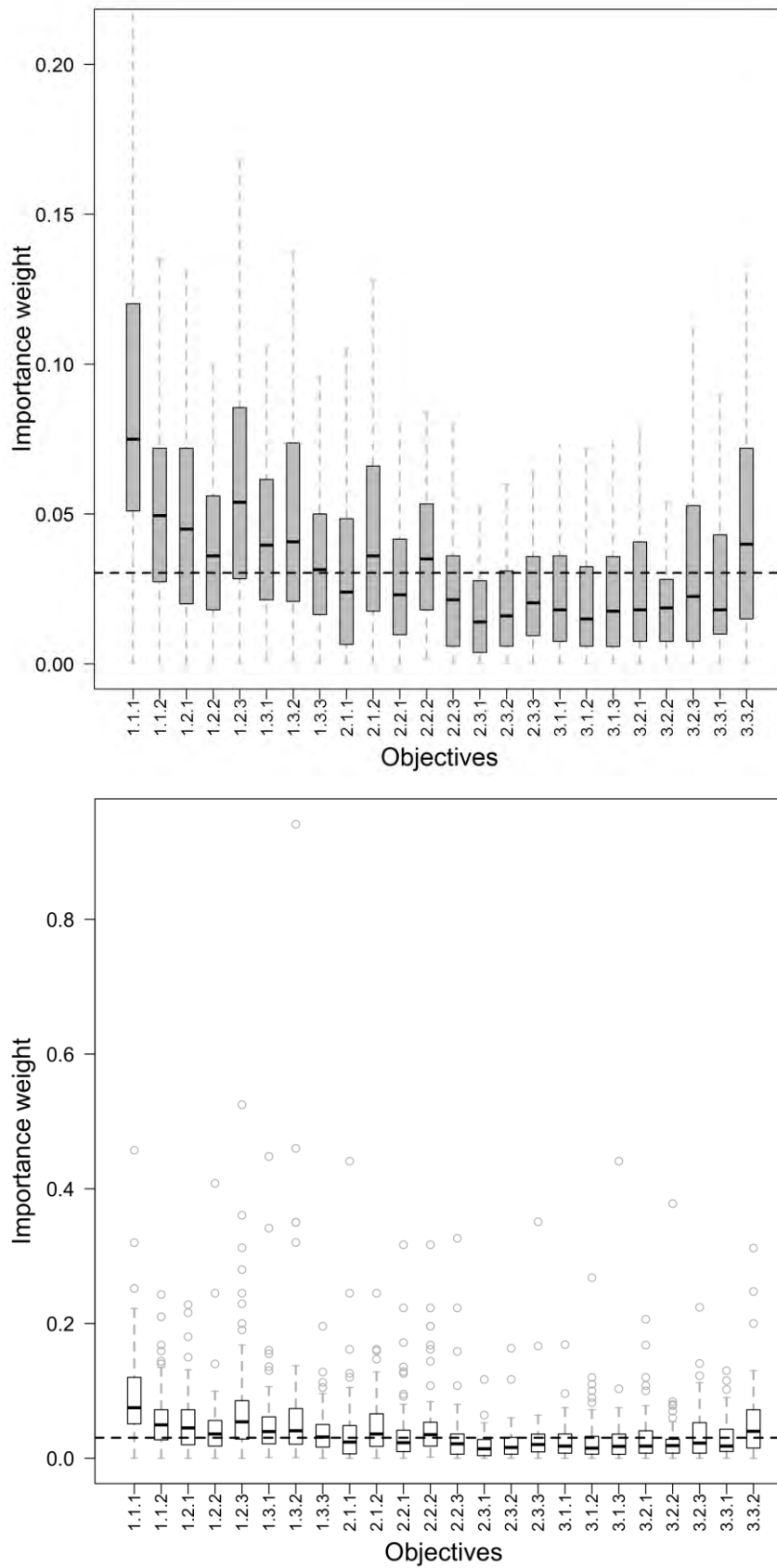


Figure 14: Box and whisker plot of the relative weights of the objectives for the Mackay region with (top) and without (bottom) outliers.

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	Fresh water 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.	Fresh water 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, health care, 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) Commonwealth (62)
	b	Increase community resilience to climate change pressures through planning and building of capacity	Community capacity & resilience	
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 knowledge 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 of 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 compensatory 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

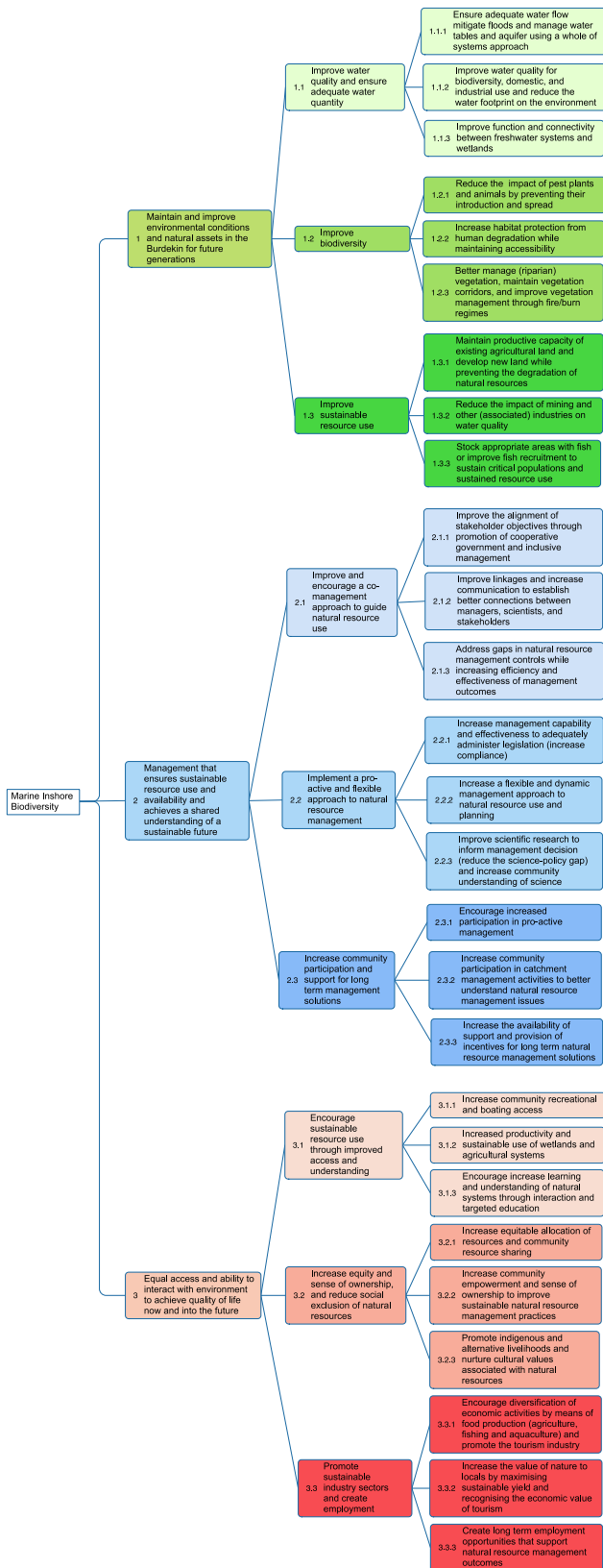


Figure 16: Final objectives tree for Bowen-Burdekin.

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 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

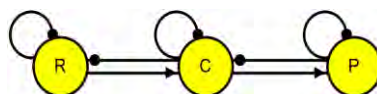
8.1 Introduction

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 ($\rightarrow$)), and the prey receives a negative direct effect (i.e., mortality, which shown as link ending in a filled circle ($\bullet\rightarrow$)). 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.

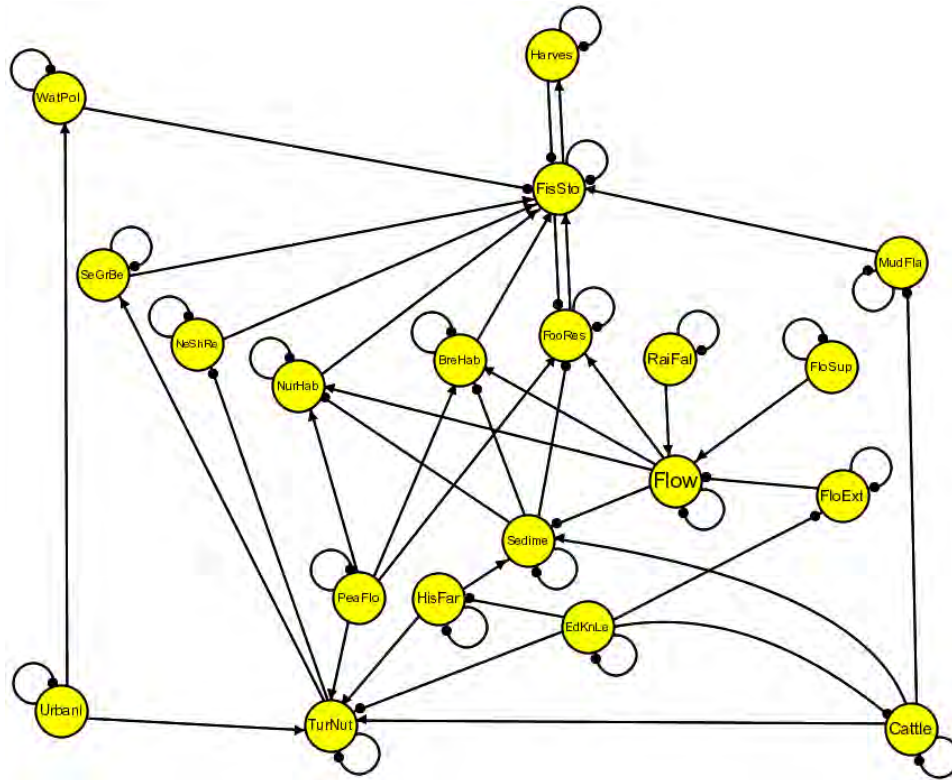


Figure 17: Creek Habitats & Cumulative Impacts model. BreHab: Breeding Habitats for fish stocks, Cattle: Cattle Farming, EdKnLe: Education Knowledge & Learning, FisSto: fish stocks, FloExt: Flow Extraction, FloSup: Flow Supplementation, Flow : river flow , FooRes: Food Resources, Harves: Harvest, HisFar: 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 from 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.

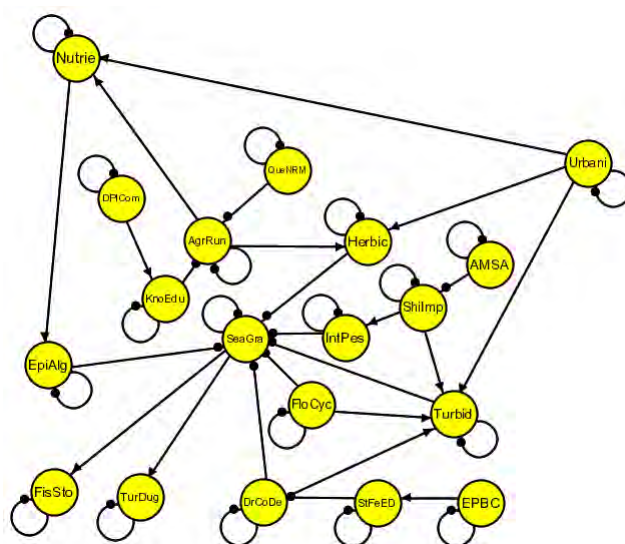


Figure 18: Sea Grass & Coastal Development model. AgrRun: Agricultural Runoff, AMSA: Australian Maritime Safety Authority, DPICom: Dept. Primary Industries Community Outreach, DrCoDe: Dredging from Coastal Development, EPBC: Environment Protection and Biodiversity Conservation, EpiAlg: Epiphytic Algae, 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).

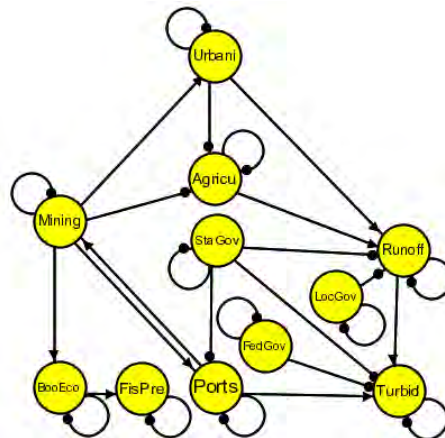


Figure 19: Coastal Development (i) model. Agricu: Agriculture, BooEco: boom economy, FedGov: Federal Government, FisPre: fishing pressure, LocGov: Local Government, Mining: mining industry, Ports: port developments & activities, Runoff: land use runoff, StaGov: State Government, Turbid: Turbidity, Urbani: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

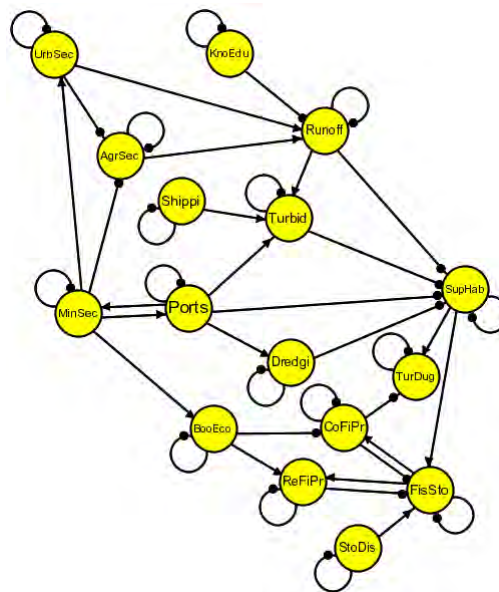


Figure 20: Coastal Development (ii) model. AgrSec: agricultural sector, BooEco: boom economy, CoFiPr: commercial fishing pressure, Dredgi: dredging, FisSto: fish stocks, KnoEdu: knowledge & education, MinSec: mining sector, Ports: port developments & activities, ReFiPr: recreational fishing pressure,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

Table 19: Description of links in signed digraph of above figure.

To	From	Comment
SupHab	Runoff	Degradation from sediment loads
SupHab	Turbid	Habitat degradation
SupHab	Dredgi	Habitat degradation
SupHab	Ports	Habitat degradation
TurDug	SupHab	Critical habitat & resource for turtles and dugongs
FisSto	SupHab	Critical habitat & resource for turtles and dugongs
FisSto	StoDis	Enhances productivity following storms
TurDug	CoFiPr	Mortality from encounters with fishing gear
CoFiPr	FisSto	Fishing pressure increases with catch
FisSto	CoFiPr	Harvest mortality
CoFiPr	BooEco	Labour shortage on fishing vessels from competition with mining jobs
ReFiPr	BooEco	Disposable income invested in high-end vessels, which increases fishing power
BooEco	MinSec	Boom economy driven by mining sector
MinSec	Ports	Mining sector depends on ports
Ports	MinSec	Ports depend on mining sector
Turbid	Ports	Ports contribute to near shore turbidity
Turbid	Shippi	Shipping contributes to near shore turbidity
AgrSec	MinSec	Mining sector suppresses agriculture
UrbSec	MinSec	Mining sector drives urban growth
AgrSec	UrbSec	Urban sector suppresses agriculture
Dredgi	Ports	Ports increase dredging activity
Turbid	Runoff	Runoff increases turbidity
Runoff	AgrSec	Source of runoff
Runoff	UrbSec	Source of runoff
KnoEdu	Runoff	Knowledge and education works to reduce runoff from urban and agriculture sectors

8.3.1.2 BURDEKIN LMAC REFERENCE GROUP

The first of two meetings were held with the Burdekin LMAC RG on May 14, 2013 and produced a list of key assets to the region and a barramundi model.

Attendees: CSIRO, GBRMPA, LMAC members, Burdekin Council

Asset
Wetlands - Habitat for migratory birds (subset of wetlands) - Riparian vegetation
Land use - Ownership, stewardship - Economic and social - Infrastructure
Fish resources (barramundi, mud crabs)

River
Inshore coral
Seagrass
Mangroves
Water resources - surface - subsurface - Ocean
Wildlife

Model 1. Barramundi model (i)

A life-stage model of barramundi was developed to describe the inter-relationships of various impacts, including commercial and recreational fishing, changes to stream flow, habitat and water quality, and the influence of fish stocking programs (see Figure and Table below). The model includes the influence of a black market for recreationally caught barramundi, which acts to increase effort in the recreational fishery and suppress the commercial fishery. Included also is life stage-specific protandrous hermaphroditism, in which younger (and smaller) adults are all males prior to maturing into females, and also cannibalism, where barramundi consume individuals of the previous (smaller) life stage.

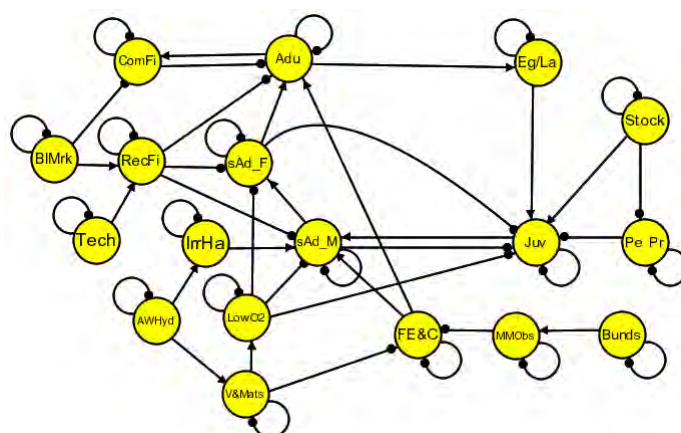


Figure 21: Barramundi model from the Burdekin LMAG reference group. Adu: adult barramundi, AWHyd: altered wetland hydrology, BIMrk: black market for recreationally-caught fish, Bunds: bunds (small dams), ComFi: commercial fishing, Eg/La: barramundi egg and larvae, FE&C: flow events and stream channel connectivity, IrrHa: irrigation-based habitat, Juv: juvenile barramundi, Low O2: low dissolved oxygen, MMObs: man-made obstructions, Pe Pr: pest and predator species, RecFi: recreational fishing, sAd_F: subadult female barramundi, sAd_M: subadult male barramundi, Stock: stocking of juvenile barramundi, Tech: fishing and sport equipment technology, V&Mats: vegetation and mats.

Table 20: Description of links in signed digraph of above figure.

To	From	Comment
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To	From	Comment
Eg/La	Adu	Fecundity & reproduction
Juv	Eg/La	Life stage development
sAd_M	Juv	Life stage development
sAd_F	sAd_M	Life stage development
Adu	sAd_F	Life stage development & maturation
Juv	Stock	Stocking of hatchery reared juvenile barramundi
Pe Pr	Stock	consumption of pest and predator species by stocked barramundi
Juv	Pe Pr	Suppression of juvenile barramundi by pest and predator species
FE&C	MMObs	Changes to hydrology and stream connectivity from man-made obstructions to stream flow
sAd_M Adu	FE&C	Life-cycle requirements dependent on stream migration natural flow regimes
FE&C	V&Mats	Obstruction of stream flow by vegetative mats
LowO2	V&Mats	Reduction in dissolved oxygen from biological oxygen demand of decaying vegetation and reduced stream flow
Juv sAd_M sAd_F	Low O2	Low levels of dissolved oxygen suppresses growth and survival of barramundi life stages
ComFi RecFi	BlMark	Black market for recreationally-caught barramundi suppresses commercial fishery and increases recreational fishery
sAd_M	IrrHa	Irrigation channels provide rearing habitat for subadults
Adu sAd_F sAd_M	RecFi	Fishing mortality to barramundi life stages
Adu	ComFi	Fishing mortality to adult barramundi
IrrHab V&Mats	AWHyd	Altered wetland hydrology contributes to irrigation-based habitat and also vegetation and mats
Juv	sAd_M sAd_F	Cannibalism-based mortality of juvenile barramundi
RecFi	Tech	Increased catchability from increased availability of fishing technology and sports equipment
ComFi	Adu	Commercial fishing effort sensitive to relative abundance of adult barramundi

The second meeting in Burdekin was held on the July 2, 2013.

Attendees: CSIRO, GBRMPA, LMAC, Burdekin Council

Model 2. Social value of fishing and governance

A model was developed to describe the social values, and the personal, family and community dynamics associated with fishing or harvest activities (see Figure and Table below). The principle driver of harvest was described as an appreciation of the interaction with the natural environment. This sentiment is itself driven by the relative abundance of the natural resource and a basic respect for the environment. The appreciation of the natural environment is an important driver of a sense of community, which in the presence of role models, provides the basis of education for

the next generation of fishers, thus leading back to and enhancing respect for the environment. The level of harvest activity depends on the having sufficient access to the fishing grounds, which can be limited by a lack of available time for the activity or by crowding. Crowding can also act to diminish the relative amount of solitude, which is an important factor in the appreciation of the interaction with the natural environment. Natural disturbances and anthropogenic pressures can act to diminish the abundance of the natural resource.

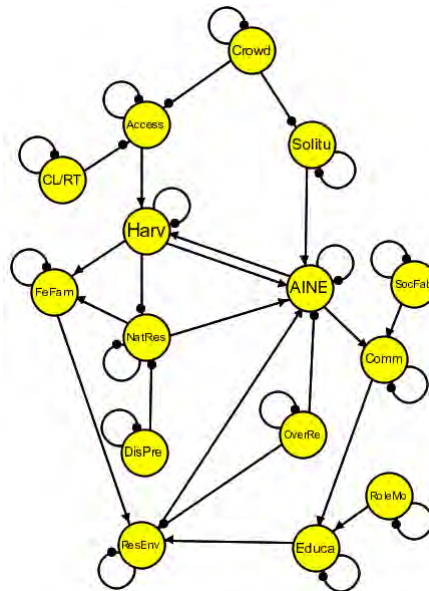


Figure 22: Social v alues of fishing and other resource activities. Access: access to fishing grounds, AINE: appreciation of interaction with natural environment, CL/RT: increased cost of living and decreased recreation time, Comm: sense of community, Crowd: crowding, DisPre: natural disturbances and anthropogenic pressures, Educa: education of younger generation of fishers, FeFam: feeding family, Harv : fisheries harvest & catch, NatRes: natural resource, Ov erRe: ov er regulation of fishing, ResEnv : respect for the environment, RoleMo: role models, SocFab: social fabric, Solitu: solitude.

Table 21: Description of links in signed digraph of above figure.

To	From	Comment
Harv	AINE	Fish harvest activity contributes to appreciation of interactionw ith natural environment
AINE	Harv	Appreciation of interaction with natural environment contributes to harvest activity
FeFam	Harv	Harvest activity leads to feeding of family
ResEnv	FeFam	Feeding of family leads to respect for environment
AINE	ResEnv	Respect for environment increases appreciation of interactionw ith natural environment
AINE	Solitu	Solitude enhances the experience of interacting w ith natural environment, leading to increased appreciation
NatRes	Harv	Harvest leads to reduced levels of natural resource
FeFam	NatRes	Abundant natural resources result in increased catch levels

To	From	Comment
AINE	NatRes	Abundant natural resources result in increased appreciation of interaction with natural environment
Harv	Access	Access to fishing grounds facilitates harvest activity
CL/RT	Access	Access to fishing grounds limited by lack of available time
Access Solitud	Crow d	Crow ding diminishes experience of solitude and interferes with access to fishing grounds
NatRes	DisPre	Natural disturbances and anthropogenic pressures reduce abundance of natural resources
AINE ResENV	OverRe	Over regulation of fishing activities suppresses appreciation of interaction with natural environment and respect for the environment
Comm	AINE SocFab	Strong social fabric and appreciation of interaction with natural environment contributes to an increased sense of community
Comm	Educa RoleMo	Strong sense of community and availability of role models facilitates education of younger generation of fishers
ResEnv	Educa	Education leads to increased respect for the environment

8.3.1.3 BRISBANE

Two sets of meetings took place in Brisbane – the first on the August 6, 2012.

Attendees: CSIRO, DERM, DAFF, DSEWPAC, DEHP

Model 1. Sea Turtle (i): Cumulative Impacts

This model depicts a general life history of sea turtles through four life stages, including egg, hatchling, sub-adult and adult (see Figure and Table below). Each of these life stages flow into the next through the process of maturation or reproduction. The focus of this model was to highlight the principle sources of natural and anthropogenic mortality and their interrelationships. Key resource variable for sea turtles include seagrass beds and nesting habitat, with the principle human-caused threats to the system coming from coastal development, dredging, and agricultural runoff. Natural disturbances include river flow cycles (i.e., storm flows) and cyclones.

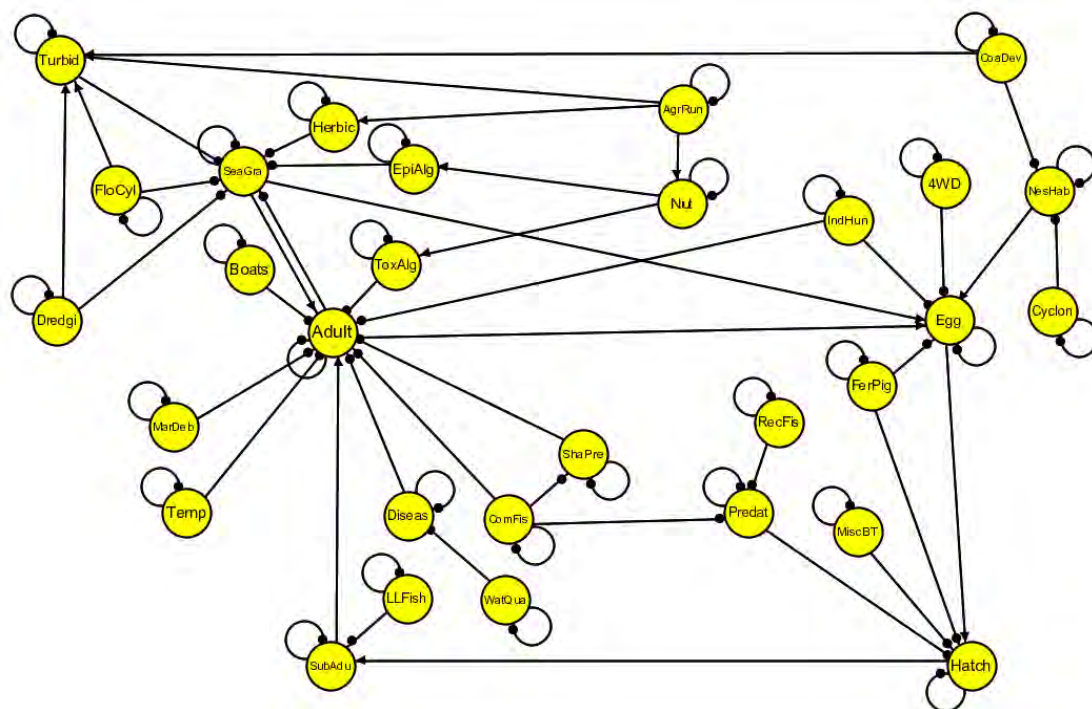


Figure 23: Sea Turtle (i): Cumulative Impacts model. 4WD: off-road vehicle traffic over nest sites, Adult: turtle adult, AgrRun: agricultural runoff, Boats: boat strike and disturbances, CoaDev: coastal development, ComFis: commercial fishing, Cyclon: cyclone, Diseases: disease, Dredgi: dredging, Egg: turtle egg, SubAdu: turtle subadult, EpiAlg: epiphytic algae, FerPig: feral pigs, FloCyl: river flow cycle, Hatch: turtle hatchling, Herbic: herbicide, IndHun: indigenous hunting, LLFish: long line fishing, MarDeb: marine debris, MiscBT: miscellaneous beach threats (e.g., foxes, native predators, night lights). NesHab: turtle nesting habitat, Nut: nutrients, Predat: predators, RecFis: recreational fishing, SeaGra: seagrass, ShaPre: shark predation, Temp: temperature, ToxAlg: toxic algae, Turbid: turbidity, WatQua: water quality.

Table 22: Description of links in signed digraph of above figure.

To	From	Comment
Adult	Boats	Boat strikes and disturbance of turtle feeding activity
Adult	SeaGra	Nutrition that reduces mortality from starvation
Adult	Tox Alg	Mortality
Adult	IndHun	Harvest mortality
Adult	ShaPre	Shark predation mortality
Adult	ComFis	Mortality from encounters with commercial fishing gear
Adult	Diseas	Disease mortality
Adult	Temp	Increases in temperature affects sex ratio and possibly success of hatchlings
Adult	MarDeb	Mortality from encounters and ingestion of marine debris
Egg	IndHun	Harvest mortality
Egg	4WD	Destruction of nests from vehicles on beaches
Egg	FerPig	Predation mortality from feral pigs

To	From	Comment
Egg	SeaGra	Increased fecundity from nutrition
Hatchling	MiscBT	Various threats to hatchlings, including predation from foxes and native predators, and disorientation from night lights
Hatchling	FerPig	Predation mortality
Hatchling	Predat	Mortality from fish predators
SubAdu	LLFish	Mortality from encounter with long line fishing gear
SeaGr	Dregi	Direct removal of seagrass beds from dredging
SeaGr	FloCyl	Natural impacts to seagrass beds from storms flows
SeaGr	Turbid	Smothering of seagrass beds from turbidity
SeaGr	Herbi	Mortality or decline in growth from herbicide
SeaGr	EpiAlg	Loss of growth from shading by epiphytes
SeaGr	Turtles	Grazing from turtles
Turbid	AgrRun	Contribution of turbidity from agricultural land use
Herbic	AgrRun	Contribution of herbicide from agricultural land use
ToxAlg	Nut	Toxic algal blooms from nutrients
EpiAlg	Nut	Increase growth from enrichment
Nut	Agr	Contribution of nutrients from agricultural land use
Turbid	CoaDev	Contribution of turbidity from land use runoff
Turbid	Dredgi	Increased turbidity from dredging
Turbid	FloCyc	Natural contribution of turbidity
NestHab	CoaDev	Destruction of nesting habitat
NestHab	Cyclone	Destruction of nesting habitat
Disease	WatQual	Poor water quality inducing increase in disease of adult turtles
Predat	ComFis	Harvest mortality
Predat	RecFis	Harvest mortality
ShaPre	ComFis	Harvest mortality
Adult	SubAd	Life-stage transition
SubAd	Hatch	Life-stage transition
Hatch	Egg	Life-stage transition
Egg	Adult	Life-stage transition

Model 2. Sea Turtle (ii): Fishery Impacts & Regulation

This model describes interaction between turtles, fisheries and management agencies (see Figure and Table below). Here the focus is on the regulation of commercial (inshore net, inshore trawl, crab potting) and recreational fisheries for the purpose of limiting encounters of turtles with fishing gear. DAFF observer and logbook programs provide information on fishery-turtle interactions that are acted upon by DAFF by such measures as regulation of fishing gear (e.g., turtle excluding device) spatial closures, and effort reduction. There is a possible link to the observer program from recreational fishers, but it was judged to be weak and was not included in the model. The observer information also enhances public perceptions, which motivates the industry association to limit the impact of fishing on turtles (via gear modifications).

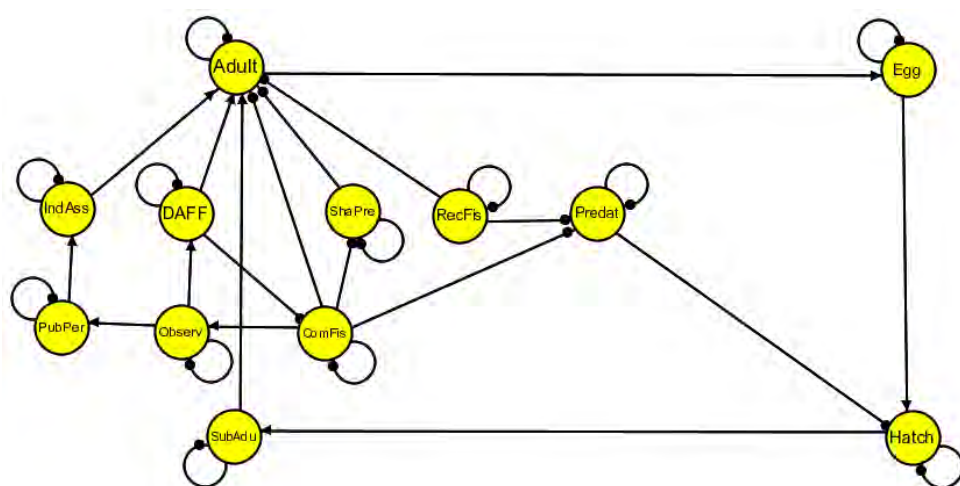


Figure 24: Sea Turtle (ii): Fishery Impacts & Regulation model. Adult: adult turtle, ComFis: commercial fishing, DAFF: Dept. Agriculture, Fisheries & Forestry, Egg: turtle egg, Hatch: turtle hatchling, IndAss: industry associations., Observ: observer program, Predat: predators, PubPer: public perception, RecFis: recreational fishing, ShaPre: shark predators, SubAdu: turtle subadult.

Table 23: Description of links in signed digraph of above figure.

To	From	Comment
Adult	ShaPre	Shark predation mortality
Adult	RecFis	Mortality from encounter with fishing gear
Adult	ComFis	Mortality from encounter with fishing gear
ComFis	DAFF	Regulation of fishing effort
Adult	DAFF	Reduction of encounters fisheries
Observ	ComFis	Information on encounters of turtles with fishing gear
DAFF	Observ	Information on encounters of turtles with fishing gear
PubPer	Observ	Information on encounters of turtles with fishing gear
IndAss	PubPer	Influence of public perception of encounters of turtles with fishing gear
Adult	IndAss	Reduction of encounters fisheries
Hatch	Predat	Predation mortality
Predat	ComFis	Harvest mortality
Predat	RecFis	Harvest mortality
ShaPre	ComFis	Harvest mortality
Adult	SubAd	Life-stage transition
SubAd	Hatch	Life-stage transition
Hatch	Egg	Life-stage transition
Egg	Adult	Life-stage transition

Model 3. Seagrass (i): Water Quality and Regulation

This model focuses on seagrass as affected by agricultural runoff through diminished water quality, and also the role of water quality monitoring and regulation (see Figure and Table below). Seagrass beds are affected by the natural cycle of river flows, which create erosion of seagrass beds and turbidity; seagrass growth can also be limited naturally by epiphytic algae. Anthropogenic effects include direct removal or covering of beds from dredging and coastal development, and increases to turbidity, herbicides and nutrients. These latter effects are driven by commercial interests, but are also observed and reported in water quality monitoring programs. This reporting feeds back on the system in the form of regulation and influence on public opinion, albeit these pathways for feedback are largely compromised by weak influence.

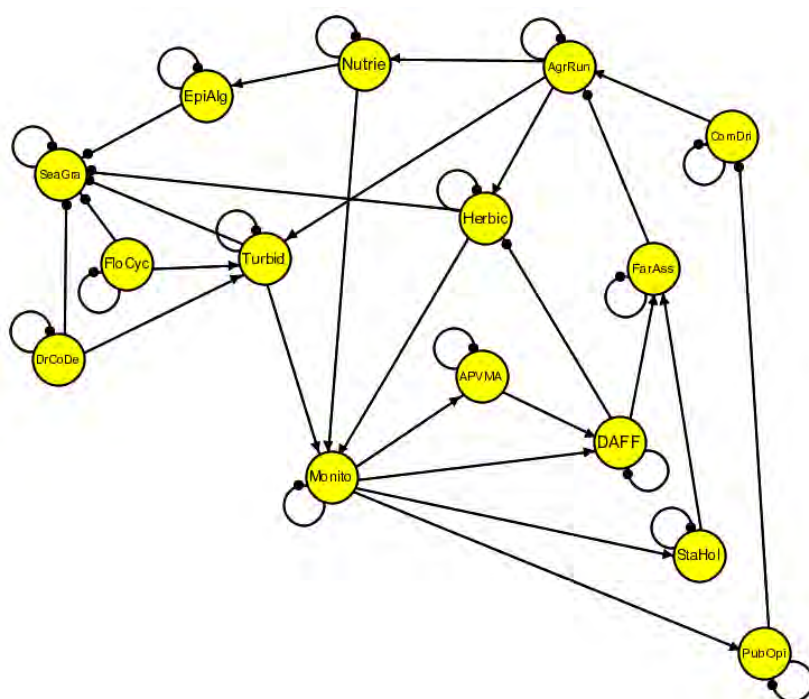


Figure 25: Seagrass (i): Water Quality and Regulation model. AgrRun: agricultural runoff, APVMA: Australian Pesticides and Veterinary Medicines Authority (with DSEWPaC), ComDri: commercial drivers, DAFF: Dept. Agriculture, Fisheries & Forestry, DrCoDe: dredging & coastal development, EpiAlg: epiphytic algae, FarAss: Farming associations, FloCyc: river flow cycle, Herbic: herbicides, Monito: monitoring program, Nutrie: nutrients, PubOpi: public opinion to protect or improve water quality, SeaGra: seagrass, StaHol: stake holders, Turbid: turbidity.

Table 24: Description of links in signed digraph of above figure.

To	From	Comment
SeaGr	EpiAlg	Diminished growth from shading
SeaGr	FloCyc	Disturbance to seagrass beds from high flows
SeaGr	DrCoDe	Removal/destruction of seagrass beds

To	From	Comment
SeaGr	Turbid	Suppression of growth from turbidity or mortality from smothering
SeaGr	Herbic	Mortality or suppression of growth from herbicides
AgrRun	ComDri	Commercial pressure to engage in land use practices that lead to increased runoff
Nutrie	AgrRun	Increased nutrients in runoff
Turbid	AgrRun	Increased turbidity in runoff
Herbic	AgrRun	Increased herbicide in runoff
EpiAlg	Nutrie	Increased growth from enrichment
Monito	Nutrie	Monitoring of nutrients in runoff
Monito	Herbic	Monitoring of herbicides in runoff
Monitor	Turbid	Monitoring of turbidity
APVMA	Monitor	Water quality reporting
DAFF	Monitor	Water quality reporting
StaHol	Monitor	Water quality reporting
PubOpi	Monitor	Water quality reporting
APVMA	DAFF	Setting of regulatory rules and targets
Herbici	DAFF	Suppression of agricultural runoff
FarAss	DAFF	Regulatory motivation to reduce agricultural runoff (critical but weak link)
FarAss	StaHo	Regulatory motivation to reduce agricultural runoff (critical but weak link)
ComDri	PubOpi	Motivation to reduce agricultural runoff
Turbid	FloCyc	Natural contributions to turbidity from seasonal flow cycle

Model 4. Seagrass (ii): Coastal Development

A second model for seagrass was developed that focused on the impacts of coastal development (see Figure and Table below). Here seagrass beds are directly removed or covered by dredging and reclamation projects. Such activities can be managed by Department of Industries as an area of special development, which has the potential to reduce the impact of dredging on seagrass beds and turbidity. Increasing the urban footprint of mining-associated communities also leads to increased dredging, turbidity and nutrients. Regulation of this latter pressure is the responsibility of regional planning authorities.

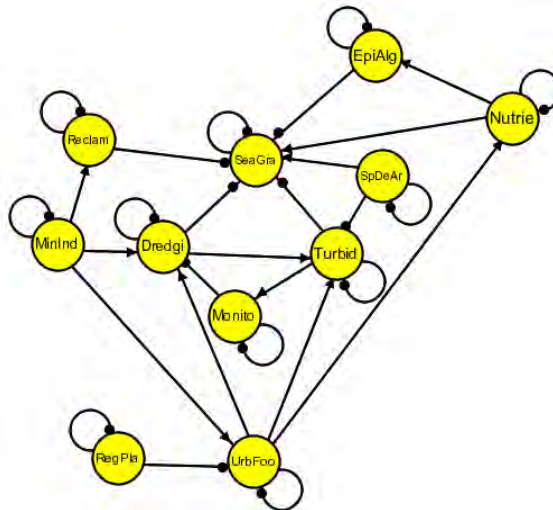


Figure 26: Seagrass (ii): Coastal Development model. Dredgi: dredging, EpiAlg: epiphytic algae, MinInd: mining industry, Monito: monitoring, Nutrie: nutrients, Reclam: reclamation, RegPla: regional planning, SeaGra: seagrass, SpDeAr: special development areas, Turbid: turbidity, UrbFoo: urban footprint.

Table 25: Description of links in signed digraph of above figure.

To	From	Comment
SeaGra	Reclam	Destruction of seagrass beds
SeaGra	Dredgi	Destruction of seagrass beds
SeaGra	Turbid	Smothering of seagrass beds
SeaGra	EpiAlg	Reduced growth of seagrass from shading
SeaGra	Nutrie	Increased growth of seagrass from enrichment
Reclam	MinInd	Increased reclamation from mining associated projects
Dredgi	MinInd	Increased dredging from mining associated projects
Turbid	Dredgi	Increased turbidity from dredging operations
UrbFoo	MinInd	Increase in urban areas and growth from mining associated communities
Dredgi	UrbFoo	Increase in dredging from urban developments
Turbid	UrbFoo	Increased turbidity from urban runoff
UrbFoo	RegPla	Restriction of spatial extent and impact of urban growth
Nutrie	UrbFoo	Increased nutrient runoff from urban growth and foot print
EpiAlg	Nutrie	Increased growth from enrichment
Monito	Turbid	Water quality monitoring
Dredgi	Monitor	Regulation of dredging activities based on water quality reporting
SeaGra	SpDeAr	Limitation of dredging impacts by Dept of Industry regulation.
Turbid	SpDeAr	Limitation of dredging impacts by Dept of Industry regulation.

Model 5. Barramundi (ii): Cumulative Impacts

A second life-stage model of barramundi was developed to describe the inter-relationships of various impacts, including commercial and recreational fishing, migration barriers, loss of coastal wetlands, water quality and riparian vegetation, and the effects of introduced species such as tilapia and feral pigs (see Figure and Table below). The model included monitoring of water quality, fish populations and riparian vegetation, and a number of management activities. The model includes stage include hermaphroditism as a life history feature, and also consumption of previous (smaller) life stage through cannibalism.

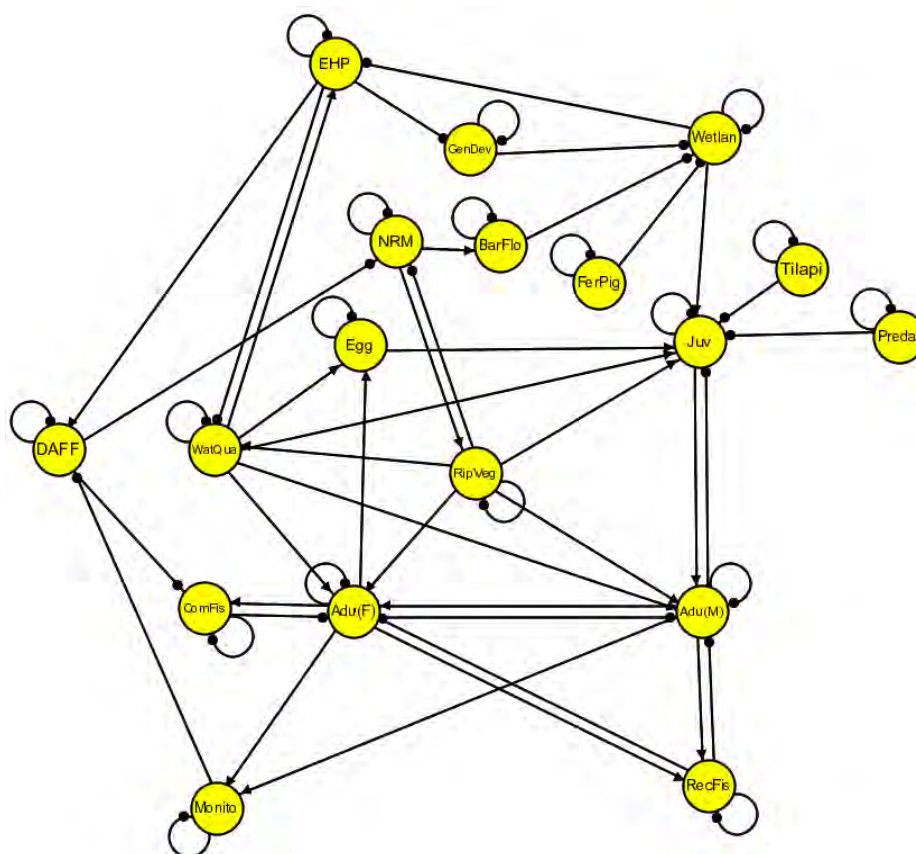


Figure 27: Barramundi (i): Cumulative Impacts model. Adu(F): barramundi adult females, Adu(M): barramundi adult males, ComFis: commercial fishing, DAFF: Dept. Agriculture, Fisheries & Forestry, Egg: barramundi eggs, EHP: Ecosystem Health Monitoring Program, FerPig: feral pigs, GenDev: general development, Juv: barramundi juveniles, Monito: monitoring, NRM: QLD Regional Natural Resource Management, Predat: predators, RecFis: recreational fishing, RipVeg: riparian vegetation, BarFlo: barriers & flow extraction, Tilapi: tilapia, WatQua: water quality, Wetlan: wetlands.

Table 26: Description of links in signed digraph of above figure.

To	From	Comment
Adu(F)	Adu(M)	Maturation
Adu(M)	Adu(F)	Mortality from cannibalism

To	From	Comment
Adu(M)	Juv	Maturation
Juv	Adu(M)	Mortality from cannibalism
Juv	Egg	Development
Egg	Adu(F)	Reproduction
Adu(F)	RipVeg	Critical habitat (i.e., ambush)
Adu(M)	RipVeg	Critical habitat (i.e., ambush)
Juv	RipVeg	Critical habitat (i.e., ambush)
WatQua	RipVeg	Filtration and shade
Egg	WatQua	Critical requirement
Juv	WatQua	Critical requirement
Adu(M)	WatQua	Critical requirement
Adu(F)	WatQua	Critical requirement
Juv	Wetlan	Critical habitat (i.e., provides shelter from predation and cannibalism)
Juv	Tilapia	Degrades wetlands benefit to juvenile barramundi
Juv	Predat	Predation mortality
Wetlan	FerPig	Degradation of wetlands
Wetlan	BarFlo	Degradation of wetlands
Wetlan	GenDev	Degradation of wetlands
Adu(F)	ComFis	Fishery harvest mortality
ComFis	Adu(F)	Catch-driven fishing effort
Adu(F)	RecFis	Fishery harvest mortality
RecFis	Adu(F)	Catch-driven fishing effort
Adu(M)	RecFis	Fishery harvest mortality
RecFis	Adu(M)	Catch-driven fishing effort
Monito	Adu(F)	Population monitoring (weak link)
Monito	Adu(M)	Population monitoring (weak link)
DAFF	Monito	Reporting of population monitoring
ComFis	DAFF	Effort control of fishery
DAFF	EHP	Reporting of habitat monitoring
NRM	DAFF	Advises on water barriers
NRM	RipVeg	Monitoring of riparian vegetation, if good need for NRM decreases
RipVeg	NRM	
WatQua	EHP	
EHP	WatQua	Water quality monitoring
EHP	Wetlan	Habitat monitoring, if quality high then no need to protect
GenDev	EHP	Regulation of development to protect-maintain habitat quality
BarFlo	NRM	Protection of critical flow and connectivity (weak link)

A second meeting was held on the September 25, 2012 in Brisbane to more directly address governance within the coastal zone.

Attendees: CSIRO, AIMS, JCU, Griffiths University

Model 6. General Governance of Natural Assets

A general model was developed to describe the main feedback associated with regulation of natural assets of coastal marine environments (see Figure and Table below). Natural assets are formed and maintained by supporting natural processes, both of which can be degraded or compromised by activities associated with various sectors of the economy. The activities of economic sectors can be limited by regulations to protect the environment, which derived their motivation from management agencies and political action. Environmental non-governmental organizations and public concern for the environment both react to the status of the natural asset, mutually support each other, and act to increase political actions for the environment. Lobbyists for economic sectors, on the other hand, act to weaken political action for environmental protection.

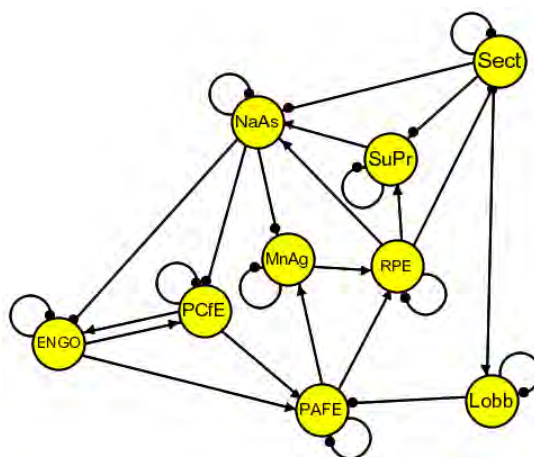


Figure 28: General Governance of Natural Assets model. ENGO: environmental non-governmental organization, Lobb: lobbyist, MnAg: management agency, NaAs: natural asset, PAFE: political actions for environment, PCfE: public concern for environment, RPE: regulations to protect environment, Sect: sector of economy, SuPr: supporting processes.

Table 27: Description of links in signed digraph of above figure.

To	From	Comment
NaAs	Sect	Degradation of asset by activity of economic sector
NaAs	SuPr	Supporting process of natural environment or ecosystem
NaAs	RPE	Regulations that limit impacts of economic sector benefit or maintain natural assets
SuPr	RPE	Regulations that limit impacts of economic sector benefit or maintain natural processes
Sect	RPE	Limitation of activity of economic sector
MnAg	NaAs	Status of natural asset provided motivation for management
RPE	MnAg	High motivation for management increases regulations to protect environment
ENGO	NaAs	Low asset status increases activity of non-governmental organizations

To	From	Comment
PCfE	NaAs	Low asset status increases activity of political action for environment
ENGO	PCfE	Activity by ENGO increases public concern
PCfE	ENGO	Public concern increases activity by ENGO
PAFE	PCfE	Public concern leads to increased political action to protect environment
PAFE	ENGO	ENGO activity increase political action to protect environment
MnAg	PAFE	Political actions for the environment increases strength of management agency
PAFE	RPE	Political action strengthens regulations
Lobb	Sect	Economic sectors support lobbying
PAFE	Lobb	Lobbying suppresses political actions for environment

Model 7. Coastal Wetlands

A model for coastal wetlands considers the influence of bunds (or flow blockages) and associated land use in coastal wetlands on a number of natural assets (see Figure and Table below). A natural flow regime maintains fish populations (i.e., barramundi, mangrove jack, giant herring, milk fish and tarpon), but is compromised by bunds, weed growth and an extended dry cycle (i.e., El Nino). Bunds create semi-permanent freshwater swamps, which increase agricultural land and wading bird habitat, but also weed growth. Weed growth in turn suppresses the natural flow regime and habitat for juvenile fish. A natural flow regime is critical for settlement of fish larvae. Bunds also suppress tidal swamps which are important habitat for juvenile fish and mangroves. The model examines other impacts of an extended dry cycle as well as sea level rise.

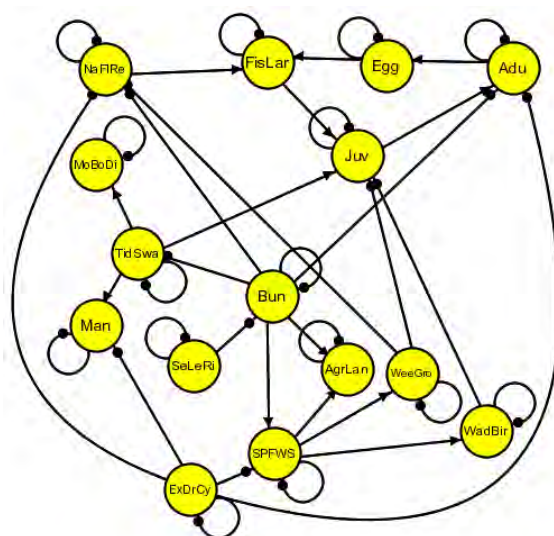


Figure 29: Coastal Wetlands model. Adu: adult fish, AgrLan: agricultural lands, Bun: bunds (or flow blockages), Egg: Fish eggs, ExDrCy: extended dry cycle (El Nino), FisLar: fish larvae, Juv: juvenile fish, Man: mangroves, MoBoDi: mosquito-borne disease, NaFRe: natural flow regime,

SeLeRi: sea level rise, SPFWS: semi-permanent freshwater swamps, TidSw a: tidal swamps, WadBir: wading birds, WeeGro: weed growth.

Table 28: Description of links in signed digraph of above figure.

To	From	Comment
FisLar	Egg	Maturation
Juv	FisLar	Maturation
Adu	Juv	Maturation
Egg	Adu	Reproduction
NaRiRe	FisLar	Successful settlement of fish larvae flow dependent
Adu	ExDrCy	Dry cycle limits juvenile-to-adult survival
Adu	Bun	Bunds suppress juvenile-to-adult survival by blocking access to key habitats
NaRiRe	ExDrCy	Natural flows diminished in extended dry cycle
NaRiRe	WeeGr	Weeds suppress natural flow regime
NaRiRe	Bun	Bunds suppress natural flow regime
Juv	TidSw a	Tidal swamps critical habitat for juvenile fishes
Juv	WeeGro	Weed growth degrades juvenile habitats
Juv	WadBir	Predation mortality
WadBir	SPFWS	Supporting habitat for wading birds
WeeGro	SPFWS	Favourable to weed growth
AgrLan	SPFWS	Favourable to agricultural land use
SPFWS	Bun	Bunds create semi-permanent freshwater swamps
TidSw a	Bun	Bunds eliminate tidal swamps
Mag	TidSw a	Mangroves require tidal swamps
Mag	ExDrCy	Mangroves diminished by extended dry cycle
MoBoDi	TidSw a	Tidal swamps for mosquito-borne disease
Bun	SeLeRi	Sea level rise will diminish bunds
SPFWS	ExDrCy	Extended dry cycle diminishes semi-permanent freshwater swamps

8.3.1.4 TOWNSVILLE

Attendees: CSIRO, GBMRPA, JCU, DEHP

Model 1. Seagrass (iii): Dynamics & Cumulative Impacts

A model of seagrass dynamics was developed that distinguished between what were termed colonizing and climax growth forms and species and seagrasses (see Figure and Table below). In the absence of agents of disturbance, the climax seagrass will outcompete colonizing seagrass, but where there is grazing by dugongs or storms of intermediate intensity then the balance is shifted in favour of colonizing seagrass. This model also addressed the influence of impacts via land use runoff, ocean acidification and increases in extreme temperature events.

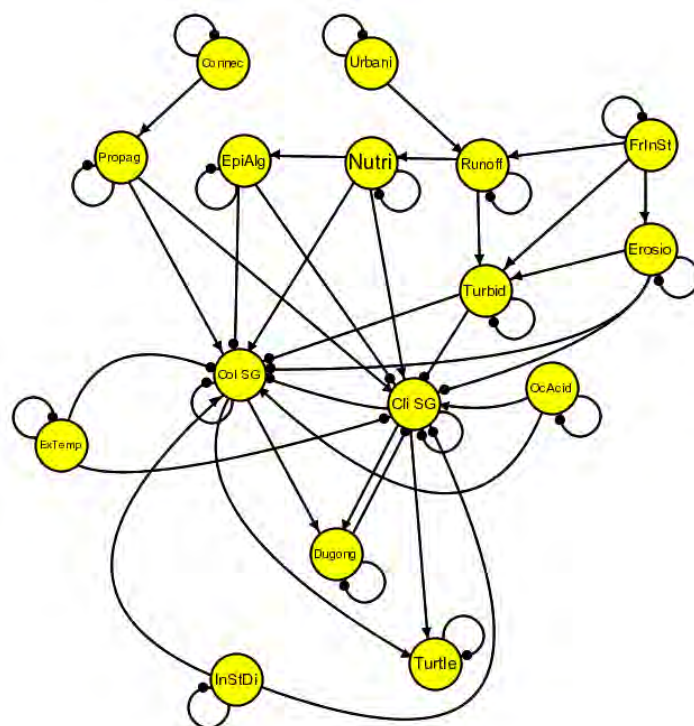


Figure 30: Seagrass (iii): Dynamics & Cumulative Impacts. Cli SG: climax seagrass, Col SG: colonizing seagrass, Connec: connectivity, Dugong: dugong populations, EpiAlg: epiphytic algae, Erosion: wave erosion, ExTemp: extreme temperatures., FrInSt: frequency of intense storms, InStDi: intermediate (intensity) storm disturbances, Nutri: nutrients, OcAcid: ocean acidification, Propag: propagules, Runoff: land use runoff, Turbid: turbidity, Turtle: turtle populations, Urbani: urbanization.

Table 29: Description of links in signed digraph of above figure.

To	From	Comment
CliSG	Dugong	Destructive grazing
ColSG	CliSG	Competitive dominance
Dugong	CliSG	Consumption of resource
Dugong	CliSG	Consumption of resource
ColSG	ExTemp	Mortality from extreme temperature
CliSG	ExTemp	Mortality from extreme temperature
ColSG	InStDi	Intermediate disturbance that favours colonizing seagrasses
CliSG	InStDi	Intermediate disturbance that suppresses climax seagrasses
Turtle	CliSG	Resource consumption
Turtle	ColSG	Resource consumption
ColSG	OcAcid	Shift to more favourable pH
CliSG	OcAcid	Shift to more favourable pH
CliSG	Propag	Recruitment from distant seagrass beds
ColSG	Propag	Recruitment from distant seagrass beds
Propag	Conne	Connectivity of source-sink populations (distance between beds, current flow and direction)

To	From	Comment
CoISG	EpiAlg	Reduced growth from shading
ClISG	EpiAlg	Reduced growth from shading
CoISG	Nutri	Increased growth from enrichment
ClISG	Nutri	Increased growth from enrichment
EpiAlg	Nutri	Increased growth from enrichment
CoISG	Erosio	Destruction of seagrass bed
ClISG	Erosio	Destruction of seagrass bed
CoISG	Turbid	Smothering of seagrass bed
ClISG	Turbid	Smothering of seagrass bed
Turbid	Erosio	Increased movement of sediments in near shore waters
Runoff	FrInSt	Increased sediments from storms
Erosion	FrInSt	Increased wave energy from storms
Turbid	FrInSt	Re-suspension of sediments in near shore waters
Runoff	Urbani	Increased delivery of sediments to runoff
Nutri	Runoff	Increased delivery of nutrients
Turbid	Runoff	Delivery of sediments to near shore waters

Model 2. Water Quality Monitoring, Regulation & Governance

This model focused on the monitoring, regulation and governance of water quality in near shore waters (see Figure and Table below). Water quality (sediment, toxins and nutrients) is impacted by coastal development and monitored via the reef water quality protection plan, with monitoring reports informing actions of the Queensland environmentally relevant activities (QLD ERA), the world heritage status. Disease and mortality events are driven by water quality, but also natural events, and influences public concern for the environment, which is a driver for more restrictive regulation of coastal development by QLD ERA. This restriction, however, is strongly countered by lobbying pressure from economic interests. Economic interests drive coastal development, but also can affect the relative demographics of transient versus long-term communities, which has the effect of eroding proportion of the public that is concerned for the environment. Commonwealth legislation and policies are seen to be sensitive world heritage status, public concern, and the QLD ERA, but can also be influenced by lobbying for economic interests. A major concern of this model was that most of the links required to achieve effective environmental monitoring, reporting, and regulation were weak, and those associated with economic interests were overwhelmingly strong.

To	From	Comment
		protect environment
Lobby	EconIn	Economic interests increase strength of lobbying
CW L&P	Lobby	Lobby suppresses motivation of commonw ealth to protect environment
CW L&P	PuCoEn	Public concern strengthens motivation for commonw ealth to protect environment (described as w eak link)
CW L&P	QldERA	Strong state motivation to protect environment diminishes motivation of commonw ealth
QldERA	CW L&P	High motivation of commonw ealth to protect environment stimulates motivation of the state
CW L&P	WoHeSt	Low status stimulates motivation of commonw ealth to protect environment

Model 3. Barramundi (iii): Supporting Habitats and Seasonal Flows

A third model for barramundi focused on the importance of supporting habitats and seasonal flows for six different life stages, but did not include hermaphroditism as a life history feature (see Figure and Table below). Seasonal flows play a critical role in life stage transitions, primarily through flow-based habitat connectivity. Supporting habitats are also critical for providing refuge from predation and cannibalism. Restocking of barramundi juveniles, while it is seen to increase juveniles, ultimately suppresses egg production through degradation of the genetic fitness of the population.

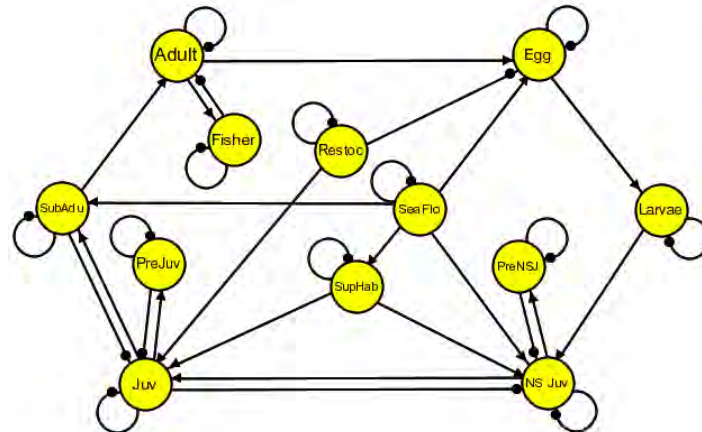


Figure 32: Qualitative model of Barramundi supporting habitats and seasonal flows. Adult: barramundi adult, Egg: barramundi egg, Fishery: commercial and recreational fisheries, Juv: barramundi juveniles, Larvae: barramundi larvae, NS Juv: newly settled barramundi juveniles, PreJuv: predators of juvenile barramundi, PreNSJ: predators of newly settled juvenile barramundi, Restoc: barramundi restocking, SeaFlo: seasonal flows, SubAdu: barramundi subadults, SupHab: supporting habitats.

Table 31: Description of links in signed digraph of above figure.

To	From	Comment
Larvae	Egg	Maturation

To	From	Comment
NS Juv	Larvae	Maturation
Juv	NS Juv	Maturation
SubAdu	Juv	Maturation
Adult	SubAdu	Maturation
Egg	Adult	Maturation
NS Juv	Juv	Mortality from cannibalism
Juv	SubAdu	Mortality from cannibalism
NS Juv	SupHab	Suppression of cannibalism and predation
Juv	SupHab	Suppression of cannibalism and predation
NS Juv	PreNSJ	Predation mortality
PreNSJ	NS Juv	Consumption of prey
PreJuv	Juv	Consumption of prey
Egg	SeaFlo	Flow triggers spawning
NS Juv	SeaFlo	Natural flows allow juveniles to settle in critical wetland habitats
SupHab	SeaFlo	Natural flows critical to habitat quality
SubAdu	SeaFlo	Natural flows required for juvenile survival
Juv	Restoc	Restocking of juveniles increases juvenile population
Egg	Restoc	Restocking degrades genetic fitness of barramundi populations
Adult	Fisher	Fishing mortality
Fisher	Adult	Fishing pressure increases with catch

8.4 Discussion

Looking across the range of models developed in this work, there appears to be a consistent theme of how coastal development and land use interact with assets of near-shore Great Barrier Reef. The chief modes of impact include runoff associated with urban and agricultural runoff, and commercial activities or footprints from industrial operations. Regulation and management of these impacts, especially those related with water quality were described as being hampered by relatively weak links associated with effective environmental monitoring, reporting and regulation, while those associated with economic interests were considered to be comparatively stronger.

Impacts from fishing (both recreational and commercial) played a key role in the species specific models, but by comparison, had stronger and more effective controls and regulations in place than those for management of water flows, water quality and wetland habitats. However, a “boom economy” from mining was perceived as having a dramatic and problematic effect on fishing power, as well as undermining the effectiveness and strength of community-based protection of environmental assets.

The collective understanding embedded within the above the qualitative models were used to subsequently engage with each Reference Group to develop objectives and strategies for the management of inshore biodiversity. Objectives identified from subsequent stakeholder elicitations (Section 7) broadly encompass the elements, causal processes and dynamics identified through the qualitative modelling workshops, and can be generally described as strengthening the model

connections associated with community cohesion and the monitoring and management of water flows, water quality and aquatic and riparian habitats, and curtailing the influx of pollutants into runoff leading to freshwater and near-shore environments.

9 Available information

9.1 Introduction

In order to allow for an informed discussion about the fisheries within Mackay and the Bowen-Burdekin region some relevant region specific information was provided. These were mainly used in Mackay and made available during the fisheries discussions of Section 10.

9.2 Methods

A review of available information was undertaken. The bulk of the review concentrated on distribution maps of the key environmental assets of Mackay, as this is a key information source for the RG to use as input into the management strategies discussion. Given that fisheries information is a key topic of interest to the group a detailed data analysis was also undertaken by DAFF.

9.3 Mackay regional inshore fisheries profile

Authors: Malcolm Dunning, Julia Davies and Anna Garland
Fisheries Queensland, Brisbane

9.3.1 INTRODUCTION

For the purposes of this study, the Mackay region is defined as extending from 20.5°S to 22.5°S and offshore approximately 30 nautical miles from Repulse Bay in the north to Broad Sound in the south. It includes grids N24, O24, O25, P25, O26, P26, O27 and P27 of the Queensland Department of Agriculture, Fisheries and Forestry (DAFF) commercial fisheries logbook grid system (DAFF, 2012a). This area represents most of the coastal Cape Clinton to Gloucester Head fishing region as defined for the statewide recreational fishing survey (that includes the Whitsundays). In terms of participation by recreational fishers, this region falls within the Mackay area of residence for the DAFF telephone surveys—however it is important to note that the Mackay residential area is much larger than the area shown in Figure 33. It is possible that the recreational participation rate would be higher than the estimate provided due to the close proximity of these grids to the coast (DAFF, 2012a).

There are extensive commercial fisheries closures in the region imposed by Great Barrier Reef and Queensland marine parks zoning (Marine National Park and Conservation Park zones) and Dugong Protection Areas declared under the Fisheries Act 1994 (Figure 33). Trawling is further restricted to General Use zones in the region while recreational fishers are only restricted by Marine National Park zones.

To capture recent interannual variability, information for the last four years, 2010 to 2013 are presented in the following sections. In section *Trends in Regional*

Commercial fisheries information is presented back to 2005. Catchability, catch and catch rate of inshore species will be impacted by recent environmental conditions including summer flooding and cyclone Yasi in early 2011.

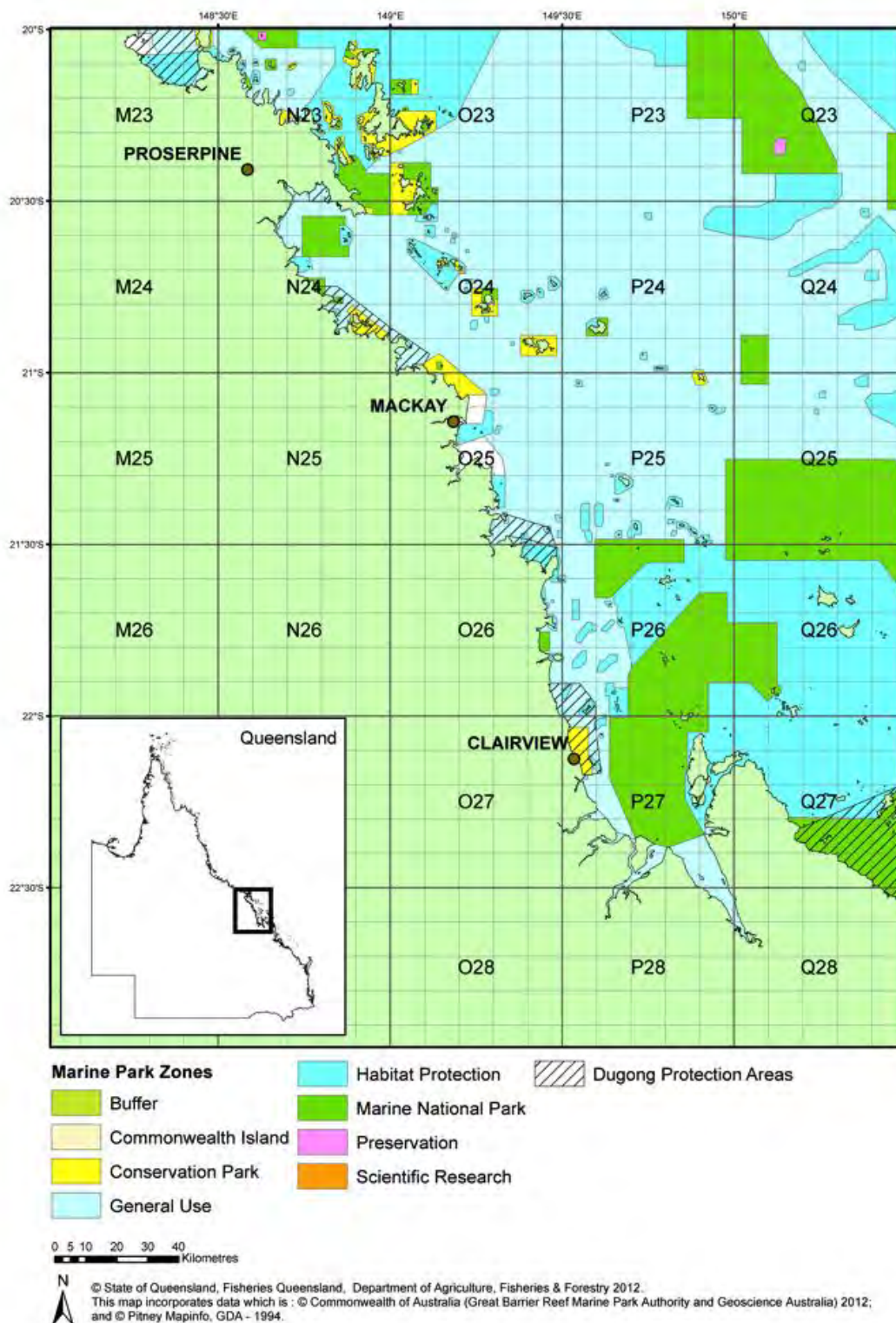


Figure 33: Mackay region showing Dugong Protection Areas and Marine Parks zoning.

9.3.2 COMMERCIAL FISHING OPERATIONS

Most commercial fishing operations have multiple endorsements which allow them to switch fishing apparatus and target different fisheries resources. In addition some fishing operations, especially otter trawlers, are mobile and may shift their fishing operation to adjacent areas to maximise their profits. Consequently, the number of commercial fishers operating in an area will change from year to year.

In 2010, there were 111 active commercial fishing licences in the Mackay region. In 2011 and 2012, this number dropped to 87 and 99 respectively. In 2013 logbook data reported a return to 2010 levels with 109 commercial fishing licences submitting returns.

Fluctuating levels of active fishing licences in the Mackay region are largely attributed to the annual variability in the number of otter trawlers (Figure 34). Between 2010 and 2013 all licences which reported otter trawling did not undertake any other method of fishing. In 2010 there were 42 otter trawlers - which then reduced by more than 40% to 22 and 24 in 2011 and 2012 respectively. During 2013 an increase in the number of otter trawlers was recorded which saw numbers rise to 35. The largest constituent of active commercial fishing licences in the Mackay region utilise pot and net apparatus in combination to fish for crab and inshore fin fish species. Between 2010 and 2013 the number of licences fishing in the net and pot fisheries increased. In 2010, 46 fishers went pot fishing and 44 fishers undertook net fishing - of these 27 partook in both. In 2011, 44 and 42 fishers submitted logbooks for pot and net fishing activities. In 2012, 47 pot fishers and 45 net fishers submitted logbook returns - of which 26 used a combination of the two fishing methods. The highest number of active commercial fishing licences reporting fishing activity in the net and pot fisheries was in 2013, 47 licences went net fishing and 53 licences went pot fishing, of these 31 engaged in both during the year.

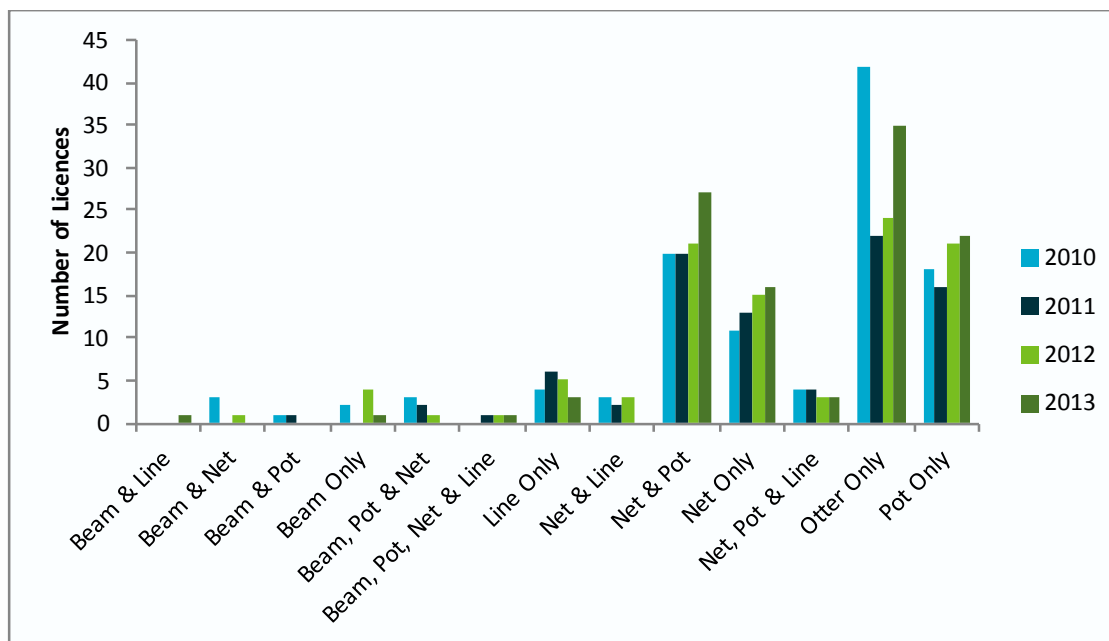


Figure 34: Count of licences against fishing operations by fishing method for the Mackay region.

In Mackay, line fishing is the second smallest fishery by count of active fishing licences - the smallest is beam trawl. In 2010 there were 11 line fishers, shortly thereafter licence numbers peaked at 13 and 12 in 2011 and 2012 respectively before dropping to a total of eight fishers in 2013. More than 50% of commercial line fishers in the Mackay region participate in other fisheries - predominantly net and pot.

The majority of beam trawlers in the Mackay region operate in multiple fisheries. In 2010, nine beam trawlers reported catch in the Mackay region. In 2011 this number was reduced to less than half, logbooks were received for only four operators - 2012 saw an increase to seven operators. Beam trawler numbers reduced to their lowest in 2013, where only three operators submitted logbook returns.

Every year, between 2010 and 2013, approximately 30% to 35% of the operators in the Mackay region participate in multiple fisheries - the majority operate solely in one fishery using one type of fishing method. In 2010, the Mackay region produced a total of 543 tonnes of seafood - in 2011 a decreased to 500 tonnes was recorded. Yield from commercial fisheries in the region have increased in the last two years with 563 tonnes and 635 tonnes being reported in 2012 and 2013 respectively.

9.3.3 INSHORE COMMERCIAL TRAWL FISHERIES

The inshore waters of the Mackay region support both beam and otter trawling. In 2010, 42 otter trawlers retained 252.7 tonnes. In 2011 and 2012, 112.2 and 133.9 tonnes were recorded through logbook returns; the downturn in catch directly proportional to the decrease in active commercial licences during the same period. An increase to 247.4 tonnes was recorded in 2013. Banana and blue leg king prawns

are the dominant retained species contributing between 80% and 95% of the yearly catch.

Nine beam trawlers retained 4.1 tonnes in 2010. Catch decreased to 2.6 tonnes in 2011, increased to 3.8 tonnes in 2012 and most recently decreased to 3.5 tonnes in 2013. Banana and greasy prawns were the only species reported by beam trawl fishers in the Mackay region - banana prawns dominated catch statistics with a minimum of 97% of the annual harvest.

A total of 29 taxa, including 13 prawn taxa, were reported by the trawl fisheries between 2010 and 2013. Otter trawl species composition is largely dominated by a handful of species (as detailed above) with the remaining retained species contributing less than 1% to the total catch by weight. The top species by weight for 2010, 2011, 2012 and 2013 are shown in Figure 35.

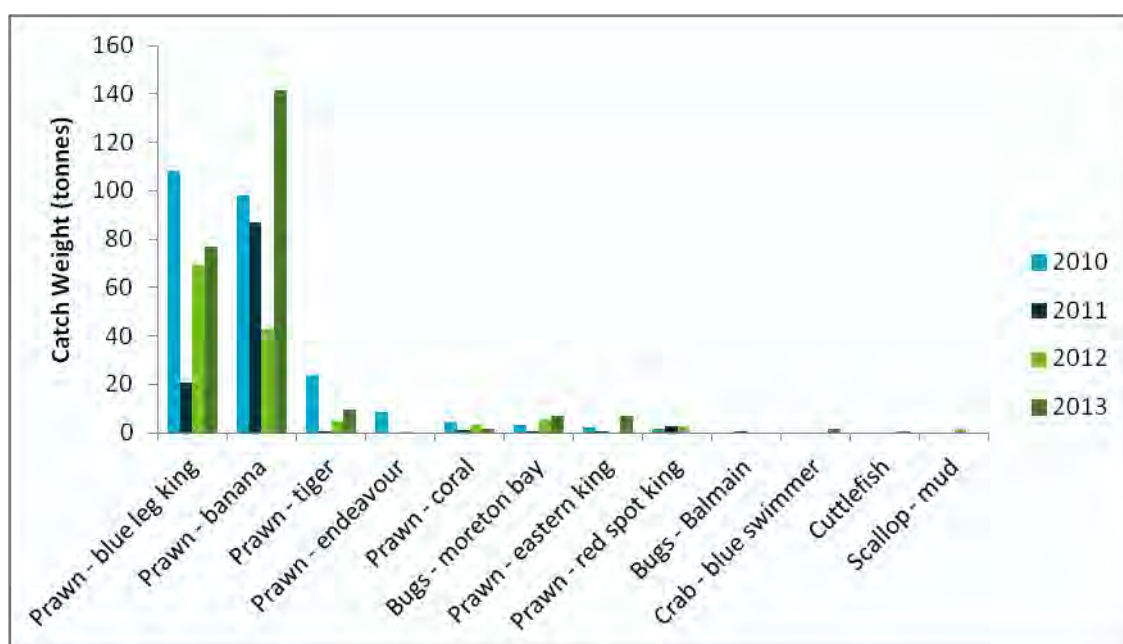


Figure 35: Top annual otter trawl species by weight (tonnes) for the Mackay region in 2010, 2011, 2012 and 2013.

9.3.4 INSHORE COMMERCIAL NET FISHERIES

The top five taxa harvested in the inshore net fishery represent approximately 70% of the harvest by weight (barramundi, king threadfin, blue threadfin, mullet and grey mackerel), with a further 98 taxa retained as by-product. Included in the count are 20 shark taxa with whaler species the most abundant. Figure 36 shows the catch in tonnes of the top annual species for 2010, 2011, 2012 and 2013.

In 2010, the total catch for the region from 1202 fishing days was 158.7 tonnes - the lowest catch per effort yield during the four year time period. In 2011, active fishing licences decreased to 42, the number of fishing effort days increased to 1272 and the total reported weight was 193.9 tonnes. Effort and catch continued to increase in

2012 with 45 boats reporting 249 tonnes of catch. In 2013, 47 licences fished for 1378 days with logbooks returns totalling 207.3 tonnes.

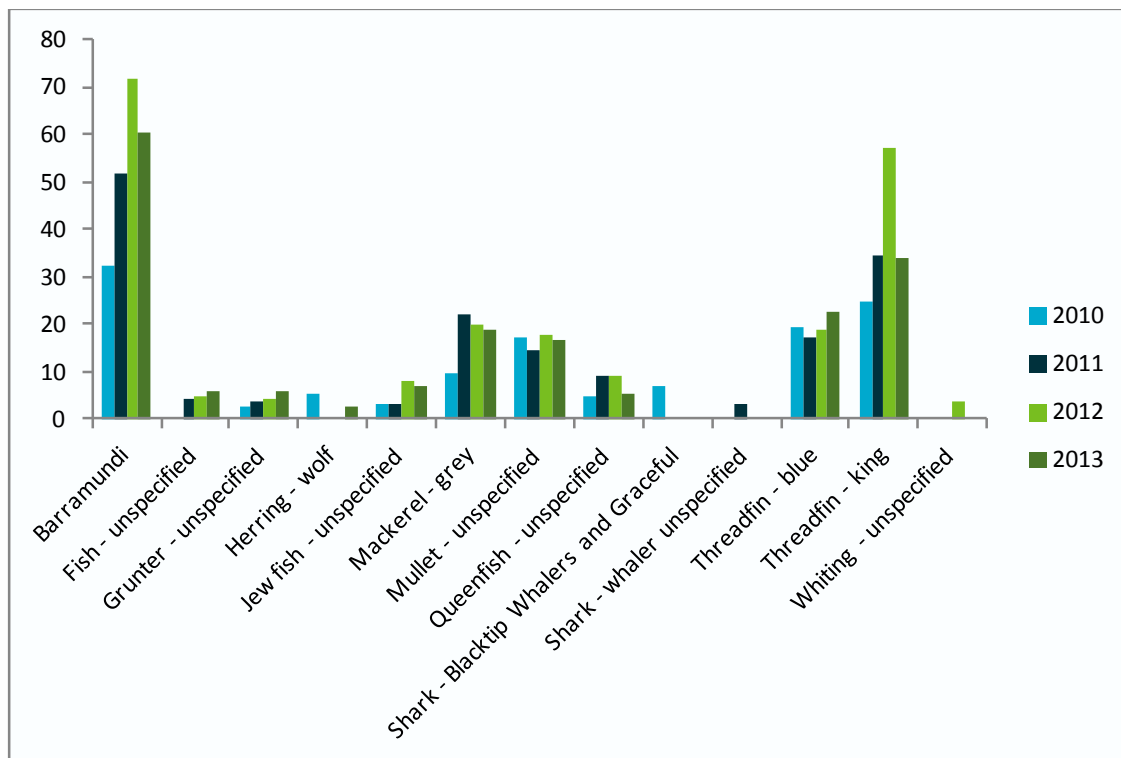


Figure 36: Top annual species by commercial net fishers between 2010 and 2013 for the Mackay region. Catches are in tonnes.

9.3.5 INSHORE COMMERCIAL POT FISHERIES

Mud crabs represented over 99% of the retained catch from the pot fishery—blue swimmer crabs, crabs - unspecified, baitfish, barramundi and mullet were also retained albeit in very small quantities as by-product.

Catch and effort attributed to pot fishing in the region has increased over the time period. In 2010, 46 licences recorded 3620 days of effort which yielded a total of 142.7 tonnes. In 2011, these figures increased to 44, 4312 ad 186.5 tonnes for licences, fishing effort days and retained weight respectively. Fishing effort continued to increase with 2012 reporting 47 licences and 4425 days of fishing effort and 2013 reporting 53 licences and 4971 days of fishing effort. Both years yielded a total of 173 tonnes - overall 2012 averaged a slightly higher catch per unit of effort.

9.3.6 INSHORE COMMERCIAL LINE FISHERIES

The commercial line fishery contributes the smallest amount of product by weight in comparison with other fishing method types in the Mackay region. Between 2010 and 2013 a total of 28 licences utilised line apparatus with a total reported catch of 13.8 tonnes. Line catch included 44 taxa - high catch species were Spanish

mackerel, silver jewfish and coral trout as shown in Figure 37. The presence and reported weight of line caught species differ quite significantly between years, unlike other fishing method types; this suggests that line fishing in the area doesn't target a set list of key species.

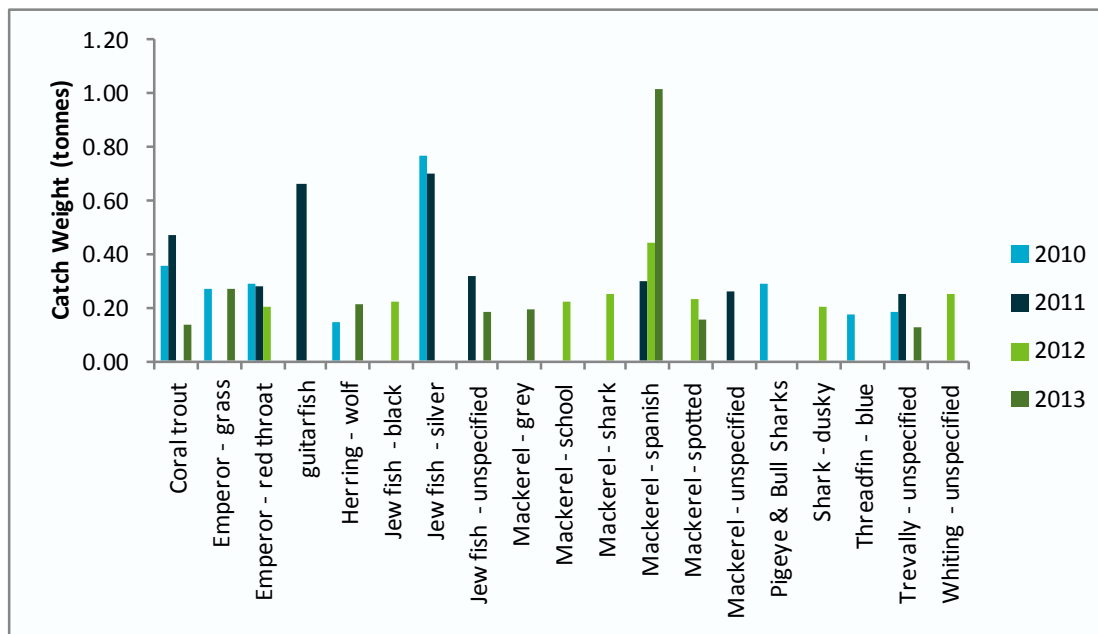


Figure 37: Highest line caught species by weight (tonnes) for the period 2010 to 2013 in the Mackay region.

Despite the very low catch in comparison with adjacent areas, Mackay is the most important port for the landing of line caught quota fish species in the east coast finfish fishery. The average annual landing of quota caught reef finfish and Spanish mackerel between 2010 and 2013 was approximately 330 tonnes.

Between 2010 and 2013, 22 charter vessels reported fishing in the Mackay region. Calculations from logbook data estimate that charter operators retained 5.1 tonnes of inshore species and discarded an additional 2.6 tonnes.

9.3.7 INTERACTIONS WITH PROTECTED SPECIES

Between 2010 and 2013, only one interaction with a Species of Conservation Interest was reported. This interaction occurred in 2012 and involved the net fishery and a saltwater crocodile, which was released alive.

9.3.8 TRENDS IN REGIONAL COMMERCIAL FISHERIES

When considering a larger time period, 2005 to 2013, it becomes evident that there has been a slight downward trend in the number of fishers operating in the Mackay region (Figure 38).

The number of otter trawlers operating in the region is highly variable annually but has declined from 69 in 2005 to only 35 in 2013. All other fisheries appear relatively

stable over the time period. Examining the trends in more detail shows active pot licences increasing slightly - most recently between 2011 and 2013 but both beam trawl and line licences decreasing to their lowest or below their lowest active licences since 2005. Oppositely, the total number of days fished across all sectors shows an increasing trend.

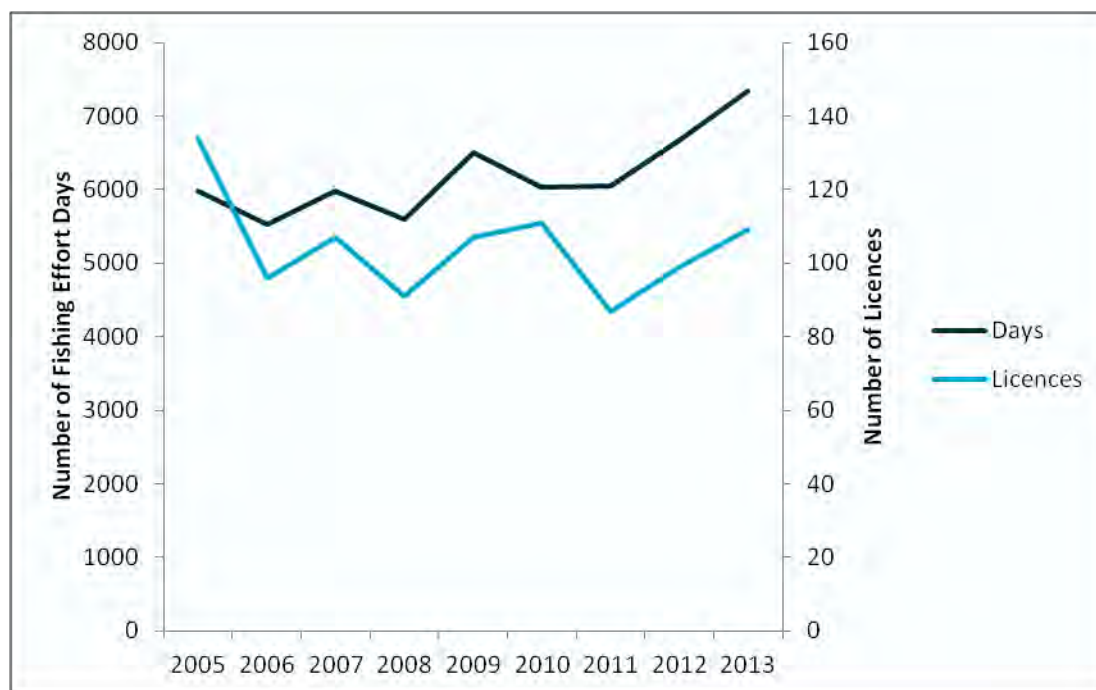


Figure 38: Overall fishery participation and effort information, 2005–2013.

Catches from the pot fishery have shown an increase over time in association with an increasing number of days fished. Net fishing days have remained relatively steady with a very slight overall decrease, on closer inspection an initial increase in catch was reported between 2005 and 2009 but declined shortly thereafter paralleling trends in days fished in that sector.

Beam trawl statistics for the time period have remained relatively stable with the exception of 2011 and 2013 where active licences, days fished and catch were at their lowest since 2005. Overall the line fishery has shown a small decline in commercial participation and catch in the region since 2005.

Otter trawl fishing effort days and catch followed a similar overall decreasing trend - with high and low fluctuations exaggerated by the catch data.

9.3.9 RECREATIONAL FISHING IN THE REGION

The Mackay region in the state wide recreational fishing survey includes Bowen, Mackay, Proserpine and the Whitsunday islands. Fishers in the region have access to excellent marine fishing environments which is reflected in their catches. Information included in this section describes the recreational fishing activities of residents of the Mackay region. Residents of the Mackay region did most of their fishing where they

lived but some ventured south to the Fraser Coastal waters and the south-eastern catchment.

The Mackay region showed the highest recreational fishing participation rate of all Queensland regions according to the 2010 DAFF telephone survey. It was estimated that 28% of residents fished at least once recreationally in the twelve months prior to July 2010 - much higher than the state wide average of 17% - a total of 45 322 fishers (+/- 3478 se) which was 8493 fishers more than in 2000.

Fishers were distributed across all age groups with the 30–44 year olds making up the bulk of recreational fishers. As with the rest of Queensland more males than females participated in recreational fishing.

More days were spent fishing from boats (Figure 39) than the shore and most of this was done in marine waters. People go fishing throughout the year but peaks in fishing activity were recorded in April and September, coinciding with school holidays.

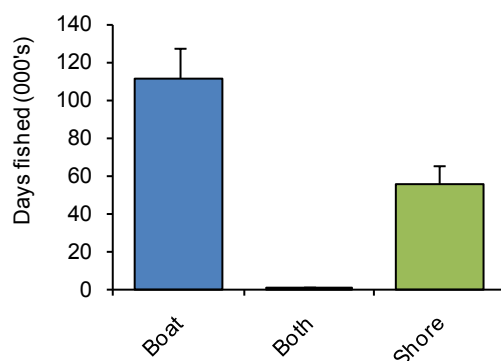


Figure 39: Number of recreational days fished from a boat or the shore.

Residents of the Mackay region caught over 200,000 mud crabs. Marine cod and pikey bream were also commonly caught species. Approximately 70,000 marine cod were caught with 85% of them released. Approximately 25,000 barramundi were caught and 75% of those were released (see Figure 40).

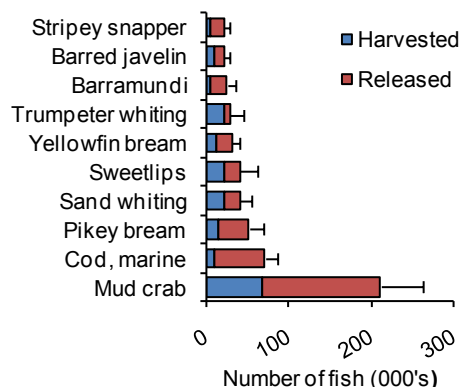


Figure 40: Top ten recreational species caught by number.

Although redthroat emperor was not one of the top ten species caught by residents of the Mackay region, they did take approximately 25% of Queensland's recreational harvest of this species. They also took more than 20% of Queensland's harvest of silver javelin and stripey snapper.

9.3.10 REFERENCES

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Data from the DAFF commercial fishery logbook database: 12 May 2014.

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9.4 Burdekin regional inshore fisheries profile

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9.4.1 INTRODUCTION

Fisheries Queensland defines the Burdekin region as extending from 19°S just north of Herald Island to 20.5°S encompassing Edgumbe Bay and waters approximately 30 nautical miles from the coastline. For the purpose of this report the Burdekin region includes grids J21, K21, K22, L21, L22, M22 and M23 of the Queensland Department of Agriculture, Fisheries and Forestry (DAFF) commercial fisheries logbook grid system (DAFF, 2012a). This area represents a small portion of both the Cape Clinton to Gloucester Head (including the Whitsundays) fishing region and Edgumbe Bay to Lucinda Point fishing region as defined in the statewide recreational fishing survey. In terms of participation by recreational fishers, the Burdekin grids fall within both the Mackay and Northern area of residence for the DAFF telephone surveys - it is important to note that the Mackay and Northern residential areas are far larger than the area shown in Figure 41. It is possible that the recreational participation rate would be higher than the estimate provided due to the close proximity of these grids to the coast (DAFF, 2012a).

There are extensive commercial fishery closures in the region imposed by Great Barrier Reef and Queensland marine parks zoning (Marine National Park and

Conservation Park zones) and Dugong Protection Areas declared under the Fisheries Act 1994 (Figure 41). Trawling is further restricted to General Use zones in the region while recreational fishers are only restricted by Marine National Park zones.

To capture recent interannual variability, information for the last four years, 2010 to 2013 are presented in the following sections. In section *Trends in Regional Commercial fisheries* information is presented back to 2005. Catchability, catch and catch rate of inshore species will be impacted by recent environmental conditions including summer flooding and cyclone Yasi in early 2011.

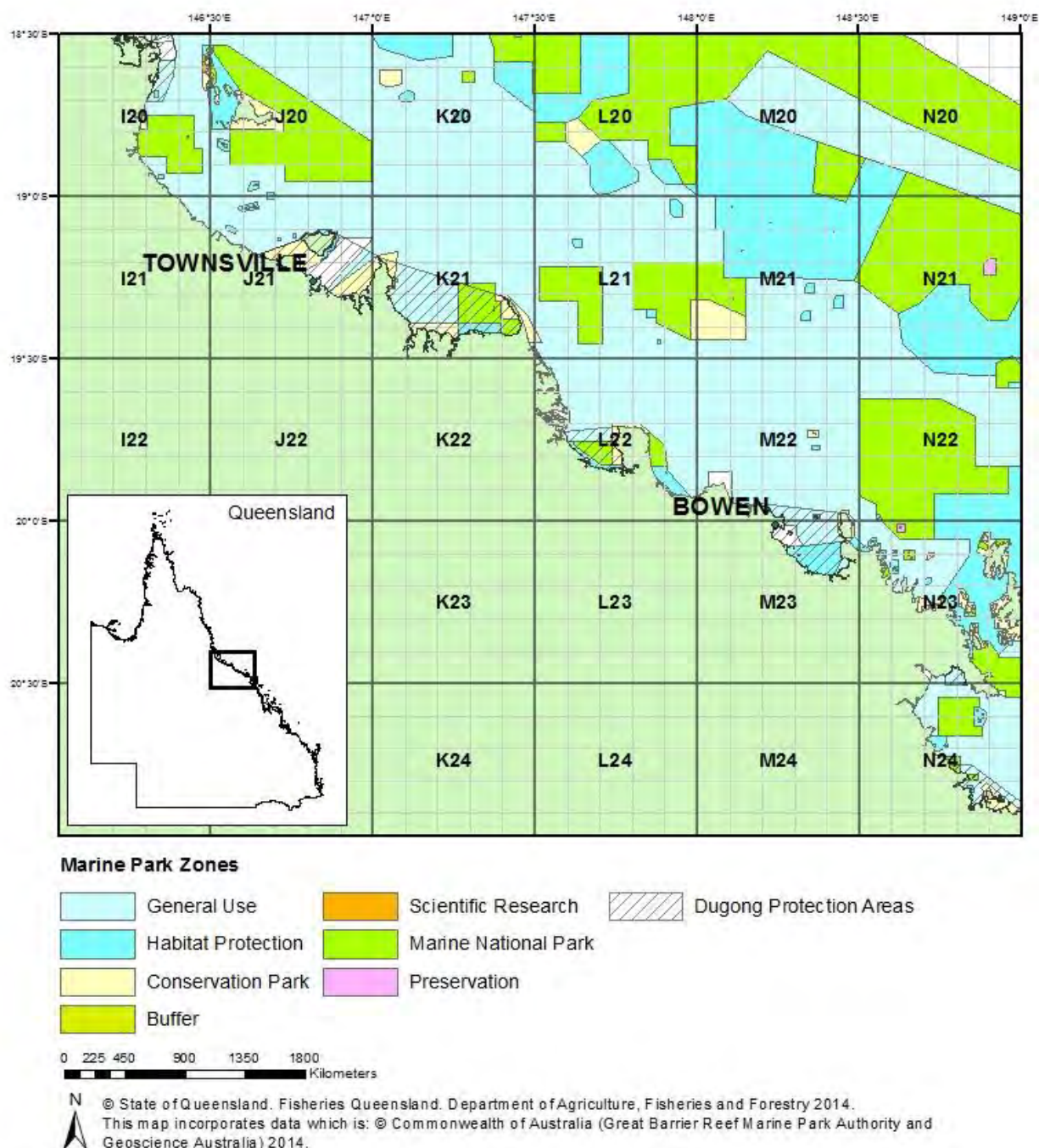


Figure 41: Burdekin region showing Dugong Protection Areas and Marine Parks zoning.

9.4.2 COMMERCIAL FISHING OPERATIONS

Most commercial fishing operations have multiple endorsements, which allow them to switch fishing apparatus and target different fisheries resources. In addition some fishing operations, especially otter trawlers, are mobile and may shift their fishing operation to adjacent areas to maximise their profits. Consequently, the number of commercial fishers operating in an area will change from year to year.

In 2010, there were a total of 134 active commercial fishing licences in the Burdekin region (Figure 42). In 2011 and 2012 fisher numbers decreased to 117 and 106 respectively. Most recently in 2013, 123 operators reported the catch of inshore species via logbook returns.

Similarly to the Mackay region, fluctuating levels of active fishing licences in the Burdekin region can be attributed to the variability in the number of otter trawlers and to a smaller extent in recent years, the line fishers. In 2010 there were 55 otter trawlers operating within the defined Burdekin region; this number dropped to 34 and 31 in 2011 and 2012 respectively. An increase to 39 operators was recorded in 2013. During this time period there were approximately three otter trawlers annually participating in alternative fisheries - predominately gillnetting.

A 45% drop in the number of active line fishers between 2011 and 2012 combined with the declining number of otter trawlers, resulted in the noticeable drop in the total number of active fishers, particularly in 2012. In 2010, the number of active line fishers was 31 - in 2012 this number peaked to 33. Thereafter, the activity of line fishers decreased to 22 in 2012 and rose slightly again to 27 in 2013. Annually between 35% and 55% of line fishers in the Burdekin region participate in other fisheries - 70% of the multiple endorsed operators fish in the net and pot fisheries.

In recent years the pot and net fisheries have reported the largest number of active commercial licences - since 2010 the net fishery has been the greatest source of inshore finfish catch in the Burdekin region. In 2010, 57 fishers reported net catch and 40 fishers reported pot catch - of these, five fished solely in the pot fishery, 19 fished using net apparatus only and 23 used a combination of both methods. Between 2011 and 2013 net fishers remained reasonably constant, ranging from 56 to 59 operators. The pot fishery displayed an initial decrease from 45 in 2011 to 42 operators in 2012 followed by a return to 2011 levels in 2013. Between 2011 and 2013 the number of exclusive net fishers and the number of combination fishers remained relatively stable, however operators solely undertaking pot fishing have steadily increased and in 2013 were at 150% of 2010 levels. Fishers that engage in net and pot fishing also fish using otter trawl, beam trawl and line apparatus.

In the Burdekin region the least number of operators - out of all commercial fishing method types - fish using beam trawl equipment. In 2010, three operators submitted beam trawl logbook returns. This number then dropped to a single operator in 2011 and remained stable at two fishers during 2012 and 2013. It is evident through logbook data that in 2010, 2011 and 2013, with the exception of 2012, beam trawl operators fished in combination with other fishing method types.

Every year, between 2010 and 2013, approximately 30% to 40% of the operators in the Burdekin region participate in multiple fisheries - the majority operate solely in one fishery using one type of fishing method. Between 2010 and 2013 the Burdekin region displayed increases and decreases in catch weight. In 2010, the region retained 661 tonnes of product which then increased to 733 tonnes in 2011.

Commercial seafood production in 2012 decreased, recording levels similar to that in 2010 with a reported 627 tonnes of catch - figures increased in 2013 to 708 tonnes.

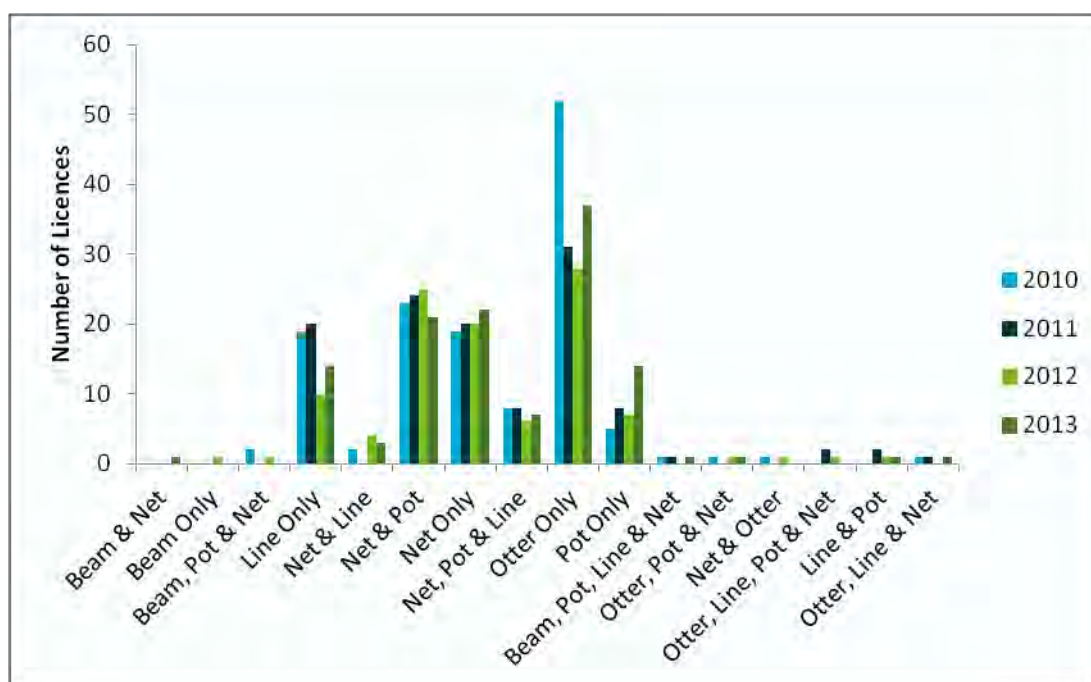


Figure 42: Number of licences participating in the different fishing method type combinations in the Burdekin region.

9.4.3 INSHORE COMMERCIAL TRAWL FISHERIES

Of the two types of commercial trawling available to fishers in the Burdekin region, otter trawling is the predominant trawling method - otter trawling is second to net fishing in its total production of inshore species by weight. In 2010, 55 operators, fished for a total of 930 days to retain 145.7 tonnes of seafood. Numbers of operators fishing using otter trawling equipment decreased to 34 in 2011 along with the number of fishing effort days to 850, inversely, catch weight increased to 155.3 tonnes. In 2012, otter trawl effort and catch fell to its lowest during the time period, 31 operators, 446 fishing days - 50% of that recorded in 2011 - and 104.7 tonnes of total catch. Fishing effort and catch increased in 2013 to 39 operators, 1329 days and 241.1 tonnes.

Several species are identified in the Burdekin region as being the highest caught, however the 'species list' changes on a yearly basis. Only two species are caught consistently at a slightly higher weight than all other species - Moreton Bay bugs and red spot king prawn. Moreton Bay bugs feature as a top caught species between 2010 and 2013 where they contributed between 12% and 40% to the total weight. During the time period red spot king prawn, in all years apart from 2012, also features as a dominant species with catches contributing between 20% and 30% to the annual total otter trawl production. In 2011, banana prawns contributed an astounding 68% to the total recorded weight. Similarly, peaks in mud scallop during 2012 contributed more than 40% of the total catch and tiger prawns contributed 20% during 2013.

Three beam trawlers retained 1.6 tonnes of catch in 2010. Since then catch has fallen well below one tonne. Banana prawns are the dominant species in the beam trawl fishery with very miniscule quantities of greasy prawns reported in some years.

A total of 29 taxa, of which 12 are prawns, were reported by the trawl fisheries between 2010 and 2013. The majority of the otter trawl catch weight consists of a handful of species; the remaining retained species contributed approximately two to three percent to the total catch by weight. The highest caught species by weight for 2010, 2011, 2012 and 2013 are shown in Figure 43.

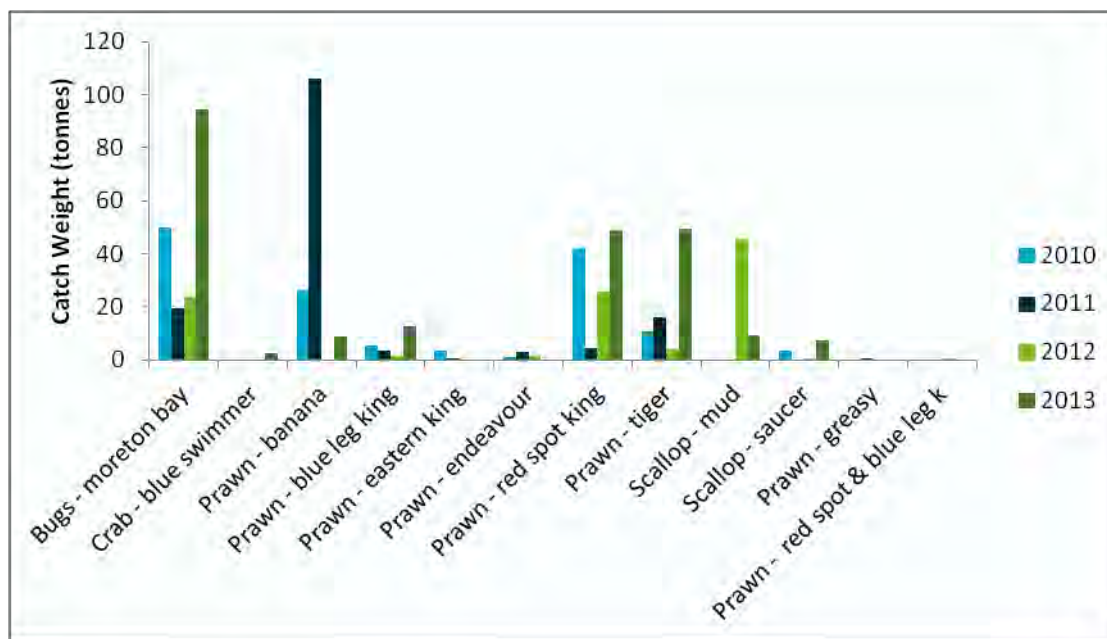


Figure 43: Top annual otter trawl species by weight (tonnes) for the Burdekin region in 2010, 2011, 2012 and 2013.

9.4.4 INSHORE COMMERCIAL NET FISHERIES

The top five taxa in the inshore net fishery differ slightly from those caught in the neighbouring Mackay region. In the Burdekin region the top five species contribute on average 70% by weight to the total annual fishery harvest - these species are barramundi, grey mackerel, mullet, queenfish, blacktip whalers and graceful sharks (complex) and blue threadfin. An additional 87 taxa are reported but retained in smaller by-product quantities. Of the reported taxa, 23 are sharks with the blacktip and graceful shark complex reported as the most abundant. The catch in tonnes of the top annual net species for the period 2010 to 2013 is illustrated in Figure 44.

In 2010, the total net catch for 2165 days of fishing was 366.3 tonnes. The yield of catch per unit of effort increased in 2011, with 2245 fishing effort days reported and total retained weight increasing to 410.3 tonnes. In 2012, active net fishers increased to 59, the number of fishing effort days decreased to 2115 and total weight declined

by 45 tonnes from 2011 to 364.8 tonnes. Fishing effort days and catch weight continued to decrease in 2013 with fishers catching 363.3 tonnes in 1998 days.

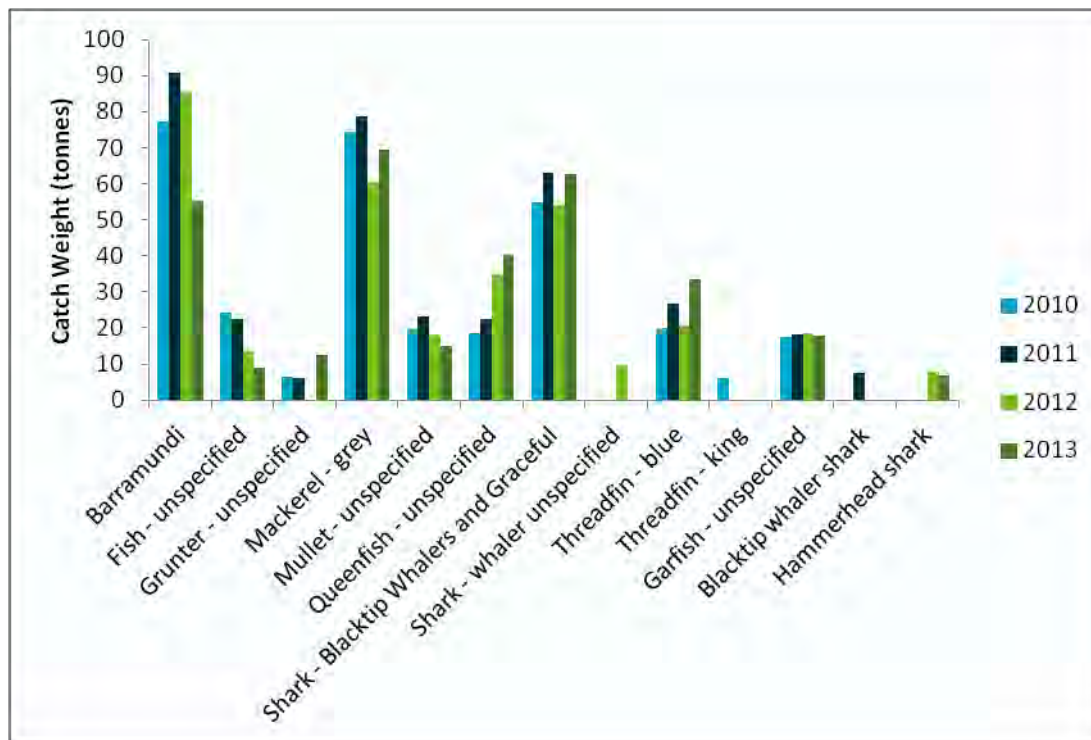


Figure 44: Top annual species by commercial net fishers between 2010 and 2013 for the Burdekin region. Catches are in tonnes.

9.4.5 INSHORE COMMERCIAL POT FISHERIES

Catch and effort in the Burdekin pot fishery has fluctuated over time - it is apparent that the numbers of operators, number of fishing effort days and total catch do not increase or decrease in direct proportion. In 2010, 40 pot operators submitted logbooks, which reported 3602 days of fishing effort and the harvest of 104.6 tonnes of crustaceans and inshore fin fish. The highest yield per unit of effort for the fishery was recorded in 2011 when 45 operators went fishing for a total of 4155 days and retained 138.9 tonnes of catch. The following two years, 2012 and 2013, recorded large decreases in catch levels to 122 tonnes and 81.4 tonnes respectively.

Mud crabs represented over 98% of the retained catch from the pot fishery in the Burdekin region - blue swimmer crabs were also retained but in small quantities. Species of bream, mullet, grunter, threadfin and cod were also retained as by-product in quantities smaller than 200 kilograms.

9.4.6 INSHORE COMMERCIAL LINE FISHERIES

The commercial line fishery contributes the second smallest amount of product by weight in comparison with other fishing method types in the Burdekin region. The number of annual fishing effort days in the line fishery decreased from 316 in 2010 to

196 in 2013. In 2010, 43 tonnes of inshore finfish species were harvested, this figure decreased in 2011 to 28.1 tonnes. Although the number of operators and fishing effort days decreased in 2012 catch weights increased to 35.2 tonnes. In 2013, retained catch reached its lowest point during the time period - a total of 21.9 tonnes was reported via logbook returns.

Line catch statistics include a total of 66 taxa - Spanish mackerel was the highest contributing species by weight. Other dominant line species (although not in the same quantities as Spanish mackerel) were coral trout, grey mackerel, unspecified mackerel and spotted mackerel (Figure 45).

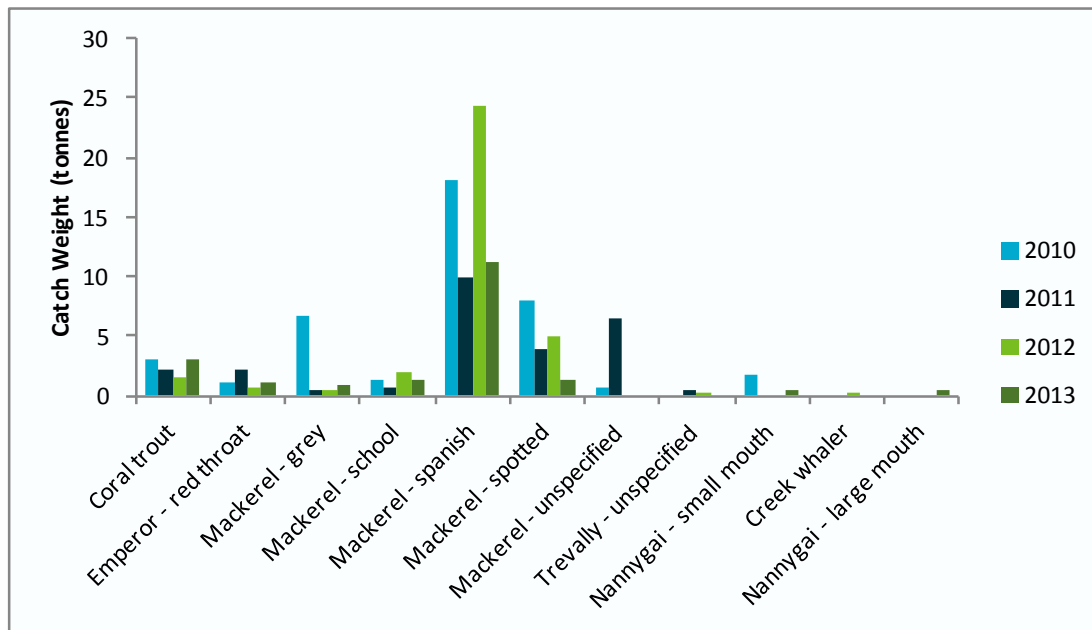


Figure 45: Highest line caught species by weight (tonnes) for the period 2010 to 2013 in the Mackay region.

Despite lower catch weights than other areas, the Burdekin is an important port for the landing of line caught quota fish species in the east coast finfish fishery. The average annual landing of quota caught reef finfish and Spanish mackerel between 2010 and 2013 was approximately 260 tonnes.

Between 2010 and 2013, 27 charter vessels reportedly spent 910 days fishing in the Burdekin region. Logbook data estimate charter operators retained 11.2 tonnes of inshore species and discarded an additional 11 tonnes over the time period.

9.4.7 INTERACTIONS WITH PROTECTED SPECIES

Between 2010 and 2013, multiple interactions with Species of Conservation Interest were reported. In 2010, the net fishery interacted with five loggerhead turtles and a saltwater crocodile, all were released alive. During the same year the trawl fishery interacted with a seahorse which was released alive and a total of 393 sea snakes, of which six were injured, seven were released dead and 380 were released alive. Interactions in 2012 decreased significantly to one fatal interaction between a net

and an offshore bottlenose dolphin and 27 sea snake interactions with the trawl fishery - all survived with the exception of one which was released dead. In 2012 and 2013 combined the net fishery interacted with four hawksbill turtles which were all released alive.

9.4.8 TRENDS IN REGIONAL COMMERCIAL FISHERIES

Over the last nine years the Burdekin region has illustrated a decreasing trend in the number of operators - fishing effort appears relatively stable through time apart from a small peak in 2008 (Figure 46).

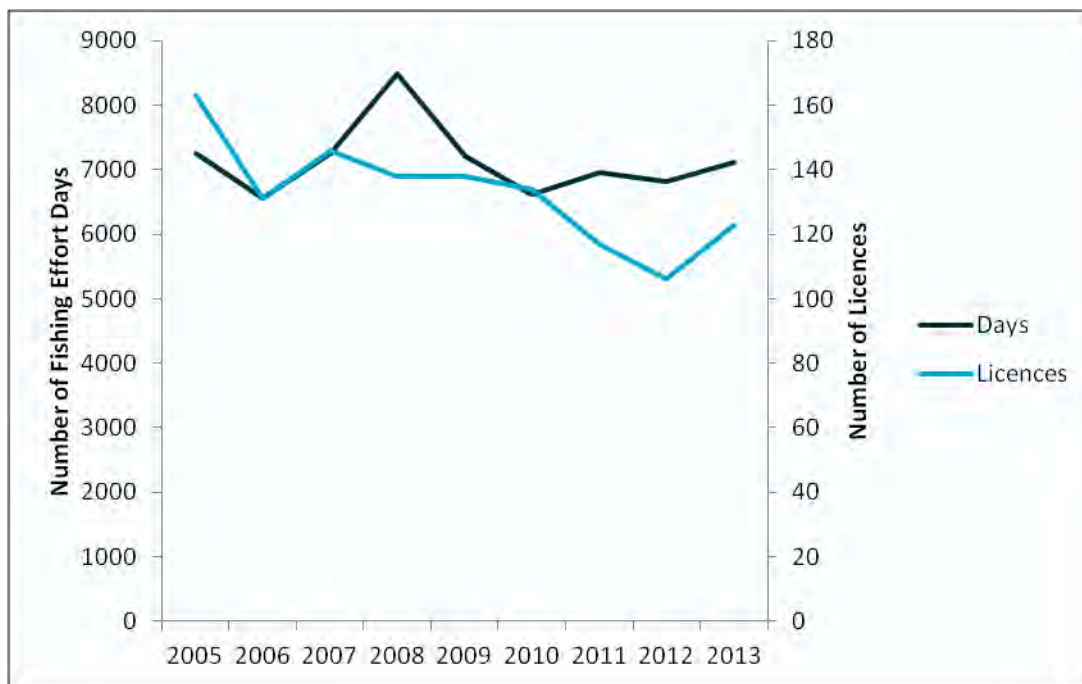


Figure 46: Overall fishery participation and effort information, 2005–2013.

Figure 47 illustrates the most noticeable decline in the number of operators in the otter trawl fishery. Operator numbers decreased from 92 in 2005 to 39 in 2013. Between 2005 and 2013 all other fishing method types exhibited relatively steady trends in active fishers - close observation shows very slight increases in the pot and net fisheries and a small decrease in the line fishery.

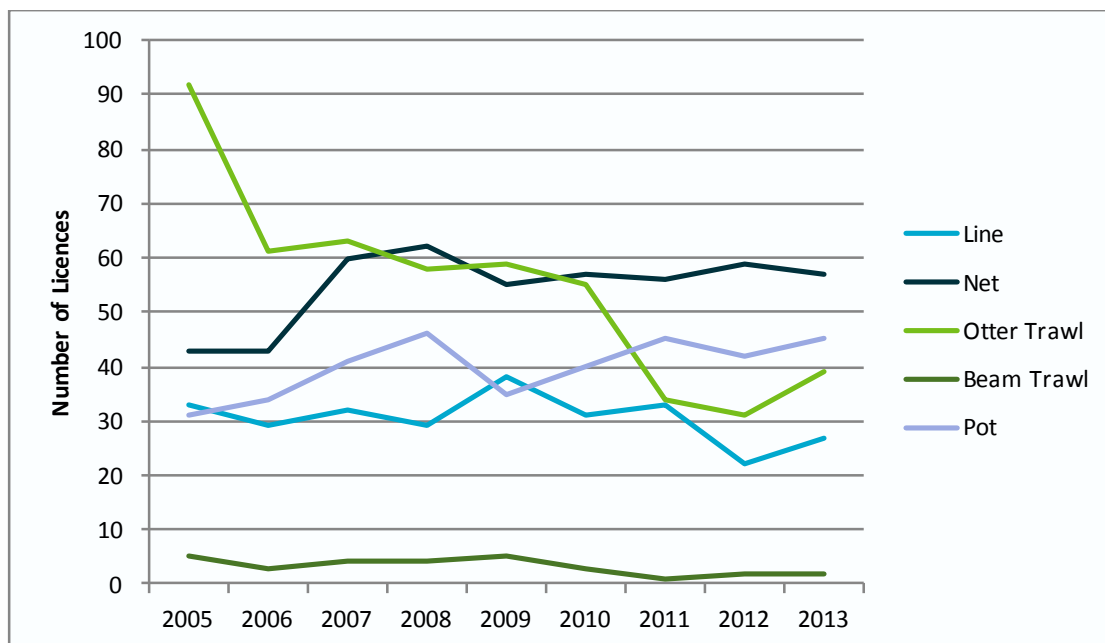


Figure 47: Number of active fishing licences by fishing method type , 2005–2013.

Over time, fishing effort days in the net, line and beam trawl fisheries appear relatively stable - pot and otter trawl fisheries fishing days appear proportional to increases or decreases in operator numbers. Otter trawl fishing effort days and catch followed an overall decreasing trend - with high and low fluctuations exaggerated by the catch data (Figure 48). The overall trend in the pot fishery illustrates an increase in the number of fishing effort days and catch - catch weights began increasing in 2008 and peaked in 2011 but have since decreased, although to levels higher than in 2005.

Whilst operator numbers and fishing days have remained fairly stable, fluctuations in net catches have been recorded throughout the time period, 2005 to 2013. Peaks in catch were recorded in 2005, 2008, 2009 and 2011, with the remaining years consistently reporting in the mid to high 300 tonnes.

Line fishery catch weights appear relatively stable in Figure 48 with data suggesting that after peaking in 2009 and 2010 the line fishery is decreasing slightly. Oppositely, catch yield per day of fishing effort has increased over time period with the exception of the most recent year 2013.

At its highest, in 2005, the beam trawl fishery retained 5.1 tonnes of catch in the Burdekin region, since then beam trawl catch statistics have decreased over time. In 2013, a mere 220 kilograms of inshore fin fish species were reportedly retained - the lowest reported during the time period.

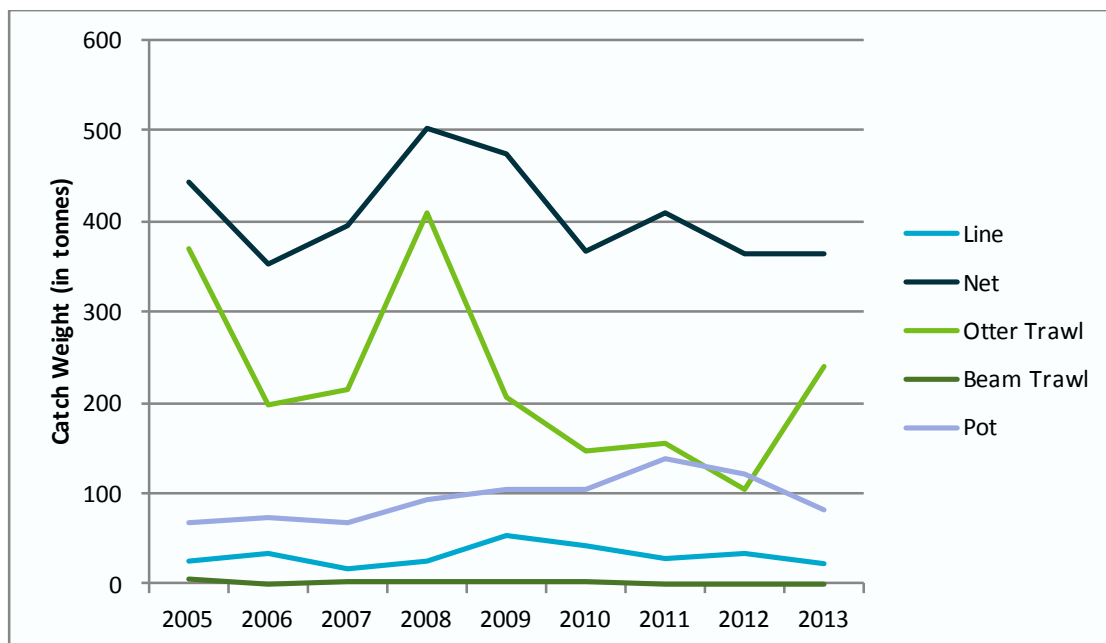


Figure 48: Catch weight (in tonnes) by fishing method type, 2005–2013.

9.4.9 RECREATIONAL FISHING IN THE REGION

The Mackay residential region in the statewide recreational fishing survey includes Bowen, Mackay, Proserpine and the Whitsunday islands. Fishers in the region have access to excellent marine fishing environments which is reflected in their catches. Residents of the Mackay region did most of their fishing where they lived but some ventured south to the Fraser Coastal waters and the south-eastern catchment.

The Northern residential region includes Townsville and Ingham and provides access to fish habitats such as the mangrove lined Hinchinbrook channel and the Great Barrier. Northern residents mainly fish close to where they live in the central coast catchment and the Cairns and Townsville coastal waters but some also ventured north and fishing in Cooktown's coastal waters.

The Burdekin grids allocated for this report fall inside both the Mackay and Northern residential regions of the recreational fishing survey. This report presents a simple average of the two residential regions to present effort and catch based information for the Burdekin region. Information included in this section describes the recreational fishing activities of residents of the Mackay and Northern residential regions.

Approximately 24% of Burdekin residents aged five years or above went fishing in the 12 months prior to the survey. This was much higher than the statewide average of 17%.

For the combined region fishers were distributed across all age groups with the 30-44 year olds making up the bulk of recreational fishers. As with the rest of Queensland more males than females went recreational fishing.

More days were spent fishing from boats (Figure 49) than the shore and most of this was done in marine waters. People go fishing throughout the year but peaks in

fishing activity were recorded in April and September, coinciding with school holidays.

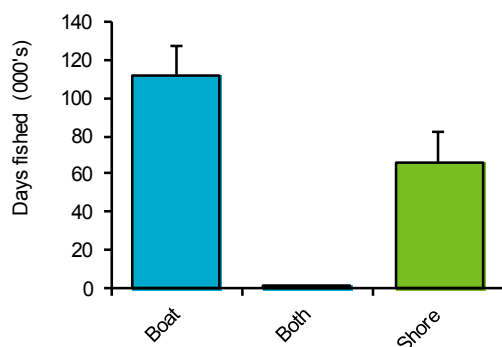


Figure 49: Number of recreational days fished from a boat or the shore (average of Mackay and Northern Residential areas).

Residents of the Burdekin region caught more mud crabs than other species, with marine cod, barramundi and pikey bream also featuring as commonly caught species (Figure 50).

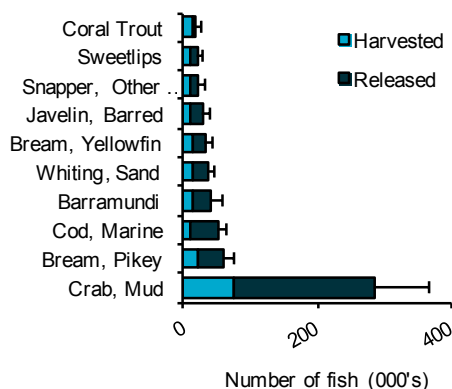


Figure 50: Top ten recreational species caught by number (average of Mackay and Northern Residential areas).

9.4.10 REFERENCES

Department of Agriculture, Fisheries and Forestry Queensland (DAFF) (2014). Logbook Maps.

Department of Agriculture, Fisheries and Forestry Queensland (DAFF) (2012a). Fact sheet: 'Recreational fishing in the regions: Mackay residents' A snapshot from the 2010 statewide recreational fishing survey, Brisbane, viewed 14 May 2014, http://www.daff.qld.gov.au/__data/assets/pdf_file/0003/50970/mackay-regional-summary-final.pdf

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Data on recreational fishing from the DAFF recreational fishing survey 2010-11.

10 Management options and their relative importance in Mackay

10.1 Introduction

The coastal zones of the world, especially those associated with estuaries, are environmentally, economically and socially complex (91). These zones support many important industries (e.g. fisheries, ports, tourism), key habitats (e.g. wetlands, salt marshes, seagrass, mangroves), and iconic or threatened species (e.g. dugongs, inshore dolphins, water birds). The coastal zone and associated estuaries are one of the most impacted ecosystems (1, 92), often experiencing cumulative impacts of more than 15 human-induced stressors (1). Land and catchments adjacent to the Great Barrier Reef (GBR) region in Australia can be a source of nutrients, sediments and contaminants to the reef (2). On the other hand, estuaries provide nursery habitats to reef biodiversity (93, 94).

Stakeholder input (aka. a partnership approach) is seen as essential for good management in many industry sectors (13, 95). For example, the Australian commonwealth manages fisheries with the input from a series of committees with industry, scientists, managers and the conservation sector represented to provide technical (Resource Assessment Groups) and management advice (Management Advisory Committees) (13). However, these fisheries structures tend to focus on industry and conservation as their stakeholders, while local communities are not often directly involved. The Australian forestry sector has attempted to engage the general community although at times highly contentious and seemingly irresolvable issues were shown to be difficult to resolve due to outside, non local influences and interest groups (96). It could be argued that the coastal zone has developed a form of community engagement through the use of report cards produced and used by, for instance, regional Natural Resource Managers (NRMs) that explicitly provide environmental health status. Examples of these report cards can be found in many parts of the world (e.g. Chesapeake Bay <http://ian.umces.edu/ecocheck/report-cards/chesapeake-bay/2013/>) including the GBR (<http://www.reefplan.qld.gov.au/measuring-success/report-cards/assets/report-card-2012-2013.pdf>) and South-east Queensland (<http://www.health-e-waterways.org/reportcard>).

An important component of regional management is mechanisms for stakeholder and community input local management (97, 98) and to also consider these inputs in management decisions. Engagement mechanisms provide a two-way flow of communication between stakeholders (including communities, industry and government) and managers who are able to ground truth and further develop possible management actions with locals. By actively participating in the decision process and having inputs into decisions, communities are also able to obtain relevant information and better appreciate and understand trade-offs associated with different decisions. This gives community members a greater sense of ownership through participation. The concept of citizen participation in management has a long (although intermittent) history in Australia (99). In the coastal zone this engagement is not trivial as the issues and management structures are inherently complex. However, often the engagement with the community has been somewhat linear and aimed at addressing singular issues and possible management responses

(e.g. Pressey, Cowling and Rouget (37)). Few have undertaken a structured approach as described in the adaptive management loop (100, 101).

Adaptive management follows control theory (6, 102) and includes the steps of firstly reviewing knowledge, then determining management objectives, developing management actions, establishing monitoring program, and lastly implementing management actions (Figure 51).



Figure 51: Adaptive management loops steps (Redrawn from (103))

In this section, a structured approach, following the adaptive management loop, was adapted from a method used in a trawl fishery in Queensland (104) and applied to a coastal case study. The purpose was to test the method in a multiple-use coastal setting using a community group (as opposed to a stakeholder representative group) and managers. The research was applied in a coastal case study city in rural Queensland (Australia) to investigate the articulation of management options and their relative importance with regards to coastal fisheries and inshore biodiversity.

10.2 Methods

10.2.1 MANAGEMENT STRATEGIES

The LMAC RG was used as a representative of a community group in Mackay. It consists of a group of interested residents and relevant agencies (as part of the project). A key aspect of the process is to provide the RG access to many of the relevant management agencies to the coastal zone and information relevant to the topic. Of importance is that the management options elicitation process came after a lengthy deliberation of their objectives and relative weights, and developing

qualitative models of key assets in the region. A transitional meeting leading the RG from the objectives weighting to the management options was undertaken, showing existing management being undertaken by the different agencies and NGOs.

The process of management options elicitation followed a standard process, with only minor refinements in each session: an initial discussion about which topic in the coastal zone would be the subject of management discussions, and then for each topic one or two presentations from an expert in the field asked to concentrate on information relevant to Mackay, the development of an issues register, and the production of two classes of management options and the related relevant agency to which it relates. The RG was asked to produce two classes of management options for each issue – direct and indirect options. The former was seen as working directly with the relevant management agency e.g. the local council whereas the indirect was seen as working in an influencing manner to potentially achieve the same or a similar outcome (although the degree and effectiveness may differ). This was seen as important by the project team, to ensure people do not get unrealistic expectations that a government action is achievable and needed as the only option.

Apart from the presentations, the RG were provided printouts of the qualitative models they produced (when applicable), a distribution map of the topic, the water quality Outlook results for Mackay. The map was used as way of geo-locating any issues and the RG were provided with post-it notes, one for each issue, so that they could place on the maps.

Initially, due to perceived time constraints, the presentation and issues register was undertaken as a separate session to developing management option. This was viewed by the group as unnecessary and also means people forgot what was discussed between sessions. There were also practical considerations such as trying to keep the same groups between two meetings when there was not always a consistent membership. The next options were to undertake the topic in the same meetings as a series of presentation, issues register and management options discussions. However, after one session in this format, the group naturally completed the process as presentation with subsequent discussion on issues and management options at the same time. This process seemed more intuitive to people. The project team observed that the groups still produced a reasonably comprehensive list of issues and completed at least two management options for each issue.

Existing management measures: setting the scene

A series of presentations were provided as a transitional meeting between the objectives weighting and management options sessions:

- An overview of the catchment to coast framework concentrating on the Reef Catchment Plan;
- Upper and middle catchment statistics, issues, plans and existing management measures;
- Coastal statistics, issues, plans and existing management measures;

- Biodiversity statistics, issues, plans and existing management measures; and
- Fisheries statistics, issues, plans and existing management measures.

Issues register

Seven topics were chosen that were relevant to the coastal zone and of interest to the group:

- Coastal water quality;
- Seagrass and associated ecosystem;
- Mangroves and associated megafauna;
- Inshore corals;
- Urban development;
- Port development; and
- Fisheries.

Since upper catchment water quality was out of scope in the project, the RG decided to bundle coastal water quality and seagrass into a single session. The two were seen as very interrelated.

Management Strategies elicitation

Elicitation of management options from stakeholders is a key component of this project. The elicitation of management options is aimed at maintaining the balance between practical, cost-effective options and creative ideas to address inshore biodiversity and fisheries issues in the Mackay region. The project team combined management solutions from the community with ideas from Queensland management organisations on how to best implement them.

From June 2013 to March 2014 the GBR NERP project team met with the Mackay reference group (RG) almost monthly to discuss issues and management options for the Mackay inshore region. The RG is a sub-committee formed from the Mackay Local Marine Advisory Committee and consists of local Mackay residents that are, amongst others, local farmers, fishers, conservation group members, employees from council and Qld Bulk Ports.

The outcomes of these meetings were discussed in a 3-day project team workshop to develop management strategies and discuss the best ways of implementing them. The objective of the meeting was to provide a first cut at combining these management options into practical grouped management strategies that could be garnered from over 300 options mentioned by the group. The United Nations Environment Program (UNEP) assessment framework was used as a basis for this process.

This list of management strategies and associated description were then discussed and changed (if needed) to reflect the views of the RG. The objective of this report was to present and discuss the list of management strategies of the RG to managers and other interested parties that could help move these ideas towards implementation. It was the main seed document to the workshop that was held at the end of May 2014. At this meeting these management strategies were discussed

in the context of a) what is currently being done in the context of each management strategy, b) what more can be done, c) what would this extra work cost and d) what the social, economic and ecological impact of undertaking this work would be.

In order to distil the resultant large number of management options into a more practical, combined set of management strategies, the project team spent three days reviewing each of the management options elicited from the RG. There was always someone at the meeting that was at the table when an option was discussed and this memory and notes taken were very useful as some of the options were often written in short hand. In order to articulate the pathway of combining management options, the project team used the well-known United Nations Environment Program risk assessment framework known as DPSIR (Drivers, Pressures, States, Impacts and Response) as a basis for their thought processes. This framework first started in a more simplified form of Pressure-State-Response – this basic version was used here.

The management options from the RG were grouped into management strategies, following a process of naming management strategies via aggregation, addition, exclusion and re-wording of the original management options. Each strategy is a response to address the pressures affecting the inshore GBR, which are expected to influence the ecological, social or economic states. An Access and a GIS database have been created also allowing one to follow each management option, its spatial location (if provided) and which management strategy it was placed in. No management option has been ignored or deleted in the process. This work was then edited and changed by the RG to reflect the views of the group rather than only the project team. The final list below is therefore the result of 2 years of work by the RG to provide local views of the issues and the potential management strategies to address these.

The resultant management strategies were discussed and reviewed with the Mackay reference group on May 14, 2014. The agreed management strategies were presented to managers and other interested parties that could help move these ideas towards implementation in a workshop Mackay on May 28, 2014. Managers were defined as people whom either directly or indirectly influence management decisions. The below are the resultant management strategies that went to this management meeting.

10.2.2 IMPACT ASSESSMENT

Two phases of impact assessment were undertaken – the first was before the management workshop and undertaken by the RG members only. The second was during the management workshop by all participants based on any suggestions made within the workshop of possible management actions. By nature of the process, the latter list of management options will be a smaller more implementable list than that brought to the management workshop.

The method of obtaining the impact assessments were different to the two steps in that the first were against the full list of objectives, whereas the second was against the goals "social" "economic", "ecological" and "governance". The scoring scale was unchanged. For both, they also scored their uncertainty ("confidence") of their answers against each objective.

The aim of the two assessment surveys was to determine how the thirteen different management strategies compare to the current system. The time horizon was 10 years i.e. the changes that would occur over a 10-year horizon if the strategy were to be implemented over that period. The idea was to identify strengths and weaknesses of each strategy, and also if they will have different effects on the different management objectives for the Mackay region.

To complete the survey participants placed a value ranging from -3 (considerably worse than the current system) to 3 (considerably better than the current system) against a) management objectives in the case of the pre-management workshop impact assessment undertaken by the RG and b) during the management workshop but at the goal level (both RG and managers).

Table 32 summarises the meaning of each score. Participants were also asked to provide their confidence score from 1 to 5 (Table 33) as to their confidence in providing the answer relating to each objective, with 1 indicating very unsure and 5 indicating certain.

The impact assessment form for the pre-management workshop is shown in Table 38 and that for the management workshop in Table 42. The preambles (details of respondent, ethical statement, introduction and instructions – including Table 34 to Table 36) for each meeting are provided before these two tables respectively.

Table 32: Details of scores on how participants think each strategy performs against each objective.

Scale	Meaning
3	Considerably better than current situation
2	Moderately better than current situation
1	Slightly better than current situation
0	Same as current situation
-1	Slightly worse than current situation
-2	Moderately worse than current situation
-3	Considerably worse than current situation

Table 33: Details of scores on how confident participants were about the way they scored against each objective.

Confidence

Scale	Meaning
1	Very unsure
2	Fairly uncertain
3	Moderately certain
4	Fairly certain
5	Certain

Pre-management workshop impact assessment form

Your details



Name: _____

Email: _____

Please choose the group that you mostly associate with by checking (✓) the appropriate stakeholder group

Stakeholder groups	Tick one
Commercial Fishing	
Charter Fishing	
Commercial seafood processing	
Recreational Fishing	
Diving	
Tourism	
Fisheries Management	
Fisheries Compliance	
Tackleshops, Recreational Service Industry	
Marine Services Industry	
Mining	
Port Authority	
Farmer	
Grazier	
Conservation organisation	
Great Barrier Reef Marine Park Authority	
Queensland Parks and Wildlife Service	
NRM group	
Local Government	
State Government	
Aboriginal & Torres Strait Islander	
Local Resident	
Scientists	
Student - High School	
Student - Tertiary	
Other	

Please indicate the region where you are located

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

Instructions

This survey is being undertaken as part of the project 'Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)'. It is currently limited to members of the Mackay LMAC reference group.

The aim of the survey is to determine how the fourteen different management strategies presented earlier compare to the current system. The time horizon is 10 years i.e. the changes that would occur over a 10-year horizon if the strategy were to be implemented over that period. The idea is to identify strengths and weaknesses of each strategy, and also if they will have different effects on the different management objectives for the Mackay region.

To complete the survey, please place a value ranging from -3 (considerably worse than the current system) to 3 (considerably better than the current system) in each of the boxes on the tab 'Mackay_Obj and MgtStrat' in the Excel spreadsheet or in the attached hard copy. The table below summarises the meaning of each score. Please also provide your confidence score from 1 to 5 as to your confidence in providing the answer relating to each objective, with 1 indicating very unsure and 5 indicating certain (see 'confidence score' table below for details).

Details about management objectives elicited in an initial stage of the project are provided below. The description of each management strategy and information on how they were constructed is provided in a separate document.

Information you provide will only be used for the purposes of aggregate analysis, and individual responses will be kept confidential. We ensure your confidentiality by not making public the individual content of the information you provided both verbally and also on the Excel and paper spreadsheets. The information will be used for research purposes only, without reference to specific facts or events. For any reporting your individual information will not be presented - all information will be presented in summarised form based on collating all spreadsheet data.

After use, the recorded material you provide will be kept at a secure location on the CSIRO network only accessible to a core team of people until Dec 2014. Before that date, participants will be able to access, upon request, the material corresponding to their own spreadsheet. After that date, all recorded material will be securely deleted.

It is your right to withdraw from the workshop at any time if you wish to do so. Also, if you do not wish the project team to use the data you provided you will have 30 days from today (14 May 2014) to advise the project team.

Thank you for your participation!

Cathy Dichmont

Table 34. Details of scores on how you think each strategy performs against each objective.

Scale	Meaning
3	Considerably better than current situation
2	Moderately better than current situation
1	Slightly better than current situation
0	Same as current situation
-1	Slightly worse than current situation
-2	Moderately worse than current situation
-3	Considerably worse than current situation

Table 35. Details of scores on how confident you are about the way you scored against each objective.

Confidence

Scale	Meaning
1	Very unsure
2	Fairly uncertain
3	Moderately certain
4	Fairly certain
5	Certain

Table 36. Example of how to give your relative score (-3 to 3) of how you think each of the management strategies will perform against each management objectives.

Objectives	Address littering through education, legislation and operating procedures	Develop and implement weed and pest management plans for regions	Confidence (score 1-5)
1.1.1 Reduce direct impacts of infrastructure and development	1	0	3
1.1.2 Minimise human induced changes in water flow regimes	2	3	5
1.2.1 Ensure Reef Plan water quality targets are met	0	0	2

Explanation about management objectives for the Mackay region

Table 37. Objective hierarchy showing levels (branches of the tree) and descriptors of the objectives presented in Figure 1.

Level	Objective	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)
Level	Objective	Descriptor
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
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

Level	Objective	Descriptor
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
Level	Objective	Descriptor
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
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

Level	Objective	Descriptor
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

Table 38. Impact assessment form at the objective level undertaken by RG members.

Objectives																Confidence (score 1-5)
1.1.1 Reduce direct impacts of infrastructure and development																
1.1.2 Minimise human induced changes in water flow regimes																
1.2.1 Ensure Reef Plan water quality targets are met																
1.2.2 Increase feral animal control and environmental friendly weed control strategies																
1.2.3 Reduce influx of pollutants																
1.3.1 Sustainable human use of marine resources																
1.3.2 Maintain habitat function and structure																
1.3.3 Reduce impacts on Threatened, Endangered,																

Objectives															Confidence (score 1-5)
Protected (TEP) species															
2.1.1 Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning, diversification in the economy)															
2.1.2 Increase compliance with environmental and resource use regulations															
2.2.1 Increase management acceptability															
2.2.2. Increase stakeholder engagement and community ownership/stewardship															
2.2.3 Sustainable financial costs															
2.3.1 Increase policy integration															
2.3.2. Increase regulatory integration															
2.3.3 Increase															

Objectives															Confidence (score 1-5)
implementation integration															
3.1.1 Improve regional economic development and industry diversity															
3.1.2 Improve family livelihoods in the region															
3.1.3 Ensure that natural resource based industries are profitable and sustainable															
3.2.1 Minimise conflicts between stakeholders															
3.2.2 Conserve traditional activities and cultures															
3.2.3 Ensure community equity															
3.3.1 Improve workplace and family health and safety in the region															
3.3.2 Improve education, training, social infrastructure and networks															

Scale	-3: Considerably worse than current situation	-2: Moderately worse than current situation	-1: Slightly worse than current situation	0: Same as current situation	1: Slightly better than current situation	2: Moderately better than current situation	3: Considerably better than current situation
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Confidence score (1-5)	1: Very unsure	2: Fairly uncertain	3: Moderately certain	4: Fairly certain	5: Certain
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Management workshop impact assessment form

Your details

Name: _____

Email: _____



Please choose the group that you mostly associate with by checking (✓) the appropriate stakeholder group

Stakeholder groups	Tick one
Commercial Fishing	
Charter Fishing	
Commercial seafood processing	
Recreational Fishing	
Diving	
Tourism	
Fisheries Management	
Fisheries Compliance	
Tackleshops, Recreational Service Industry	
Marine Services Industry	
Mining	
Port Authority	
Farmer	
Grazier	
Conservation organisation	
Great Barrier Reef Marine Park Authority	
Queensland Parks and Wildlife Service	
NRM group	
Local Government	
State Government	
Aboriginal & Torres Strait Islander	
Local Resident	
Scientists	
Student - High School	
Student - Tertiary	
Other	

Please indicate the region where you are located

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

Instructions

This survey is being undertaken as part of the project 'Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)'. It is currently limited to members of the Mackay LMAC reference group.

The aim of the survey is to determine how the fourteen different management strategies presented earlier compare to the current system. The time horizon is 10 years i.e. the changes that would occur over a 10-year horizon if the strategy were to be implemented over that period. The idea is to identify strengths and weaknesses of each strategy, and also if they will have different effects on the different management objectives for the Mackay region.

To complete the survey, please place a value ranging from -3 (considerably worse than the current system) to 3 (considerably better than the current system) in each of the boxes in the attached hard copy. The table below summarises the meaning of each score. Please also provide your confidence score from 1 to 5 as to your confidence in providing the answer relating to each objective, with 1 indicating very unsure and 5 indicating certain (see 'confidence score' table below for details).

Information you provide will only be used for the purposes of aggregate analysis, and individual responses will be kept confidential. We ensure your confidentiality by not making public the individual content of the information you provided both verbally and written. The information will be used for research purposes only, without reference to specific facts or events. For any reporting your individual information will not be presented - all information will be presented in summarised form based on collating all spreadsheet data.

After use, the recorded material you provide will be kept at a secure location on the CSIRO network only accessible to a core team of people until Dec 2014. Before that date, participants will be able to access, upon request, the material corresponding to their own spreadsheet. After that date, all recorded material will be securely deleted.

It is your right to withdraw from the workshop at any time if you wish to do so. Also, if you do not wish the project team to use the data you provided you will have 30 days from today (28 May 2014) to advise the project team.

Thank you for your participation!

Cathy Dichmont

Table 39: Details of scores on how you think each strategy performs against each objective.

Scale	Meaning
3	Considerably better than current situation
2	Moderately better than current situation
1	Slightly better than current situation
0	Same as current situation
-1	Slightly worse than current situation
-2	Moderately worse than current situation
-3	Considerably worse than current situation

Table 40: Details of scores on how confident you are about the way you scored against each objective.

Confidence

Scale	Meaning
1	Very unsure
2	Fairly uncertain
3	Moderately certain
4	Fairly certain
5	Certain

Table 41: Example of how to give your relative score (-3 to 3) of how you think each of the management strategies will perform against each management objectives.

Objectives	Ecological	Governance	Social	Economic
Address littering through education, legislation and operating procedures	3	2	1	0
Develop and implement weed and pest management plans for regions	2	3	0	2
Confidence (score 1-5)	5	4	3	1

Table 42: Impact assessment form used during management workshop.

Management Strategies	Ecological	Governance	Social	Economic
1. Address littering through education, legislation and operating procedures				
2. Develop and implement weed and pest management plans for regions				
3. Education - best development practices				
4. Education – on farm best practices				
5. Education - fishery campaign				
6. Education - improving governance				
7. Improve compliance by obtaining local stakeholder input				
8. Improve resource management through better planning, assessment and regulation				
9. Legislation changes to allocation and sustainability of fishery issues				
10. Management for protected species				
11. Reduce impacts of dredging				
12. Support, facilitate and coordinate basic research				
13. Transparent (to public) and coordinated monitoring reporting				
Confidence (score 1-5)				

Scale	-3: Considerably worse than current situation	-2: Moderately worse than current situation	-1: Slightly worse than current situation	0: Same as current situation	1: Slightly better than current situation	2: Moderately better than current situation	3: Considerably better than current situation
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Confidence score (1-5)	1: Very unsure	2: Fairly uncertain	3: Moderately certain	4: Fairly certain	5: Certain
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Impact assessment analyses

The relative impact of each management strategy was analysed as per the fisheries case described in Dichmont, *et al.* (105). The output of the relative impact assessment is an impact matrix $I_{i,j}^s$ where s is the management strategy, i is the number of objectives and j is the number of workshop participants. The confidence

scores, $C_{i,j}^s$ were applied to the impact matrix by adding the impact matrix to the average (over j) of the confidence scores, i.e. $(I_{i,j}^s * C_{i,j}^s) / \overline{C_i^s}$ as the elements of the matrix I' . This results in a higher weight being applied to strategies (s) where respondent (j) scores were more certain. The relative weights per respondent for each objective were combined into a single relative weight matrix, $W_{i,r}^g$ by stakeholder group, g , where r is the number of respondents to the survey (which is a larger number than j). The overall results can therefore be combined, $\overline{W_i^g} * \overline{I_i^s}$ for each stakeholder group and management strategy.

Where the sums of all the objectives are a positive score, an overall positive score contribution is indicated. A negative score indicates that the overall result is negative relative to the current situation. The scale of the confidence score indicated the degree of confidence in whether the positive or negative effect is likely to eventuate. In the RG workshop, the impact assessment was undertaken at the objective level on the lowest part of the objective hierarchy (i.e. 24 objectives), whereas the managers' workshop only assessed against 4 high level goals (environment, governance, economic, social). Participants were divided into "Government", "Resource users" or "Other" (Table 43).

Table 43: 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	Others
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 Chandleries	Resource users

The analyses are undertaken in R (106) and the default settings are used for the 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 $\min[\max(\mathbf{x}); Q3 + 1.5(Q3 - Q1)]$ of the data vector $\mathbf{x}$ and the lower whisker is $\max[\min(\mathbf{x}); Q1 - 1.5(Q3 - Q1)]$. Any values outside these whiskers are shown as outliers.

The level of group coherence was tested and indicates the degree to which members of the above stakeholder group have similar or dissimilar objective preferences. A measure of group coherence can be given by:

$$\bar{\rho} = \langle \mathbf{v}_i \bullet \mathbf{v}_j \rangle \quad i \neq j$$

where $\mathbf{v}_i$ and $\mathbf{v}_j$ are vectors that compromise the square root of the objective weights of individuals i and j ; $\bullet$ indicate the dot product between the two vectors and $\langle \rangle$ indicates the average of the set of dot products (107). The closer the value is to one, the greater the average agreement in opinion of the individuals. There is not accepted critical value though some authors have adopted 90%, 95% or 99% as their critical measures.

10.3 Results and Discussion

10.3.1 QUALITATIVE MODELS

RG members were very quick (within the first session) to understand the qualitative modelling method once it was explained to them. Visualising their perceptions on a whiteboard as they described the system was the most effective means of learning the method. Four different qualitative models were developed i) creek habitats with emphasis on cumulative impacts; ii) seagrass with emphasis on coastal development; iii) a generalised model on coastal development that includes most coastal space users; and iv) a coastal model that investigated the management feedback loop of water quality monitoring and public opinion.

It was interesting that although several assets were included, such as turtles and dugongs, seagrass, mud flats, mangroves and creeks, the models tended to show the same cumulative impacts as coastal development. Although these models can be used to inform management strategies and the models were provided to RG, these were not used by the RG to develop management actions or understand feedback loops. Therefore this is one part of the process that could be discretionary in order to save time.

10.3.2 GOALS AND OBJECTIVES

Each of the goals (first level) contains additional (second level) sub-goals and (third level) objectives (Table 44). The full list of goals (top), sub-goals (mid) and objectives (lower level) in a hierarchical format are shown in Appendix B Figure S.1 and described in more detail in Dutra, *et al.* (108). The objectives are used in the impact analyses for the RG results (Table 44).

The overarching goals selected by the RG differ from the usual triple-bottom line objectives (environmental, social and economic) often found in the literature (34, 109). The three goals developed here included a) environment, b) governance and c) conjoined economic and social goal of "well-being". This highlights the importance of governance goals in the hierarchy.

Although governance was also given prominence in a Queensland fisheries example (110), there were four goal levels being "Environment", "Management", "Economic" and "Social". Interestingly, in this example the word "Governance" was not liked and replaced by "Management". In this section, the term was also much discussed, but when the RG tried to find a more adequate replacement they retained its use. The RG preferred instead to further define the meaning of governance in the name of the goal: "Improve governance systems (i.e. leadership, institutions, rules and decision-making processes involved in managing inshore biodiversity)".

Table 44: Objectives used in the Research Group (RG) workshop – numbers show their lineage in the hierarchy where the first number is the goal, the second is the sub-goal and the final number is the objective itself. The management strategies were provided for the impact assessment to RG and managers' workshop. The order in which they appear does not reflect their importance

Environmental objectives	Governance objectives	Well-being objectives
1.1.1 Reduce direct impacts of infrastructure and development	2.1.1 Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning, diversification in the economy)	3.1.1 Improve regional economic development and industry diversity
1.1.2 Minimise human induced changes in water flow regimes	2.1.2 Increase compliance with environmental and resource use regulations	3.1.2 Improve family livelihoods in the region
1.2.1 Ensure ReefPlan water quality targets are met	2.2.1 Increase management acceptability	3.1.3 Ensure that natural resource based industries are profitable and sustainable
1.2.2 Increase feral animal control and environmental friendly weed control strategies	2.2.2. Increase stakeholder engagement and community ownership/stewardship	3.2.1 Minimise conflicts between stakeholders
1.2.3 Reduce in flux of pollutants	2.2.3 Sustainable financial costs	3.2.2 Conserve traditional activities and cultures
1.3.1 Sustainable human use of marine resources	2.3.1 Increase policy integration	3.2.3 Ensure community equity
1.3.2 Maintain habitat function and structure	2.3.2. Increase regulatory integration	3.3.1 Improve workplace and family health and safety in the region
1.3.3 Reduce impacts on Threatened, Endangered, Protected (TEP) species	2.3.3 Increase implementation integration	3.3.2 Improve education, training, social infrastructure and networks

10.3.3 RELATIVE WEIGHTING

When the goal and objective weightings were analysed for all respondents, the median of the environmental goal had the highest weighting, followed by governance and then well-being, although the latter two were closely scored (Figure 52). The variance of the scoring, especially the environmental goal, was high, but there were also obvious outliers in the other two goals.

In Pascoe, Mary Dichmont, Brooks, Pears and Jebreen (42) fisheries example, "Management" was the third most important goal either after "Environment", and "Economic" or "Social". However, in this paper, there is a much more diffuse management environment where there are multiple responsible agencies at all three tiers of government and non-government agencies with many disparate resource users. It could therefore be argued that the respondent groups are quite different even though they fall within the "Resource User" group as these included recreational and commercial fishers, and ports; the same applied to the "Government" group. This could explain the reasonably wide range of responses even within a group as shown by the coherency test Table 45.

Table 45 Average group coherence for goals and objectives by stakeholder group

Stakeholder group	Goals	Objectives
All	0.92	0.80
Government	0.92	0.73
Others	0.93	0.83
Resource users	0.90	0.79

The similarity of the goals by respondent group is remarkable given the diversity of stakeholders present. For instance, "Resource users" such as those from fisheries and ports may be expected to value the economic component of the well-being goal more than potentially the Government group (some of whom were not even resident in Mackay). Such similarity in the results indicates 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. This finding is similar to what has been found in a study of a coastal port in Queensland (111), but contrasts to a fisheries case in Queensland where scientists and government were very similar whereas fishers rated economic values much higher (but still less than the environment) (110).

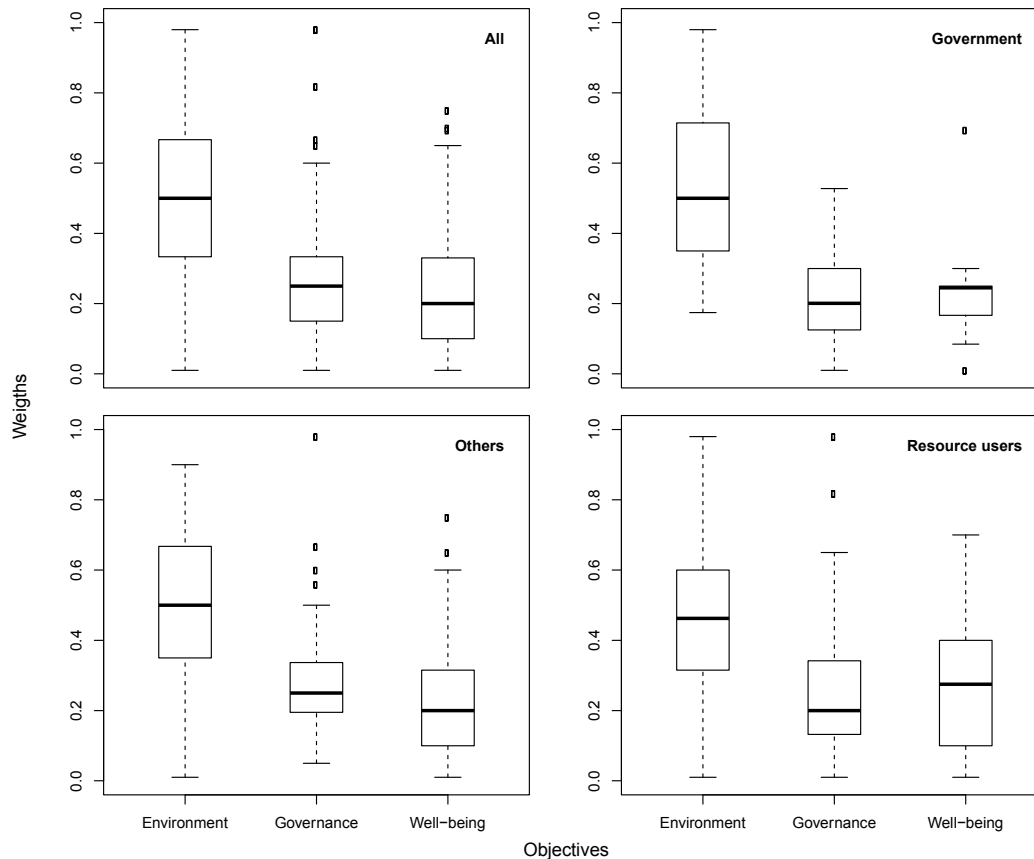


Figure 52: Goal weighting for all Mackay respondents combined ("all"), government agencies ("government"), resource users and others

When the objectives (as opposed to the goal) are considered, objectives 1.1.1 ("Reduce direct impacts of infrastructure and development") and 1.2.3 ("Reduce influx of pollutants") were the most important environmental objectives. The most important governance objective was 2.1.2 ("Increase compliance with environmental and resource use regulations"). The most important well-being objective was 3.3.2 ("Improve education, training, social infrastructure and networks") (Appendix B Fig S.2). Interestingly, the lower whiskers of the plot show that a zero rating is included in at least one of the respondent's answers in many of the goal and stakeholder combinations. Equally, the most highly weighted goal ("Environment") has the largest range. This highlights a diversity of opinion. If the outliers are included (Appendix B Fig S.3), there is a respondent that valued "Habitat" the highest, but this is clearly an outlier. The median score of the overall environmental goal consistently shows similar values for all the objectives within that goal, rather than the score being dominated by a single high or low score for an objectives i.e. people value all the objectives within the goal rather than only a few.

10.3.4 MANAGEMENT STRATEGIES

The RG selected seven topics relevant to coastal zone management. These were:

- Coastal water quality;
- Seagrass and associated ecosystem;
- Mangroves and associated megafauna;

- Inshore corals;
- Urban development;
- Port development; and
- Fisheries.

The topics are a combination of Pressures and State in the Pressure-State-Response framework (112). To the RG, combining pressures and states seemed a more natural way to categorise these topics than focussing specifically only on one or the other. Since upper catchment water quality was out of scope in the project, the RG decided to combine 'coastal water quality' and 'seagrass and associated megafauna' into a single topic. The two were seen as very interrelated.

From these six final topics, 357 non-unique management options were provided through the workshops, of which 230 fell within the category "Direct management options" and 127 as "Indirect management options". Unsurprisingly, since several groups were often working on the same topic and could mention the same "Issue" and "Management Options", there was much duplication. Identification of the "Responsible agency" produced 60 non-unique agency combinations (members may have listed several agencies for a specific action). On investigation with managers and the RG, this result demonstrated that often the RG did not know the exact jurisdiction and responsible management agencies, which resulted in misconceptions or false expectations about 'who' is supposed to manage coastal assets. The reason for this was likely to be two-fold based on discussions within the RG – members of RG did not know which agency was responsible but that there is a clear responsible agency or the responsible agency is not known given the nature of the solution. The latter was most noticeable for the options that included education campaigns.

Thirteen management strategies were derived from the 357 management options (A striking feature of this list is the breadth of impacts that are being addressed from littering – which negatively impacts biodiversity and fisheries – to incidents affecting protected species, such as boat strikes on dugongs and turtles.

Table 46). The management options are shown in Figure 53 where the outer top ring describes management strategies addressing a single impact, the inside top semi-circle represent the cross cutting management strategies, and the lower ring describes the educational campaign management. These latter strategies are aimed at integrating the outer and inner rings of the figure (the dominant indirect management option solution). In the impact analyses all the education campaigns were embedded within the 13 strategies so that their impacts were consistently addressed. The storylines that describe the background to the management strategy and the subsidiary management options are provided in Section 11.

A striking feature of this list is the breadth of impacts that are being addressed from littering – which negatively impacts biodiversity and fisheries – to incidents affecting protected species, such as boat strikes on dugongs and turtles.

Table 46: Management strategy names and their position in the conceptual diagram of Figure 53. Their abbreviation used in figures are shown in brackets

Management Strategies	Position in the conceptual diagram
1. Address littering through education, legislation and operating procedures ("Littering")	Top outer ring: Littering
2. Develop and implement weed and pest management plans for regions ("PestMgt")	Top outer ring: Pests

3. Fishery campaign (“FishCampn”)	Top outer ring: Fisheries
4. Legislation changes to allocation and sustainability of fishery issues (“Legislation”)	Top outer ring: Fisheries
5. Management for protected species (“ProtectedSp”)	Top outer ring: Protected species incidents
6. Reduce impacts of dredging (“Dredging”)	Top outer ring: Dredging
7. On farm best practices (“BestFarmPrac”)	Top outer ring: Farming
8. Best development practices (“BestDev”)	Top outer ring: Development
9. Improving governance (“Governance”)	Top semi-circle: Resources management
10. Improve resource management through better planning, assessment and regulation (“ImprvResMgmt”)	Top semi-circle: Resources management
11. Improve compliance by obtaining local stakeholder input (“Compliance”)	Top semi-circle: Compliance through stakeholder input
12. Transparent (to public) and coordinated monitoring reporting (“TransReport”)	Top semi-circle: Transparent monitoring and reporting
13. Support, facilitate and coordinate basic research (“Research”)	Top semi-circle: Basic research

The conceptual diagram was seen as a useful link between the management strategies developed by the RG and existing processes in management agencies. The project team presented the strategies to managers (decision makers that either make management decisions directly or influence the decision making indirectly) using the following steps:

1. selection of the specific impact (top outer ring) or cross-cutting topic (top semi-circle) in the conceptual diagram ,
2. the list of 13 management strategies, and
3. the storylines.

Based on the strategies from the RG, individual summary documents with reference to specific assets and issues (e.g. fisheries, littering and coastal development) were also produced (not shown here). There results were specifically presented to Fisheries and Council agencies, as these were the most important target audience for the RG.

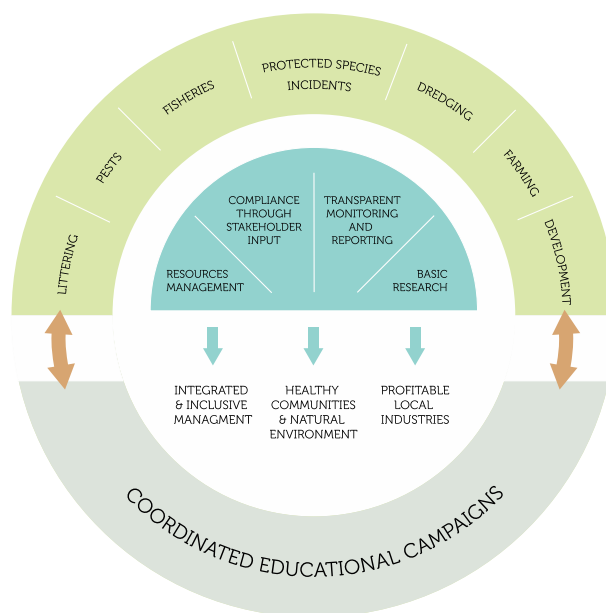


Figure 53: Conceptual diagram of the different management strategies and how they fit together

10.3.5 IMPACT ASSESSMENT FOR RELATIVE IMPORTANCE

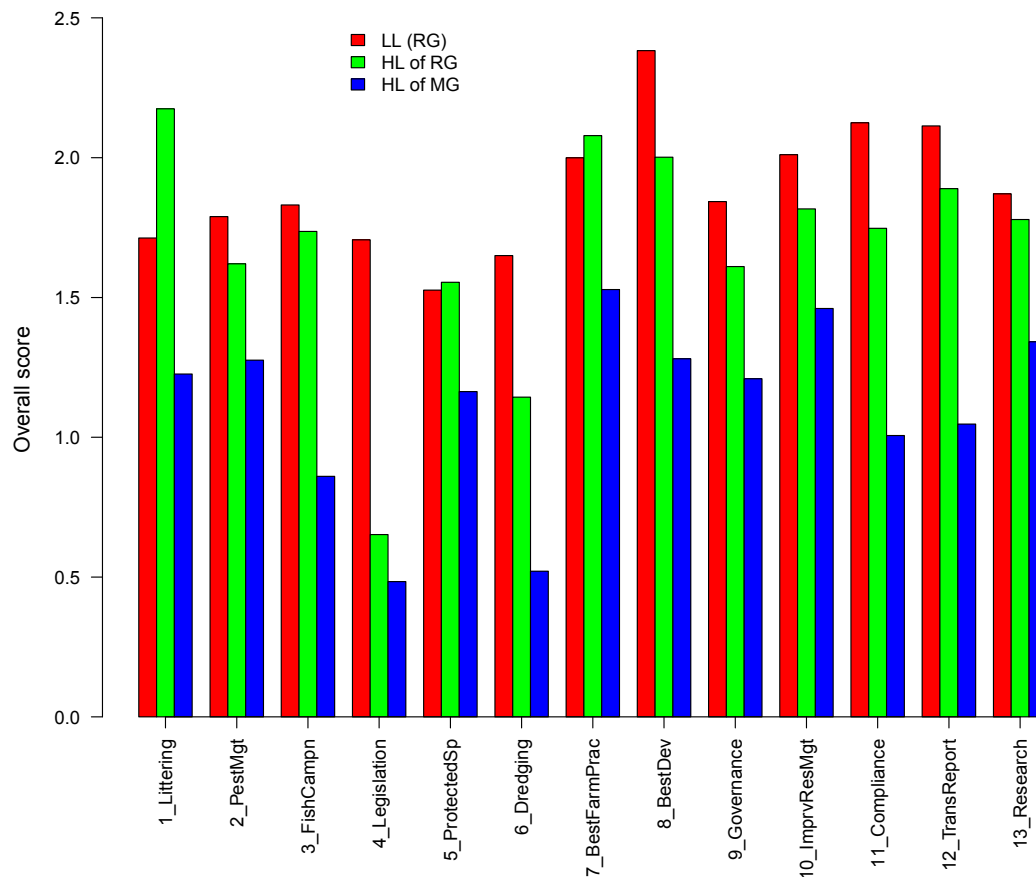


Figure 54: Average impact assessment scores (-3 to +3) without considering Confidence scores formed from i) the scores undertaken at the objective level (LL) prior to the management workshop by the RG, ii) the RG scores undertaken at the goal level (HL) at the management meeting, iii) HL scores of the managers at the management meeting.

Both the highest priority management strategy and the scale of the impact scores of the RG changed from earlier scores when they attended the Senior Managers Meeting (SMM) (although this may be confounded by the fact that they scored at the objective level prior and all participants scored at goal level at the SMM (Figure 54)). Members of the RG were contacted after the SMM to gather feedback and their overall impression was that the senior managers attending the meeting were either very negative or dismissive ("we are already doing this" or "we don't have the resources" was commonly heard). This could have influenced the perception of RG members about the effectiveness of management strategies to achieve objectives during the SMM (as opposed to their previous scoring without the managers) and thus the decrease in their impact score. The best development practice management strategy would require investment and commitment mainly by the local council representatives who were regarded by the RG as displaying the most negative attitudes. The Council members in contrast felt that RG members did not have enough knowledge of what work is being undertaken. Similarly, there is heavy investment in best farming practice in this region. Interestingly, the RG ranked littering

the highest strategy at the SMM, which is mainly managed by Council. Even though 'Council' is perceived by RG as being negative, they obviously saw that littering was a more 'tractable' strategy. Our results also indicate that the senior managers had a strong influence on the RG scores at the SMM. The managers' primary management strategy, which was of lesser importance to the RG prior to the meeting, became their second most important strategy in the course of the meeting. Of course, the method does not allow testing whether or not the RG influenced the managers, but the fact that some action, especially on fisheries compliance, was taken subsequently is indirect evidence that the engagement process between a local community group and managers also influenced managers' attitudes.

Similarly the impact assessment between the RG and managers was also quite different. Manager's impact scores were lower than that of the RG, thus managers consistently scored much less optimistically than the RG. Managers also valued different strategies to the RG. The highest (i) and second highest priority (ii), and lowest priority (iii) strategies, respectively were:

1. For managers at the goal level: i) best farming practice, ii) improved resource management, and iii) changes to legislation.
2. For the RG at goal level during SMM: i) littering, ii) best farming practice, and iii) changes to legislation, and
3. For the RG at the objective level prior to the SMM: i) best development practice, ii) increased compliance and iii) management of protected species.

Adding the confidence scores did not affect the results (Appendix B).

One of the strengths of this semi-quantitative method is that it creates a structured decision making framework that allows the evaluation of management strategies against often conflicting objectives (Hajkowicz, McDonald and Smith (113) and Dichmont, *et al.* (104)). In these two referenced cases, the trade-offs were usually identified. However, in this case neither managers nor RG members were able to identify trade-offs at the goal level at the SMM (Figure 55) and at the objective level at the RG meeting (Appendix B Fig S.5). This means that respondent were unable to identify trade-offs and felt that each management strategy would be of overall benefit against each objective. This contrasts to that found in Dichmont, *et al.* (104) which used a similar method, where people identified both negative, neutral and positive impacts for each management strategy. Although it is not clear exactly why this happened in this case study, one possibility is that the funding source for a strategy is not clear given the complex nature of coastal management. Similarly, the social impacts are unclear given the number of users in the area, but in this case study only one RG respondent provided negative impacts against some of the objectives (not provided for confidentiality reasons). Clarity on who should bear the cost and the trade-off are not easy to articulated, e.g. which Council activity would not happen if a strategy were adopted. This seems to be the case even for the managers.

Throughout the process it was observed that there is an implementation gap between what managers think they are achieving on the ground and what RG members perceive is actually happening. When this was discussed over several meetings with the RG, at the senior manager's meetings, and with managers separately, this gap seems to be due to both:

1. Community members not being fully aware of what activities are being undertaken in the area (and more subtly what activities are being rejected through approval processes), and
2. Observable issues, which are known by locals living in the area (and several of these were shown to the research team) but not necessarily known by managers. This was often due to lack of compliance and decreased investment in compliance spending.

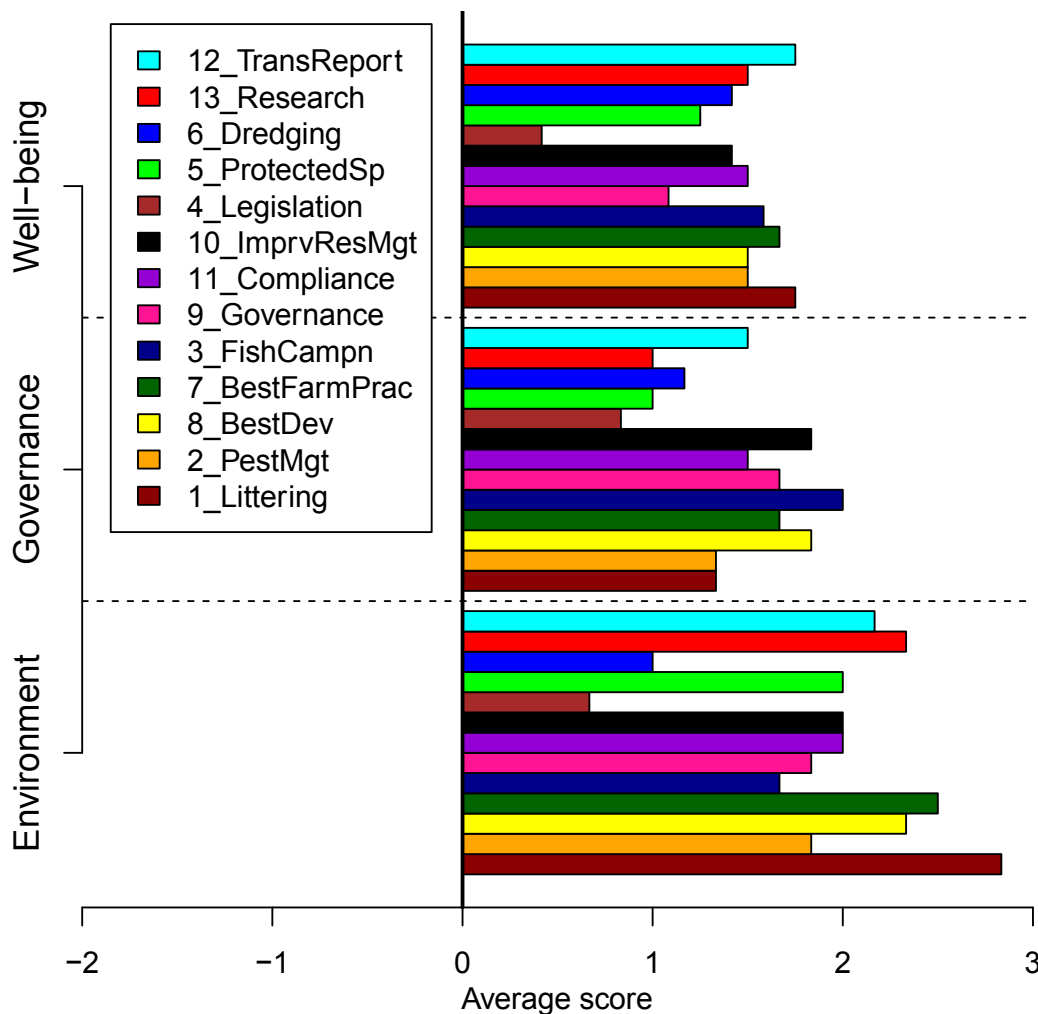


Figure 55: Average impact score of each management strategy for all participants that attended the senior manager's meeting against the three goals

10.4 Conclusions

When well informed, the results show that a community group can come up with realistic management strategies. Embedding managers in the process of developing management strategies is essential, but extending these strategies to senior managers should occur much earlier in the process to ensure greater take-up and acceptance of the output by senior managers. The RG volunteered more than 80 hours of their time per member to provide valuable local input to regional management. Providing the RG access to experts in the topic areas (also as

volunteers) meant that management strategies were well informed and thought out. Undertaking a structured process meant that overall objectives, and their relative importance were defined. Impact assessments of the management strategies also highlighted the relative priorities of different stakeholders. An added benefit of undertaking this approach was that the more controversial aspect of adaptive management, developing management strategies, occurred quite late in the process when the RG knew and trusted each other, and a clear articulation of the different values they might hold through the objective weighting process built greater mutual understanding and respect for others opinions. One weakness of this approach is that it did not articulate the trade-offs between different objectives and goals well – although this was discussed during the process, it was not resolved, even by senior managers. In contrast to single use examples, such as fisheries, defining costs are extremely difficult both in terms of scale and governance location. This seems to be a characteristic of complex socio-ecological systems such as the management of the coastal zone.

The gap between the RG and managers is important and demonstrates the need for a two-way communication approach for regional management – to obtain on-the-ground feedback from locals and to provide locals with some context of current activities. This is perhaps the most important value of this work. The approach used is very practical and produces a locally important outcome by following the adaptive management cycle with input from the community in a structured setting, especially while highlighting heterogeneity in stakeholder groups' perceptions and, through communication, achieving an agreed upon future direction.

11 Storylines for Management Strategies

11.1 Storyline 1. Address littering through education, legislation and operating procedures

In the Mackay region littering can be either through carelessness, such as plastic bags flying from boats on rough seas and security helmets and pieces of coal falling into the sea, or deliberate, such as discarding of plastic bottles, cigarette butts, and bags on land and in coastal waters.

Littering affects habitat amenity and impairment, and also leads to deaths of iconic species.

Littering occurs because of people's indifference about the effects of littering on the environment. Therefore behavioural changes are necessary to deal with littering in Mackay.

11.1.1 PROPOSED ACTIONS

Education program to change attitudes of society toward littering.

- Build from educational campaigns focusing on littering from organisations such as Mangrove Watch (<http://www.mangrovetwatch.org.au/>) and Eco Barge Clean Seas (<http://www.ecobargecleanseas.org.au/>).
- Enhance and focus the Reef Guardian Program of GBRMPA to encourage littering educational campaigns at schools and with Council.
- Develop a regional report card system in the Mackay region that also includes littering as an indicator, which will be a valuable educational resource.
- Develop signage showing connection of rubbish impact on reef – stencils on drains, green waste signs.

Legislation changes.

- Establish higher fines for those caught littering.
- Incorporate retrofitting gross pollutant traps in planning and development frameworks.

Better design of industrial and government operational procedures.

- Make littering explicit in industrial management principles and design procedures to reduce littering during activities (e.g. security hats falling during works in the jetty of coal terminal).
- Implement procedures to manage littering found in the Water Quality Improvement Plan.

Increase resources for compliance.

- Increase funding to Marine Parks and police for compliance patrols to stay longer periods at sea for littering.

Implement waste management strategies.

- Enforce adequate signage on boats on the location of rubbish bins and responsible litter disposal.
- Encourage green waste recycling.
- Reduce plastic bag usage through education and campaigns.
- Undertake stormwater studies to identify priority areas for Gross Pollutant Traps (GPTs) retrofitting/installation and build into strategy.
- Develop an asset register of GPTs and WSUDs, and undertake an analysis of their efficacy.

Targeted campaign about adequate littering in fast food shops.

- Include message about importance of responsible disposal of packaging in fast food advertisements (social media, TV, radio, print media).
- Undertake TV/radio advertisement about responsible rubbish disposal and the usefulness of composting as an alternative, where applicable.

Custodianship.

- Continue promoting attendance at national clean-up days.
- Undertake regular beach clean-ups with volunteers and schools to remove litter/debris from the coast.
- Continue the GBRMPA Future Leader Eco Challenge program that encourages students to participate in projects about sustainable living and environmental protection.
- Promote programs such as 'adopt a beach', for roads, parks, and drains to encourage individuals or groups to regularly clean particular areas in the Mackay region.

Campaigns to report illegal littering.

- Undertake a 'Name and shame' campaign, where names of people caught in illegal littering are listed in local newspapers. Alternatively, the number of people caught (instead of names) can be provided to newspapers on a regular basis.
- Promote the DEHP website for reporting illegal dumping: <http://www.ehp.qld.gov.au/waste/report-litter-illegal-dumping.html>.

Produce education newsletters and editorials about adequate disposal of rubbish.

Assign a Council waste officer to go to schools and organise tours about how the Council manages littering. For example, display litter collected in gross pollutant traps and display information about how rubbish is recycled at the library.

11.2 Storyline 2. Develop and implement weed and pest management plans for regions

Introduced pests (weeds and animals) affect the abundance and composition of native species, which leads to ecosystem degradation resulting in habitat loss and impairment.

11.2.1 PROPOSED ACTIONS

Identify and agree on management options to deal with weeds and pests that is supported by cost/benefit analysis for options.

- Work with farmers or other land holders to understand how weeds can be managed on their property.

Establish pest surveys and monitoring programs.

- Undertake an analysis of which species occur locally, if they are spreading and to where, and how they are affecting the environment for more effective monitoring.

Develop and implement regional weed and pest management plans while learning from existing programs.

Improve soil health by re-using weeds.

- Replace present weed control with more environmentally friendly methods, for example weeds can be used to re-mineralise the soil (medium to long-term) as most weeds, especially water weeds, are a very beneficial addition to compost.

Decrease use of chemicals.

- Reduce the usage of pesticides/herbicides.
- Follow guidelines from Water Quality Improvement Plan.
- Burn the weeds to ashes (peppering) and use the ashes as a spray.
- Implement effective biological control, including micro-biotic control (not just bugs).
- Understand ecosystem impacts from pest management to identify unwanted flow on effects.

Follow established guidelines and management plans (NRM, GBRMPA).

- Targeted equipment for delivery.
- Big companies (AIMS) to work with business.
- Use a collaborative approach to control weeds: 'not point the finger'.

11.3 Storyline 3. Education – Best development practices

Coastal urban, industrial and aquaculture development are causing ecosystem degradation in the Mackay region through sediment runoff and reducing ecosystem connectivity. There are established and effective practices that can minimise effects of development on ecosystems, but in Mackay wide knowledge about these practices is limited.

It is necessary to change people's behaviour and attitudes about new development practices. Education about best development practices is therefore essential to change people behaviour and reduce impacts of development on inshore biodiversity and fisheries.

11.3.1 PROPOSED ACTIONS

Initiate education campaigns.

- Inform developers and fishers about existing legislation in place to deal with development impacts on inshore biodiversity and fisheries.
- Tell the population the importance of sustainable and nutritious sources of food.

Use social media (e.g. YouTube, Twitter, Flickr) in education campaigns.

- Demonstrate the effectiveness of using alternative transport for commuting and other purposes so as to reduce development pressures (e.g. roads, hard infrastructure),
- Demonstrate effectiveness of Parkland and drainage reserves to reduce impacts of development/runoff.

Improve knowledge feedback to 'improve' best practices over time.

- Understand whether and how practices and ideas from places with different climates could work in Mackay.
- Create conditions for groups to share data and knowledge and provide feedback to each other.
- Establish research programs based on better monitoring and sampling to identify whether or not management actions are effective. Consider linking with existing surface water quality monitoring program from NQBP.
- Identify State Planning Policy objectives that are relevant to the region and investigate how these could be implemented.

Commission flood studies to identify areas at risk and articulate to public for inclusion of local knowledge.

- Promote knowledge on the role that low lying flood prone areas play in both the management of flood impacts as well as their environmental importance in ecological productivity i.e. fishery spawning and recruitment.

- Consider using freeware tools easily accessible by the community, such as Google Maps and Google Earth, to show areas at risk from floods and inundation.

Undertake education campaigns within different sections of the Mackay Council and link to successful programs in other Councils.

- Educate Council staff about successful systems used elsewhere (e.g. Brisbane/Gold Coast), such as Water Sensitive Urban Design¹, keyline planning², wetlands bio-retention, sediment basin, grass swales, and vegetated drains to improve water quality. Mackay Council have established sediment control measures in Mackay as part of State Planning Policy and it would be beneficial to improve knowledge about other options available.

Develop an asset register for handover of infrastructure to Council from developers.

- Create an asset register of infrastructure passed on from developers to Council. Developers build infrastructure in new developments to reduce impacts on the environment. After a couple of years developer hand-over this infrastructure to Council who maintains them. At the moment the Council does not have the necessary information to know exactly which infrastructure was passed on from developers and the asset's condition.
- Investigate alternatives to maintain infrastructure built by developers and handed over to Council to minimise impacts on ecosystems. An asset register would be beneficial to assist Council to adequately budget to maintain such infrastructure.

Target Australian Government water quality initiative program to develop projects to enhance water quality in waterways of Mackay.

Use water quality offset contributions to mitigate pollution from developments.

¹ Water Sensitive Urban Design (WSUD) is about integrating water cycle management into urban planning and design. It looks to manage the impacts of stormwater from development.

² a technique for development of urban and rural landscapes that considers the topography to build infrastructure (hard or green) to maximise the beneficial use of water resources.

11.4 Storyline 4. Education – on farm best practices

In Mackay, coastal farming is important. Some farms in the lower catchments are even surrounded by suburbs as Mackay has grown in size. Sediment, nutrient, pollutant and chemical runoff from farms can affect fisheries and biodiversity in the reefs of the Mackay region. In recent years farming practices were improved in Mackay, which reduced runoff to coastal waters, but on-farm practices can still be improved.

The main causes of farm runoff are: a) the agriculture activity itself which requires land clearing and use of chemicals, and b) lack of knowledge about (i) dosage of chemicals and (ii) on-farm best practices to minimise runoff.

11.4.1 PROPOSED ACTIONS

Continue to provide individual farm and crop specific training to promote best farming practices.

- Promote information on target spraying of chemicals and/or bio-inputs (spray at the right time).
- Promote the use of cane trash blanketing and its conversion to humus.
- Establish buffer zones in crops to minimise spray drift and investigate the optimal design of such buffer zones, which includes minimal maintenance.
- Promote farm and crop specific tractor traffic management to reduce soil compaction.
- Promote nutrient management, which is a technique to manage application, timing and quantity of nutrients in crops.
- Provide written advice on the best local procedures and rates of chemical use (e.g. diuron).

Encourage farmers to learn from/through stories.

- Identify and promote 'champions' to increase community engagement, and collaboration between farmers, NRM and government to achieve water quality targets.
- Relay stories in magazines and forums about lessons learnt from using best farming practices (e.g. costs and effectiveness of practices used to reduce farm runoff).
- Use Reef Guardian program to encourage farmers to learn from each other.
- Identify or establish farms that use biological or other environmental friendly methods to highlight innovative agriculture.

Implement the Water Quality Improvement Plan (WQIP).

- Use the WQIP as an educational tool to farmers as it provides valuable and clear guidelines, measurements and targets to be achieved, and also potential actions that farmers can use to reduce farm runoff.

11.5 Storyline 5. Education – fishery campaign

In Mackay, high numbers of recreational fishers, driven by the mining sector, have increased fishing effort. This growth in number of fishers, combined with greed and disrespectful behaviour of some individuals, has led to unnecessary competition and conflicts between commercial and recreational fishers.

Existing behaviour of some fishers toward each other and the environment, in addition to a reduction in compliance presence, have also led to illegal activities by fishers, which affects fishery resources and sustainability in Mackay.

The present situation of narrow research funding focusing on iconic species (rather than the broader suite of species of interest to this sector) is also an important issue that needs to be addressed to maintain long-term sustainability of a range of important fishery resources in the region.

Changing behaviour of both commercial and recreational fishers through educational fishery campaigns is therefore paramount to reduce conflicts and competition between and within fishing sectors. It is expected that these campaigns will ultimately lead to improved fishery resources and sustainability.

11.5.1 PROPOSED ACTIONS

Promote a commercial fishery open day.

- Organise a day where the general public can see operations of commercial fishers (boats, shops) and the importance of the sector to the local community.

Educate public, especially youth, about the need for responsible resource allocation.

- Start education programs at schools about the importance of seafood and fishing (e.g. health and nutrition).
- Educate fishers and the broader community about the need for different allocation for different fishing sectors as a way of reducing competition for fish resources.
- Undertake school programs to expose students to both commercial and recreational fishing and their importance to society.

Educate the recreational sector and public about the commercial fishery.

- Use TV advertisements and other media campaigns to highlight:
 - Importance of commercial fishers to the community (e.g. health/nutrition).
 - Value of good behaviour of fishers.
 - Required clearance of 150m from commercial fishing boat.
 - The meaning of and reasons for restrictions in yellow zones.

- Rules about illegal fishing, especially the consequences of buying from the black market.
- Educate recreational fishers about the extent of fishing controls in place for commercial fishers e.g. bans on commercial fishing on weekends as a way of minimising contact between commercial and recreational fishers and thus reducing conflicts.

Educate fishers about best fishing practices.

- Set up signs at boat ramps about good behaviour together with some local fishing information. Regularly maintain these signs as they are often vandalised.
- Use social media to present information about best fishing practices (species ID, season, sizes), but enhance to discuss respect of each other.
- Make up to date brochure/booklets with fishing rules more available and downloadable.
- Enhance the use of species ID cards with boating patrol.
- Enhance patrols to also educate commercial fishers so as to create a positive experience.
- Provide written communication to licence holders if management changes
- Promote FishWatch hotline 1800 017 116 to report illegal fishing activities.

Promote change in cultural attitude.

- Emphasise that recreational fishing is about enjoyment through, for example, the use fishing shows and the Reef Guardian program.
- Use regional radio for local stories about enjoyment in recreational fishing and importance of commercial fisheries.

Promote environmental branding to sell and market commercial products that are sustainably harvested.

Consistent communication campaigns.

- Re-emphasise existing communication campaigns directed towards more inshore and allocation issues using facts about Mackay, the reasons for recreation fishing (enjoyment) and the role of fisheries for the people and the economy.
- Link communication strategies between GBRMPA and QDAFF to send consistent and harmonised messages about regulation, management and best behaviour.
- Improve targeted advertising on the above fishing messages by getting local support through interviews of local fishers and other community members on local radio programs.
- Simplify ID discussions in web sites, etc.

Improve coordination between local fishers and managers.

- Create clear channels of communication.

Modify Illegal fishing and compliance risk assessment.

- Modify risk assessments so that it includes local knowledge and environmental characteristics (e.g. seasonality of fishing).
- Enhance the Fish-watch hotline so that it:
 - Links to local offices in time.
 - Enhances the DAFF compliance risk assessment in order for compliance activities to be better focused within their existing resources.

11.6 Storyline 6. Education – improve governance

Mackay is a growing city influenced by many different activities such as farming, fishing, shipping, mining tourism and recreation in its conservation areas. It has experienced significant expansion in the last 50 years and this is likely to continue in the future. The expansion from rural to urban and industrial sectors has created cumulative pressures on the region, through factors such as increased sediment runoff, construction and land- and resource-use. This requires governance that is cohesive and consistent between different management agencies. Although progress has been made, much improvement is still possible.

11.6.1 PROPOSED ACTIONS

Break down silos across the groups in Council

- Move the coordination of urban water runoff management around groups.
- Use better planning within existing staff.

Ensure development is well planned and infrastructure is well catered for.

- Take advantage of unfavourable economic conditions and low development pressure to better plan for development and infrastructure.
- Use existing network of roads to integrate new developments: recognise 'next door' 'down the road' development.
- Encourage the use of paths, walkways and alternative modes of transport to reduce traffic and the need to build new roads. Promote the use of Council online system for car pooling (<http://www.mackayregioncarpool.org/>).

Ensure funding is available to support community groups to do on-ground work.

- Establish community-based programs to plant trees, maintain vegetation, and promote the use of green areas as part of the local lifestyle.

Encourage evidence-based decision-making process supported by monitoring programs and research.

- Secure long-term funding to establish a monitoring program to measure effectiveness of existing actions (e.g. artificial wetlands, gross pollutant traps) in place aimed at improving water quality.
- Establish research programs to investigate alternative solutions and their impacts on regional water quality.
- Establish partnerships between Mackay Regional Council and research organisations to reduce costs of monitoring and reporting.
- Pilot a project to demonstrate effectiveness of WSUD in developments.

Achieve holistic outcomes from actions (e.g. water quality, aesthetics, biodiversity).

Encourage regional learning.

- Identify and disseminate examples of cost-effective practices from around the GBR region that are known to improve environmental conditions.

Provide education material to students (e.g. engineering, planning, natural resources management) on existing understanding about downstream impacts of management actions and their consequences on natural systems.

11.7 Storyline 7. Improve compliance by obtaining local stakeholder input

Existing rules and legislation are effective to deal with fisheries resources and habitat loss associated with fisheries activities, and industrial and coastal development. However, these rules and legislations are not always enforced, which may increase illegal fishing, sale of products on the black market and increase runoff from developments. These illegal activities can affect fishery resources and sustainability, and degrade or impair coastal habitats.

The current small number of compliance staff within governments poses a big challenge to resource and habitat sustainability. For example, illegal fishers follow the movements of compliance staff and know where they are, so they can break the laws without being caught. It is necessary to improve compliance through local stakeholder input on risk areas so compliance efforts can be better planned and tailored to local conditions even within existing budgets.

11.7.1 PROPOSED ACTIONS

Encourage training of compliance staff.

- Promote education of compliance staff as they must be educated and diplomatic when dealing with the community to gain support. This is important because most people comply with legislation and courteous behaviour provides greater support of compliance activities.
- Improve compliance officer training in the legislation they are enforcing such as local species identification and gear specifications.
- Provide feedback to managers on how their compliance staff interact with the public.
- Balance compliance to local risk rather than centred on a specific sector e.g. commercial fishery.

Enforce existing rules/legislation.

- Ensure compliance risk assessments include local knowledge on key compliance priorities across all fisheries in the region.
- Identify how State and Council could better work together in terms of jurisdictions so that resources are optimised. For example, Council sometimes is better positioned to check compliance of State developments, but Council has no jurisdiction on State developments (e.g. roads).

Increase the number of compliance staff in State Government.

- Direct funds from other areas to increase number of compliance staff in State Government. In Queensland State it is not possible to have self-funded compliance staff positions as no incentive-based positions are allowed.

Establish and promote a community-based reporting system.

- Establish a reporting hotline for Council, similar to FishWatch, which could be used for reporting people that do not comply with legislation. The community reporting system can be done via advertisement of hot lines on the council website. This action needs to consider costs of an officer on call after hours (nights, weekends), plus costs associated with mobile phone and maintenance of website compared to the benefit of potentially increased compliance.
- Similar to already undertaken by some agencies, publish names of non-compliant people in the newspaper.

Increase resources for compliance as a whole, not only number of staff, but also boats, cars, etc. (people and resources).

11.8 Storyline 8. Improve resource management through better planning, assessment and regulation

Management processes and regulatory frameworks are disconnected and vary between Commonwealth, State and local governments in the Mackay region.

Disconnected and inconsistent management frameworks results in multiple and inconsistent approvals for activities, which reduces (i) environmental protection, (ii) fisheries resources and sustainability, (iii) habitat amenity, and (iv) species sustainability, and increases (i) habitat loss, degradation, and impairment, and (ii) death of iconic species.

11.8.1 PROPOSED ACTIONS

Maintain long-term master plans for Ports with public input to provide certainty.

- Identify areas for Port expansion/decline and focus management on these areas.

Improve existing public consultation processes to guide assessment of development applications for approval by encouraging people to participate.

- Understand where communities want to concentrate urban development.
- Provide clearer consultation and communication strategies for major processes such as the Coastal and Inland Flood Hazard Adaptation Study to be made public in 2015 as the study will affect insurance and bank loans for particular areas within Council.

Rather than create new legislation, enforce existing legislation.

- Enforce existing legislation within government and in the public especially those that deal with impacts of population growth, coastal development and aquaculture runoff on habitat loss.

Break down silos across the groups in Council.

- Create an environment within Council that promotes cultural changes via corporate values to break down existing silos, such as moving the coordination of urban water runoff management around groups.

Apply more widely existing urban design principles and soft solutions to reduce impacts of population growth/development on habitats.

- Further use the Internal WSUD (Water Sensitive Urban Design) working group in Council to identify problems and how they will be addressed to allow more to be done in terms of better understanding effectiveness of wetlands, bio-retention, sediment basin, grass swales, grass pollution traps (GPT), vegetated drains, and establishment of drainage reserves and how to implement these in the Mackay region.

Create an asset register for handed-over infrastructure from developers to Council.

- Provide training of this register as well as requirements regarding the ownership of and responsibility over the assets to Council departments.

Use existing policy instruments to protect high value areas that are of local environmental significance.

- Examples include the GBRMPA Emergency Special Management Area (SMA), which can be used to protect specific areas within existing zoning. The SMA can use feedback from local people, maps, and measurements to provide for the closure of a specific area, such as the seagrass meadow at Hilborough identified by the RG.

Improve connectivity within the Mackay catchment.

- Identify the type of bund walls and the need to improve connectivity through fish passages using basin assessments.
- Use offsets to address lack of connectivity due to construction of bund walls
- Maintain mangrove community links to improve connectivity along the coastal and estuarine fringe.

Create an across Commonwealth to local governments integrated 'one stop shop' for applications of permits and assessments.

- Develop an on-line application tool that is hierarchical depending on risk. This should enable self-assessment prior to lodging development/approval applications. It should be a mechanism to deal with regulatory burden and minimise duplication and inconsistency of approval processes. This approval process should still uphold legislative, societal and environmental and values.

Improve decision-making process.

- Use fact-based decision-making.
 - Fund the implementation a monitoring program to measure effectiveness of management actions (e.g. installation of artificial wetlands) aimed at improving, for example, water quality. This will allow management agencies to justify further investments.
 - Fund and undertake research about alternative solutions to improve water quality and their impacts to support decisions.
- Consider local knowledge in decision-making.
- Apply lessons learnt from elsewhere such as examples of cost-effective practices from around the GBR that have been known to improve environmental conditions.
- Achieve holistic outcomes from actions by considering cumulative impacts (e.g. water quality, aesthetics, biodiversity, economic).
- Improve coast-wide understanding of cumulative impacts related to multiple dredging and seasonal river runoff in the Mackay area.
- Move towards a code of practice that can be either regulatory or non-regulatory.
- Pilot project to demonstrate benefits of WSUD in developments and justify further investments.

Investigate institutional instruments to protect the specific seagrass meadow identified by the RG.

- Investigate the GBRMPA Emergency Special Management Area (SMA) instrument to protect specific seagrass meadow in Hillborough Channel as it can use feedback from local people, maps, and measurements of extent of seagrass meadows to provide for the closure of a specific area. Local groups, such as LMAC can provide the evidence of the importance of the seagrass meadow to GBRMPA who will then investigate and make the decision about the closure of the area.

Establish partnerships and secure funding to improve connectivity.

- Use existing studies to identify, prioritise, and budget for construction of fish passages in the Mackay region. Council and Reef Catchments are working together to establish fish passages in areas identified in the Fish Barrier (Culvert) report. Needs further funding to speed up the process as priority areas were already identified. The Partnership between Reef Catchments and Council is a good example on how to act together towards a common goal.

Establish partnerships with research organisations to reduce costs of monitoring and reporting.

- Council can establish partnerships with research organisations such as CSIRO, Universities and AMS in a collective effort to get financial and human resources to support monitoring programs.

11.9 Storyline 9. Legislation changes to allocation and sustainability of fishery issues

Management controls on some species are through size and bag limits for recreational fisheries, and gear and catch restrictions for the commercial fishery. In addition to these controls, spatial and temporal restrictions are also used to protect biodiversity, restrict gear types in certain habitats, protect spawning species and allocate effort between the different sectors. Some of the existing legislation is inadequate for the appropriate control of some species and habitats, which in combination with illegal fishing activities, increases effort on fishery resources (with negative long-term consequences on fishery resources and sustainability) and degrades coastal habitats in the Mackay region.

11.9.1 PROPOSED ACTIONS

Revisit bag and size limits

- Tighten and simplify bag limits especially slot limits for iconic target species in similar groups (e.g. flathead and grunter).
- Apply bag limits to the boat not just individuals; for example having a boat limit that is twice the individual limit.
- Reduce upper slot size limits especially for king salmon and barramundi.

Tackle illegal fishing.

- Increase the recreational fishery use fund (RUF) to enforce good rules (e.g. enforcement of legislation against illegal fishing activities).
- Increase value of fines for illegal fishing so as to create a disincentive to fish illegally.

Promote flexibility in management to incorporate regional changes in permits, legislation, and zoning for trawling.

- Move the existing seagrass closure within Hillsborough channel to a nearby site as the seagrass bed has relocated.
- Provide input to the Queensland fishery review to promote the importance of local input and regional management in fisheries.

11.10 Storyline 10. Management for protected species

Mackay is well endowed with a large number of iconic species, many of which are also declared as threatened, endangered and protected species. Every year protected species such as dugongs, turtles and dolphins are killed. They can be accidentally caught in fishnets, illegally fished, or stricken by boats, causing loss of biodiversity in the Mackay region.

Indigenous fishing of protected species requires further investigation given issues related to (i) non-indigenous people claiming to be indigenous and therefore illegally fishing indigenous resources, and (ii) potential impacts of traditional fishing on stocks. However, since there was no indigenous representative in the group there were no management actions formally addressing this topic.

11.10.1 PROPOSED ACTIONS

Review the use of offshore gillnet use in Dugong Protected Area B.

- Especially with respect to bottom set nets and the use of mechanical reels allowing for shorter soak times.

Trial dugong friendly nets in Dugong Protected Area B.

- Conduct trials of dugong friendly nets that can inform industry about their use specific to the local situations.
- Investigate and collate existing industry changes to fishing gear that may already reduce capture of dugongs.
- Use Reef Guardian Program to help improve net practices with industry.
- Identify champion in local area to trial new gears to reduce deaths of protected species to see what works.

Use lead core rope and refine float line loop to reduce entanglement potential.

Trial new propeller designs to protect protected species.

- Trial folding up propellers (soft plastic propeller designed not to cut animals/people in accidents – won invention of the year prize).
- Trial other methods of modification to the propeller to reduce turtle strikes.

Create education campaigns to reduce accidental deaths of protected species.

- Use Reef Guardian program to facilitate education campaign about focusing on improved fishing practices to minimise accidental deaths of protected species.
- Educate population about new type of propellers to minimise injury/deaths from boat strikes – Develop a funding program to test the kit.

11.11 Storyline 11. Reduce impacts of dredging

Dredging is an important activity to maintain access to Ports, which benefits the regional economy. Dredging directly removes species, and destroys or impairs habitats. It also re-suspends sediments, which increases turbidity, reduces light penetration and smother benthic organisms (e.g. corals, sponges). Sedimentation and turbidity affect species composition and abundance and may also alter habitats such as coral reefs.

Impacts of dredging can be reduced to improve environmental protection and minimise habitat loss.

11.11.1 PROPOSED ACTIONS

Thorough and transparent assessments on locations for dumping spoil.

- Decision on disposal sites (inshore versus offshore) needs to be transparent to the public and thoroughly investigated.
- Use dredge spoil to create artificial islands/reef (e.g. Dubai).
- Time dredge operations to make sure it doesn't coincide with other dredging operations nearby.

Avoid the need for dredging.

- Investigate options to avoid/minimise dredging.
- Use a barge to transport the coal to the boat off shore.
- Consider costs, location, environment, logistics of alternatives to dredging, such as barge to transport coal to ships.

Apply strategic management control systems to dredge when water clarity is low.

- Identify a trigger to control how long dredging can run – monitor turbidity while dredging is underway and use data to identify such trigger points.

Research in land options for dredge spoil (although local options are limited)

- Use modelling and cost benefit analysis to investigate options for depositing dredge spoil on land not in water (e.g. industrial estate in Mackay Harbour).
- Investigate the use of spoil to back fill holes from the mines – train is empty on return.

Undertake an education and information program targeted at the local community to explain the activities of the Port and how these are being managed.

- Provide greater transparency to the community by providing greater access to information and data collected by the Port.
- Undertake a science program that uses the monitoring data for modelling to investigate Port and cumulative impacts.

Remove the existing window for dredge spoil dumping timing and investigate the optimal window time design that fits the local conditions adaptively but also consider the Port, environment and other users' needs.

11.12 Storyline 12. Support, facilitate and coordinate basic research

Predicted population growth in Mackay and associated expansion of fish markets (more people buying fish) could threaten fishery resources and sustainability. More coordinated basic research is therefore needed to increase fishery sustainability, but this is particularly challenging because current funding for research is small, highly competitive, and focuses mainly on iconic and high profile species. Basic research on non-iconic species is also important because these may become important in the future.

11.12.1 PROPOSED ACTIONS

Undertake more basic research on:

- Fish aggregation areas (e.g. king salmon).
- Species that aren't presently iconic or high profile as these are increasingly targeted and little is known about their biology, distribution and the fisheries' catch and effort. These species may become important in the future (e.g. abalone in WA, grunter).

Fund research to support decisions about how to allocate resources to different sectors and how to realistically apply it.

Look into stocking of marine species and evaluate the role of existing stocking contributions to catch.

Better understand spawning size of the grunter species as they are heavily targeted in North QLD.

Facilitate a process where local input could be obtained to influence research priorities of the QLD Fisheries Research Advisory Board (FRAB), which needs to consider local views:

- Write up a submissions for next FRAB call, which incorporates local views from Mackay, focusing on the following legislation changes.

Revisit bag and size limits:

- Tighten and simplify bag limits especially slot limits for iconic target species in similar groups (e.g. flathead and grunter).
- Apply bag limits to the boat not just individuals; for example having a boat limit that is twice the individual limit.
- Reduce upper slot size limits especially for king salmon and barramundi.

Tackle illegal fishing:

- Increase the recreational fishery use fund (RUF) to enforce good rules (e.g. enforcement of legislation against illegal fishing activities).
- Increase value of fines for illegal fishing so as to create a disincentive to fish illegally.

Promote flexibility in management to incorporate regional changes in permits, legislation, and zoning for trawling:

- Move the existing sea grass closure within Hillsborough channel to a nearby site as the seagrass bed has relocated.
- Provide input to the Queensland fishery review to promote the importance of local input and regional management in fisheries.

11.13 Storyline 13. Transparent (to public) and coordinated monitoring reporting

There are several programs collecting data in the inshore coastal zone of Mackay as part of environmental licences (e.g. air quality and marine data for Port activities) and research. Collecting data is expensive and therefore often subject to IP and commercial-in-confidence contracts, which hinders data sharing between organisations and the general public. Developers are cautious in making data publicly available because it can get 'twisted' or misinterpreted depending on who is doing the analysis.

Most data and information from existing monitoring programs in the Mackay region is not easily accessible by the general public, which causes perception problems about the actual impacts of development in general.

The public needs transparent and coordinated access to monitoring reporting as a way of understanding what the issues really are and their magnitude. This is important in dealing with issues related to multiple and inconsistent approval processes, public perception and misconception, and cumulative impacts.

11.13.1 PROPOSED ACTIONS

Establish a report card system for water quality.

- Use a report card system with clear and consistent methods to support more transparent dissemination of information to the public.

Understand expectations and public perceptions about coastal issues.

- Run surveys with the broader community to understand their perceptions and expectations about the coast, for example with regards to the perception of communities in relation to risks of shipping in the GBR.

Promote information and data sharing with public.

- Facilitate information and data sharing between industries and with the public so as to improve management of the inshore GBR, to influence perceptions related to development and to support a more evidence-based decision making process. Knowledge sharing should be mandatory and independently managed.
- Make data sharing conditional to approval processes. The big problem involved in accessing and sharing data/information from Environmental Impact Assessments and Consultancies is related to IP and commercial in-confidence contracts.

12 Can locals affect regional management? A generic method of engagement from two case studies

Although this section has a lot of overlap with earlier sections, it is kept together here for completeness as this could also be a stand alone product.

12.1 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). In the Great Barrier Reef in Australia, this region like most coastal zones, experience 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 issue. Adaptive management involves iterative decision making, evaluating the outcomes from the previous decisions and adjusting subsequent actions on the basis of this evaluation (5, 6). If undertaken in combination with effective stakeholder engagement, these two processes form essential platforms to achieving effective environmental management, being through good information, identity, institutions and incentives (7).

In the coastal zone, governance is complex with many 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 a union of scientists and government institutions. 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 and providing a) the opportunity and incentives for boundary products, b) participation of actors from different sides of the boundary and c) 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 engagements have been 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 (Figure 56). Much of the reef is managed by the Australian Commonwealth's Great Barrier Reef Marine Park Authority (GBRMPA). Although it 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.

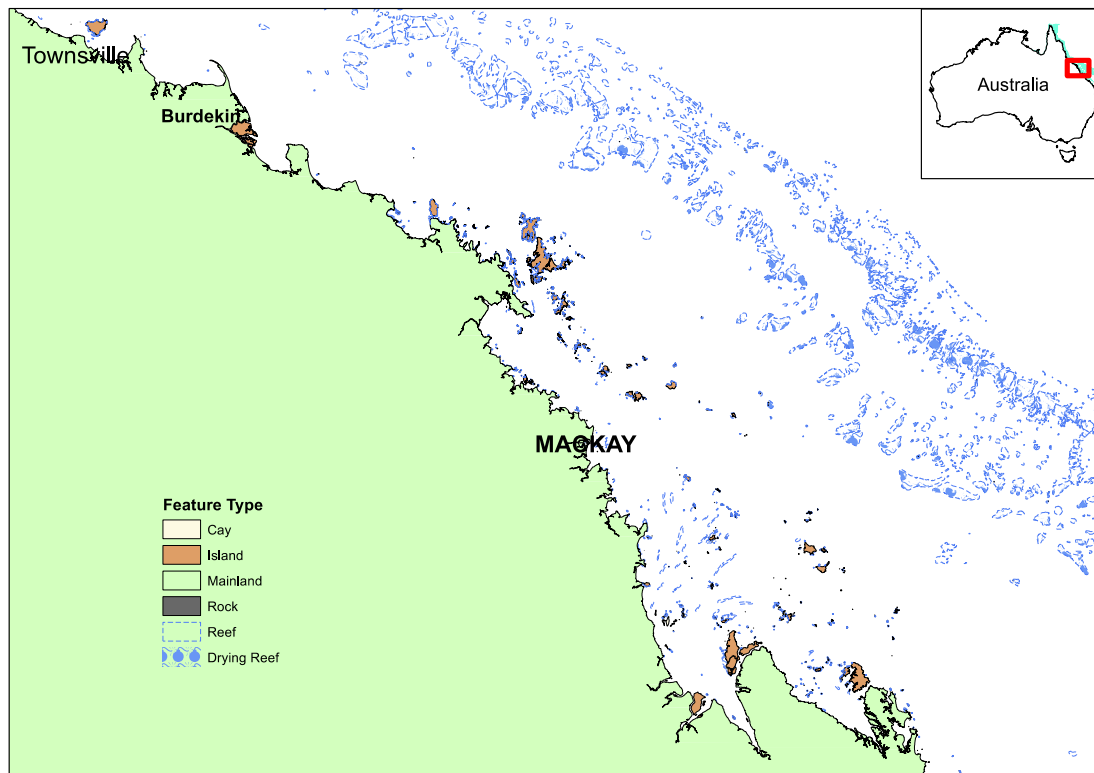


Figure 56: Case studies shown in the context of the Great Barrier Reef in Queensland, Australia.

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 Arslan 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).

12.2 Method

12.2.1 CASE STUDIES

Two coastal regions within the GBRWHA area were chosen as case studies.

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 its 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) 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.

12.2.2 ENGAGEMENT PROCESS

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>). Although the chair is elected and paid a nominal fee, the members are volunteers sourced from the community. LMACs have a 3-year term and calls for nominations are made normally to stakeholder groups, although a nominee can be an independent. There is some vetting based on what GBRMPA (or a referee) knows about an individual and their ability to contribute constructively. Membership of the LMACs in our case studies included representatives from GBRMPA, local Port and Council employees. The LMACs aim is balanced representation, although this is not always achieved. The quality of participation and 'team' output is highly variable.

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 controversy meant that participation was minimal. An alternative approach was undertaken described in detail in van Putten, *et al.* (114), but generally meant engaging with individuals directly and separately. Interactions between the different RG and LM AC members were minimal. In Mackay, the RG was very successful and was used throughout the process. However, the indigenous member resigned from the group due to circumstances external to the RG.

At various stages in the process (described further below) 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 GBRMP A person spent enormous support and engagement time in between meetings. This support was essential and provided local continuity.

A sequence of steps were undertaken – see Dichmont, *et al.* (115) for more details:

1. Qualitative modelling (116, 117) of the Mackay coastal system was carried out (118) (both case studies). The RG was asked to list assets of importance to them in the region and the impacts on these assets. They were then asked to select their priority asset and these were modelled. An introduction on terminology and how the method works were also provided (see Dichmont, *et al.* (118));
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). This was then combined into a hierarchical tree format using input from a series of workshops attended by the RG and LM AC van (108, 114); After this stage, the Bowen-Burdekin case study was dropped given the controversy around the Port development.
3. A survey of the RG, LM AC and Mackay public was undertaken to ascertain the relative importance of different objectives. Dutra, *et al.* (108) describe the analysis details and survey methods in detail but two approaches were undertaken – the recommended Analytical Hierarchical Process (42, 119) and a new Point Allocation method at each level of the objective tree and called the Hierarchical Point Allocation method (108);
4. Managers gave presentations to the RG about existing management actions that were being undertaken in the Mackay coastal zone so that they could subsequently discuss any remaining management actions that needed to be addressed for the different assets;
5. Topics relevant to the focal question of management of biodiversity and fisheries in the coastal zone were developed in session. These described both key assets (such as mangroves and seagrass) and key issues (such as development).
6. Over a period of just over 12 months, the RG undertook a series of workshops that discussed management options for these topics. Each workshop included:
 - a. Presentation by an expert of background information pertinent to Mackay about the specific topic being discussed at the workshop,
 - b. The RG, project team and invited expert workshopped an issues register, direct and indirect management options, and responsible

agencies for each issue (115). The discussions were held either in small groups or as a whole group, depending on the number of workshop participants. Direct management options were defined as a management action that is undertaken directly by the agency responsible for managing the issue and could include proposing legislative changes, whereas indirect management options were those that could have the same impact as the direct option, but undertaken indirectly through a non-responsible agency or the community. Issues or management options could be geo-located using a Google™ map of the study region. Relevant qualitative models were also made available.

- c. Initially, the issues list was developed separately from the management actions, but this was seen as inefficient. The meeting length was increased to half a day and all aspects of a topic were covered together as described above.
 - d. The topic sequence was generally down the catchment, but most of the contentious topics (port and urban development, fisheries) were left for last.
7. The project team combined all the management options into management strategies, which were presented to the RG and subsequently modified over two workshops. In order to articulate the pathway of combining management options, the project team used the well-known United Nations Environment Program risk assessment framework known as DPSIR (Drivers, Pressures, States, Impacts and Response) (120, 121). This framework first started in a more simplified form of Pressure-State-Response – this basic version was ultimately used. The results were presented with an associated storyline for each Management Strategy that provided background and a list of the relevant management options.
 8. An impact assessment was undertaken in two phases (with the analysis method described in Dichmont, *et al.* (115):
 - a. The RG was asked to rate each management strategy from -3 ("considerably worse than current situation") to +3 ("considerably better than current situation") against the low level objectives,
 - b. They were also asked to score their level of confidence in their ability to answer question a) for each objective from a score of 1 ("very unsure") to 5 ("certain") (see Supplementary material Table S.3).
 - c. A subsequent workshop was then held where the RG, Mackay coastal managers and NRMs were asked to undertake the same impact assessment scoring. However, due to time constraints scores were made during the meeting against the high level goals only (although well-being was split into social and economic goals).
 9. The overall priority list and final set of management strategies were provided to the RG for comment, and thereafter to the management workshop.
 10. Storylines of each report card were developed that described the management strategies and actions for use by RG and LMAC members. These were made available online for the community.
 11. Letters to the two management agencies most affected were also written, but drafted in language more appropriate for this target audience.
 12. All documentation was always approved by RG members before release.

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. A final framework was developed for future engagement.

12.3 Results and Discussion

12.3.1 COMPARING THE CASE STUDIES

The progress of the different case studies was heavily impacted by external factors, in this case a contentious Port development proposal. The level of distrust and at times acrimony divided the volunteers from the Bowen-Burdekin RG and LMAC such that the case study did not complete the process in the area. In that context, however, it was still possible to complete the objective review and hierarchy through individual or smaller group interactions that produced a useful product. In contrast, the RG in Mackay was highly functional and delivered more than 150 hours of volunteer time (above that of the project team). Given the time and energy they put in, ownership of the output by the Mackay RG increased over the time with members controlling the final product (in terms of both content and detailed wording), which was not the case in the Bowen-Burdekin where the project team was more influential on the final product. However, despite these differences in approach the final objective trees from each case study were quite similar which allowed generic objectives to be developed.

A further issue with the Bowen-Burdekin was stakeholder fatigue in that previous studies have used several of the members for other strategy discussions especially on fisheries. There had been intensive progress in developing regional management strategies, which then led to complete breakdown and acrimony with state-wide condemnation of their product orchestrated by a particular stakeholder group with strong influence but not resident to the area. This meant that some of the members felt the new process was repeating previous work and were also worried that the end result would be the same. In reality, the Mackay case demonstrated that the result need not always end in conflict. It is argued that a rigorous semi-quantitative sequential approach is an important aspect of this success.

As the Mackay RG increased in confidence of their own value and knowledge due to access to experts, the link between the RG and LMAC became more tenuous. RG members expressed their frustration with the LMAC being perceived to discuss small-scale issues compared to RG discussion.

The successes were that:

- There was a large and highly dedicated local volunteer force within the community, scientific community and managers. The scientific input was of excellent standard with well-pitched presentations – although verbal or written communications about what was needed had been provided. Of key importance was the dedication to provide mostly local content. These presentations were very motivational to RG members and valued, and certainly influenced the way they understand both management and biophysical processes.
- There were strong links established between managers and RG members. Discussions about contentious issues did happen but debates happened in a climate of mutual respect and understanding. They also gained immense

local knowledge through visits to local examples of good and bad management practices.

However, senior management support for the uptake of the final management strategies was variable. Lack of perceived uptake by some agencies were due to:

- The RG had no broad official mandate to represent Mackay, as they were not elected which makes management action perceived as being more risky. This is related to the conundrum that there was basic resistance to change and lack of enthusiasm to undertake the effort that would be required to effect any change – the managers needed to be open and/or empathetic to a different form of input given that a community group by nature cannot be representative of a large region.
- Managers' perception of what was happening on the ground was widely different from that of the RG. This was due to a mixture of managers not being aware of local issues and RG members not being aware of what work management agencies were undertaking (or not).
- The final management strategies were seen as "wishy washy" and not radical, and also already implemented. However, this highlighted a great implementation divide as evidence of bad and good practices were shown to the project team and some of the managers. However, these outputs had great significance to the RG members.

The process was seen as very extensive and comprehensive, but required large volunteer input. Some of this time commitment was explained by the test case nature of the work where several approaches were trialled by RG members. A shorter, less time consuming version is suggested below.

12.3.2 REVIEW OF PROCESS

The qualitative modelling was used as an introduction for the members to discuss their present knowledge of the area, to show that their view was valued and to inform the project team on key issues and assets to address. Although the project team provided these at the time of management strategy development, the models were not used by the RG members. Since the whole process was extensive – partly because different methods were trialled – this is one step that could be removed from the process or needs to be enhanced by a Bayesian Belief Network (122) which may be perceived as more useful (from a management strategy point of view).

Undertaking the objective development process before discussing management options was essential to encourage group cohesion and trust. The review was surprisingly quick and easy (given the online nature of many of the agencies) and the Mackay RG process of developing the hierarchy formed cohesion and was enjoyed. However, success was also achieved through a more individual approach although perhaps with not as much attachment to the final product. Since there were no winners and losers in this stage, conflict was low.

Several approaches were trialled when developing the management strategies. Group input in the process highlighted that discussing the assets-issue combinations as topics at the start and covering each per meeting worked best. At each meeting access to an expert with local knowledge was essential. Undertaking the Issues Register, and listing direct and indirect management options at the same time was most productive and produced a more cohesive product. Given the complex

nature of the governance system, the responsible agency was not accurately identified by the RG or was too generic and not used in the analyses. The topic sequence was roughly down the length of the catchment, which seemed to make sense and reduced overlap. It also highlighted the connectivity of the system. The most controversial topics were at the end of the process so the group was very familiar with each other's view and therefore more open to opposing management actions.

Traceability about where the objectives and management options came from was an essential component that maintained trust. The RG feedback emphasised this point and that they felt their view was listened to.

Relative importance of objectives helped highlight that there was quite a lot of consistency in the group's view and the relative importance of each goal. In session discussion of the results allowed general articulation of RG member's values and opinions in a more factual manner.

By embedding managers in the project team and RG an extremely important component of linking the community with the management system was successful. However, connection to the more senior management and thought leaders, which has been shown to be very influential in other studies for example Dutra, *et al.* (123), was weak in the process partly due to the work load on the project team. Ensuring greater connections throughout the process rather than at the end meant that getting traction was harder. However, senior managers were approached at the early stages of the process and the project team was told to wait until the end when there was more substance. The final managers meeting was destructive for some RG members even though the project team warned the RG that some negative response from managers would be expected. As a result a balance between the RG and managers' needs should be used where more regular contact is made rather than using the manager's approach of connecting towards the end.

The impact assessment was the most useful to managers. This provided relative priorities of each management strategy for funding purposes. It also uncovered an expected conundrum that does challenge the effectiveness of management: there was a significant gap between what managers thought was happening or resulting from their actions and the perception of the community as to the effectiveness (and wisdom) of these management action(s).

After the managers meeting, the final set of management strategies was separated into products for specific to the two major agencies relevant to the coastal zone (fisheries and council) and these were much more successful. These two letters were also socialised behind the scenes by key members of the project team and were more clearly put in the language of this agency rather than those of the RG. Both products are needed for the process as there was a demonstrated disconnect between local and manager's views.

12.4 Generic process

A local person that is within the project team is a huge advantage. This person can be a conduit for out of session conversations.

The process can be simplified into four steps (Figure 57) of i) developing the engagement process, ii) defining objectives (which includes the review, creating the hierarchy and obtaining their relative importance), iii) developing the management

strategies (provide information, define issues and develop actions) and set the priorities through a relative impact assessment.

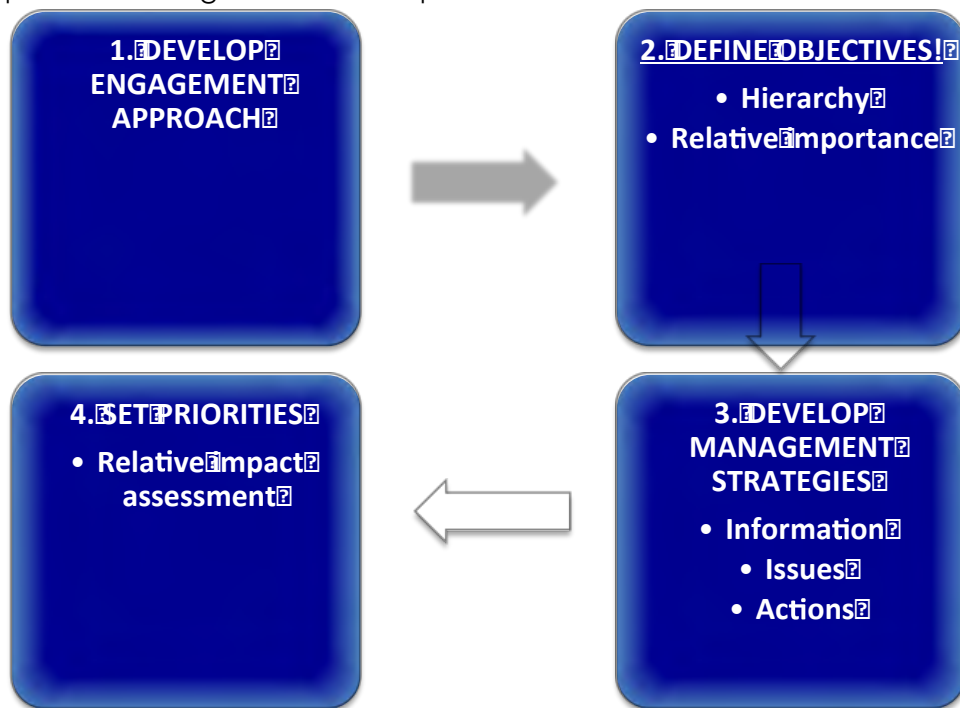


Figure 57: Generic process of developing management strategies using local community input

The engagement system should be similar to that of the Mackay RG but with much more enhanced LMAC (generically called the header group) involvement where they preferably act as a header group giving direction through defining the RGs tasks and timelines (Figure 58). The header group should meet less frequently than the RG. Managers should be embedded in the RG. The header group should preferably have some authority and representativeness, whereas the RG membership should maintain some representation but mainly consists of volunteers willing to provide their time generously. Important influencers should be identified at an early stage in the process. The RG chair should be elected from the RG membership but facilitation should be provided by the project team member to allow all RG members equal access to the discussion, but also for the chair to be able to contribute to the discussion.

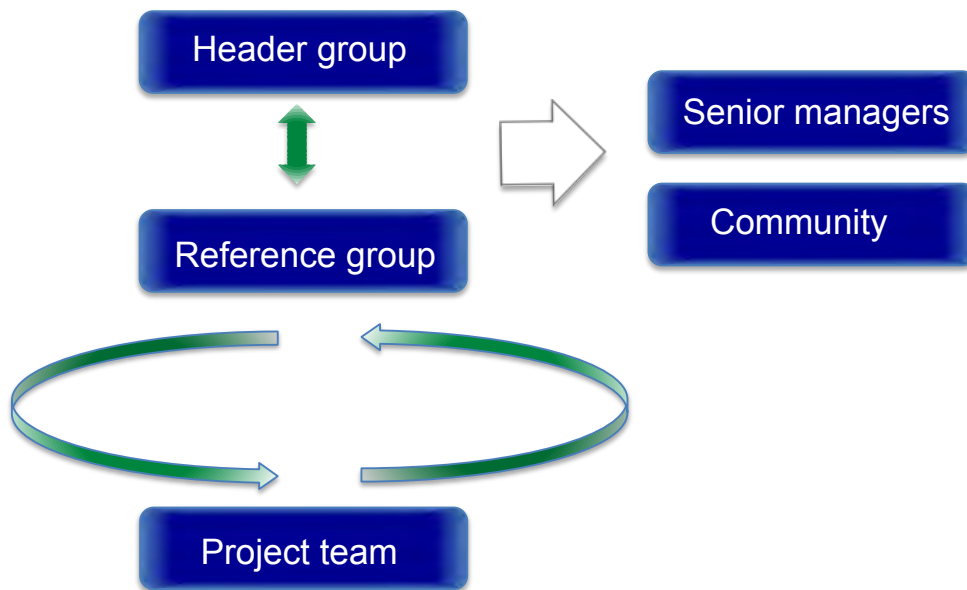


Figure 58: Generic engagement process

The objectives review should maintain links to source documents and also keep track of versions as the RG and header group input is obtained. To speed up the process if needed, a generic objective tree to develop management strategies for coastal zone fisheries and biodiversity can be used and the lower level (the objectives) can be subsequently added for more local content (Figure 59).

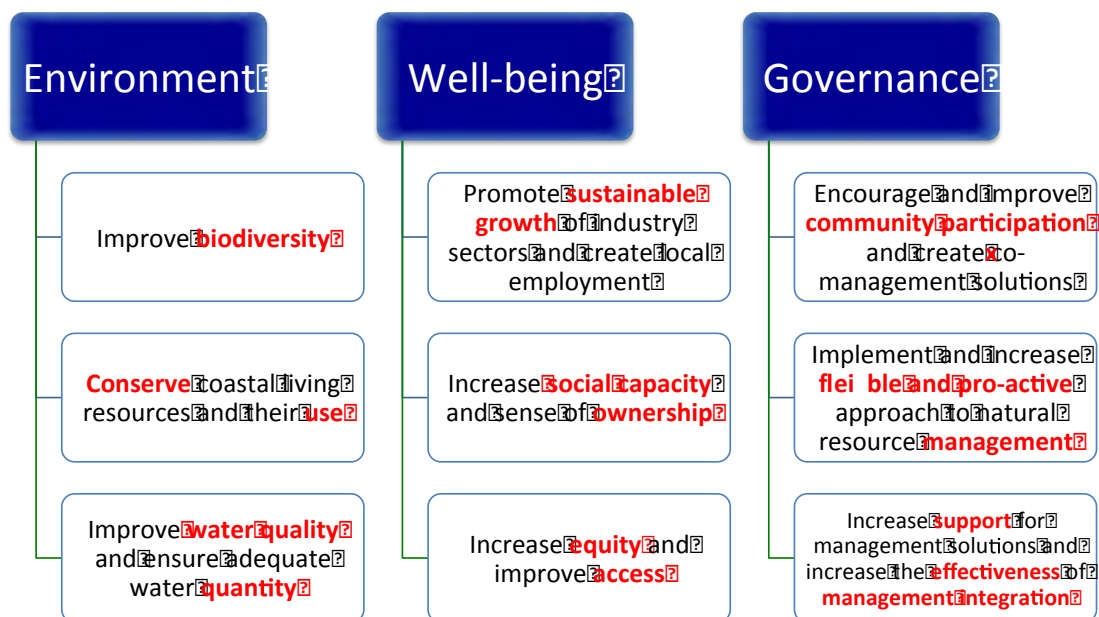


Figure 59: Generic objectives hierarchy for the management of the coastal zone fisheries and biodiversity

The objective relative weighting can be kept within the header group and RG (rather than going to the community as well), as this is more influential to the task at hand. However, if the community views can be obtained, the approach that worked best was doing local radio interviews linking to online surveys. A paper backup with a local office is also needed. A new method of obtaining these relative weights should be used rather than the more confusing and controversial approach such as the

AHP as described in Dutra, *et al.* (108). An example survey is provided using the generic objectives (Appendix C).

Management strategies should start with a meeting between managers and the RG and header group describing existing management measures. The management strategy question should be divided into topics that could be a combination of key assets and issues. The topic sequence should allow for connectivity in the system to be highlighted but controversial topics should be raised at the end. For each topic an expert with local knowledge on that topic should attend. Using the simpler Pressure-State-Response framework (Figure 60) – the precursor to the Driver-Pressure-State-Impact-Response approach (120, 121) – an issues register can be developed with direct and indirect management actions (Table 47). Some flexibility on the day is needed in term of small or whole group discussions. The project team should collate these using a database and provide these to the RG for input. The final product should be supported by the header group.

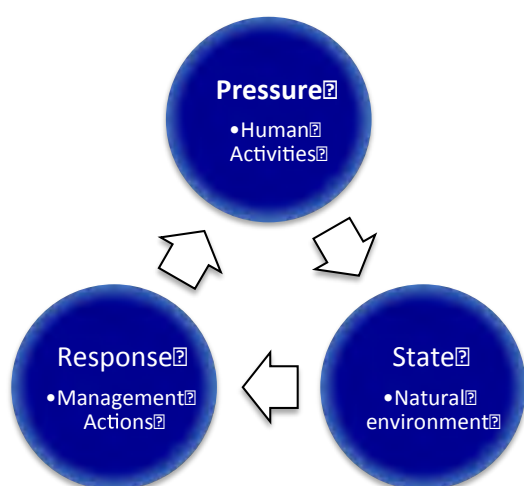


Figure 60: A drawing that could be provided to explain the Pressure-State-Response framework

Table 47: Generic management action table for use in RG discussions

Topic		
Issue	Direct management action	Indirect management action
Issue 1	Action 1	Action 1
Issue 2	Action 1 Action 2	Action 1 Action 2

The impact assessment should be undertaken at the highest level of the objectives tree by both the RG and the header group prior to the key managers meeting. It can be repeated in session at the managers meeting to obtain information on influence – see example tables in Dichmont, *et al.* (115). This is a good tool to highlight relative priorities and the difference between managers and members. The analysis method is provided in Dichmont, *et al.* (104) and Dichmont, *et al.* (115).

At least one managers meeting between senior managers, embedded managers, the header and RG should be undertaken. Follow up meetings with managers are essential and documents specific to their needs and communication style should be produced.

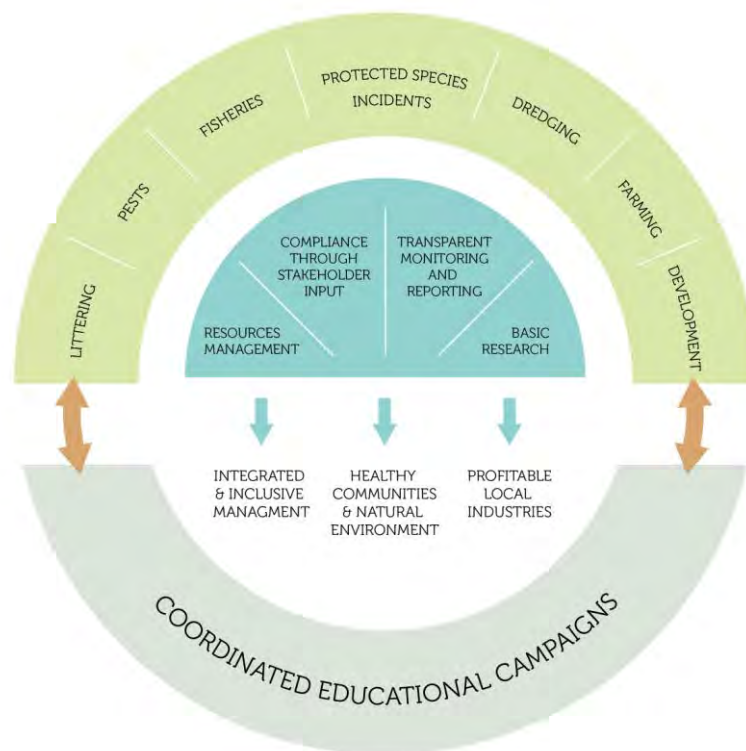


Figure 61: Generic classes of management strategies as a communication tool with which to explain the management strategies

A generic strategy communication tool (Figure 61) for the different management strategies to ensure that all bases are covered can be used. A key underlying theme of the figure is that all management actions can result from either direct actions on individual impacts, such as reducing littering and run off from farms and development (outer ring at top) or through responses by means of resource management, added compliance, and basic research (inner top semi-circle). Coordinated educational campaigns targeted at both the local community, industries and government agencies (bottom ring) are a key action that can help influence positive behaviour and attitudes towards inshore resources in the Mackay region. The final outcomes expected from the management strategies are:

1. Healthy communities and natural environment
2. Integrated and inclusive management
3. Profitable local industries.

12.5 Conclusions

A generic approach is developed from the two case studies. These highlight that embedding managers within the process and having a local person is essential to successful implementation. In addition, senior managers and thought leaders should be brought along during the process rather than only at the end when a more tangible but less controversial product is available. High volunteer time to support the process showed the wish for local scientists and community members to be part of regional management. Several steps are needed to ensure reduced risk of conflict,

but the most important is to discuss objective prior to management strategies to allow for the group to value and understand each other.

13 Communication products and project impact

13.1 Introduction and Methods

The project undertook a series of different communication forms during the life of the project. The type of and audience for the communication changed as the project stepped through its process (Figure 2). Much of the communication was aimed at Mackay where the process was less controversial and well supported by the project partners, the Mackay LMAC and RG. The project started with Fact Sheet (Figure 62), which was available for general use but also used to introduce the project in Mackay and Bowen-Burdekin. The project also produced a Poster for use at a Conference and also explains the project to a scientific and general audience (Figure 63).

An intense communication period followed to entice the Mackay public to undertake a survey of the relative importance of coastal management objectives. The following methods of communication the project survey:

- A newspaper advertisement for a 3-day in person survey session with the project team at Mercy College (Figure 64);
- Twitter and Facebook campaigns (Figure 65);
- Web page with survey link (Figure 66);
- Flyer made available at major public centres such as the Council and library; (Figure 67)
- Radio interview mentioning a 3-day in person survey session with the project team at Mercy College (Figure 68);
- Radio interviews enticing people to undertake an online survey (initially in SurveyMonkey™ and then hosted on CSIRO's web site – Figure 69)
- A paper survey available at the Mackay GBRMPA office (Section 0);

After the management strategy development phase several key products were produced (see Sections within 0):

- A letter on behalf of the Mackay RG for official submission to the Queensland Minister's fisheries management review (<https://www.daff.qld.gov.au/fisheries/consultations-and-legislation/reviews-surveys-and-consultations/fisheries-management-review>)
- A letter to the CEO of the Mackay Council
- A series of "what actions can you take" cards for use by the Mackay public and the Mackay RG. Printed versions will be available in the Mackay GBRMPA offices.

13.2 Communication products

13.2.1 PROJECT OVERVIEW

Project fact sheet

NERP Tropical Ecosystems Hub Project Factsheet

Design and implementation of Management Strategy

Evaluation for the Great Barrier Reef inshore

Project leader: Dr Cathy Dichmont (CSIRO)

Project summary

This project will develop a Management Strategy Evaluation (MSE) framework to build understanding of the key human uses and drivers of change in the inshore Great Barrier Reef (GBR), and to inform GBR stakeholders of the likely consequences, costs and benefits of particular management decisions that aim to minimise the impacts on biodiversity, particularly from inshore multi-species fisheries.

Why this research is needed

The participatory approach used in the development of the MSE framework will build a common understanding of how the socio-economic and ecological components of the inshore GBR system function and interact, and will assist stakeholders to formulate management objectives. The resulting MSE framework will be used to identify which policies and practices have the potential to meet the stated objectives of stakeholders and to assess trade-offs between social, economic and environmental outcomes.

Research-user focus

The project will deliver outcomes that are useful to a range of stakeholder organisations including local, state and federal government bodies, the fishing and other sectors, and conservation planners/managers. These organisations include the Great Barrier Reef Marine Park Authority, DSEWPaC, the Queensland Departments of Environment and Heritage Protection and Agriculture, Fisheries and Forestry and the Queensland Seafood Industry Association.

Project Partners:



Australian Government
Great Barrier Reef
Marine Park Authority



Find this project at www.nerptropical.edu.au

Theme 3: Managing for resilient tropical systems

Program 9: Decision support systems for GBR managers

Project: 9.2

For more information about this project, contact:

Dr Cathy Dichmont (CSIRO)

cathy.dichmont@csiro.au



Photos: State of Queensland, Department of Agriculture, Fisheries and Forestry, CSIRO.

Outcomes

- An understanding of the relative importance of different social, ecological, economic and governance objectives of each stakeholder group and for all stakeholders combined within the inshore GBR region.
- A qualitative model built using stakeholder input to develop a common understanding of the interactions between the various components of the inshore GBR system.
- Stakeholder driven development of alternative strategies for the management of the inshore GBR region.
- An assessment of the relative impacts of different management strategies compared with present management systems to provide clear direction about the pros and cons of different management strategies for the inshore region and their impacts on different stakeholder objectives.
- Management options aimed at biodiversity outcomes, focusing on inshore multi-species fisheries management.



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Figure 62: Project fact sheet developed at the beginning of the project

Project poster



National Environmental
Research Program

TROPICAL ECOSYSTEMS *hub*

Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore

PROJECT LEADER: Dr Cathy Dichmont

PROJECT TEAM: CSIRO, Great Barrier Reef Marine Park Authority, Department of Agriculture, Fisheries and Forestry,
Department of Environment and Heritage Protection, Department of Science, Information Technology, Innovation and the Arts,
James Cook University



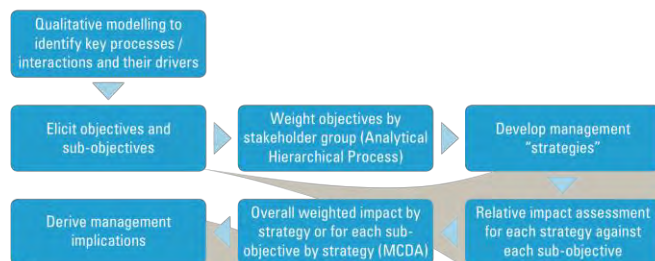
A Management Strategy Evaluation (MSE) framework is being developed to help understand the key human uses and drivers of change in the inshore Great Barrier Reef (GBR).

The framework will demonstrate the likely consequences, costs and benefits of management decisions that aim to minimise the impacts on biodiversity, particularly from inshore multi-species fisheries.

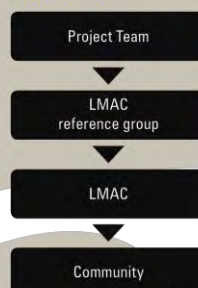
Extensive consultation with stakeholders at Mackay and the Burdekin is an important feature of the project which aims to:

1. Develop qualitative models to understand key interactions in the region, and underlying processes and drivers.
2. Identify social, ecological, economic and governance objectives of stakeholders for the inshore GBR region.
3. Identify alternative strategies for managing the inshore region, using a stakeholder-driven approach.
4. Assess the impacts of the management strategies against objectives using a semi-quantitative approach.
5. Develop management options (with end users) aimed at biodiversity outcomes, focusing on inshore multi-species fisheries management.

PROJECT PROCESS



STAKEHOLDER ENGAGEMENT



PATHWAY TO IMPACT

The project will engage local groups and key government departments linked to regional management.



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Australian Government
Great Barrier Reef
Marine Park Authority



JAMES COOK
UNIVERSITY
AUSTRALIA

Photos: Jetty and trawler - State of Queensland, Department of Agriculture, Fisheries and Forestry; Seagrass - CSIRO; Mangroves - Louise Bell; Hawksbill Turtle - Mark Vonderheide, CSIRO

Figure 63: Project poster presented at NERP Conference , Cairns 2013.

13.2.2 OBJECTIVES WEIGHTING IN MACKAY

Daily Mercury advertisement text

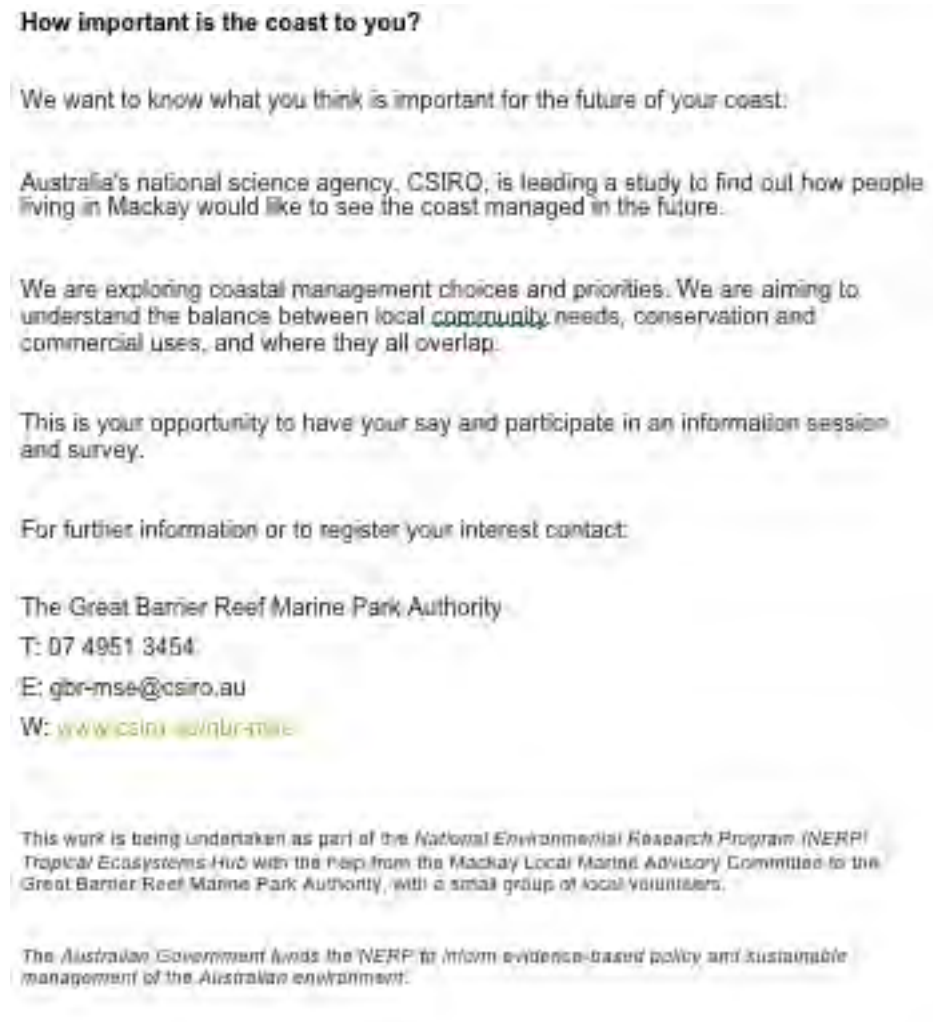


Figure 64: Daily Mercury advertisement text June 2013

Twitter and facebook



Sample tweets sent from
<https://twitter.com/CSIRONews>
 (21,679 followers)



Figure 65: Sample tweets sent to CSIRONews

Project web page hosted by CSIRO

Balancing coastal use and community values with management options

CSIRO is leading a study to learn more about how the community is using the coastal area near Mackay and the Burdekin in northern Queensland.

11 June 2013 | Updated 3 February 2014



Hawksbill turtle swimming over coral reef

Fast Facts

- It is critical to balance coastal use and community values with management choices that support the conservation of diverse marine life and protect commercial interests.
- This project aims to identify the demands on the coast, the areas valued by the local community, and deliver an assessment of the impacts of different potential management strategies compared with present management systems.

Project summary

Page 1 of 2

Balancing coastal use and community values with management choices that support the conservation of diverse marine life and protect commercial interests is important for long-term sustainability.



Holidaymakers launching boats to go fishing

To develop considerations required to meet the variety of activities undertaken along the coastal area near Mackay and the Burdekin, this project aims to identify the demands on the coast and which aspects are most valued by those who use it, and then incorporate these priorities with different options to help improve management of this region.

The results of the project will demonstrate the likely consequences, advantages and limitations of management decisions that aim to minimise the impacts on biodiversity from recreational and commercial activities.

Extensive consultation with stakeholders at Mackay and the Burdekin is an important feature of this project.

With input from the local community, industry, key government departments linked to regional management the project will direct the development of alternative strategies for the biodiversity management of the coastal and inshore Great Barrier Reef region.

Learn more about research by [Wealth from Oceans](#).

IN THIS ARTICLE

1. **Project summary**
2. [Project partners](#)

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Related Links

[Our resilient coastal Australia](#)

[Dr Cathy Dichmont: leading fisheries and ecosystems research](#)

[Online survey for Mackay residents \[external link\]](#)

[NERP Tropical Ecosystems Hub \[external link\]](#)

[Great Barrier Reef Marine Park Authority](#)



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[Publications](#)
[Careers](#)
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Balancing coastal use and community values with management options

Project partners

Page 2 of 2

Pathway to impact

In partnership Great Barrier Reef Marine Park Authority (GBRMPA), the Queensland Departments of Agriculture Fisheries and Forestry (DAFF), Department of Science, Information Technology, Innovation and the Arts (DSITIA) and Environment and Heritage Protection (DEHP).

The project will work through the Local Marine Advisory Committees (LMACs) operating in Mackay and the Burdekin area. The LMAC is a voluntary community-based committee that provides local level advice on management issues about the Marine Park to GBRMPA.

The LMACs are experienced in providing a community forum for interest groups, government and the community to discuss issues around marine resources and are central to the stakeholder engagement process for this project.

This project is being run through the National Environmental Research Program Tropical Ecosystems Hub (NERP TE Hub) in partnership with the Great Barrier Reef Marine Park Authority, Department of Agriculture, Fisheries and Forestry, Department of Environment and Heritage Protection, Department of Science, Information Technology, Innovation and the Arts, Department of Environment and Heritage and James Cook University.

The Australian Government funds the NERP to inform evidence-based policy and sustainable management of the Australian environment.

IN THIS ARTICLE

- [1. Project summary](#)
- 2. Project partners**



Mangroves are coastal forests that provide valuable nursery areas for juvenile fish and are an important source of nutrients.

Fast Facts

- It is critical to balance coastal use and community values with management choices that support the conservation of diverse marine life and protect commercial interests.
- This project aims to identify the demands on the coast, the areas valued by the local community, and deliver an assessment of the impacts of different potential management strategies compared with present management systems.

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[NERP Tropical Ecosystems Hub \[external link\]](#)

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Figure 66: Project web page hosted by CSIRO and linking to online survey address

Objectives survey flyer

How important is the coast to you?

We want to know what you think is important for the future of your coast.

Australia's national science agency, CSIRO, is leading a study to find out how people living in Mackay would like to see the coast managed in the future.

We are exploring coastal management choices and priorities from a community perspective. We are aiming to understand the balance between local community needs, conservation and commercial uses, and where they all overlap.

This is your opportunity to have your say and participate in an information session and survey.

Venue: Mercy College, corner of Penn Street and Juliet Street, Mackay

When: Tuesday, Wednesday and Thursday, 9–11 July, 6 to 8pm,
light refreshments provided (participants attend one session only)

For further information or to register your interest contact:

The Great Barrier Reef Marine Park Authority

T: 07 4951 3454

E: gbr-mse@csiro.au

W: www.csiro.au/gbr-mse

This work is being undertaken as part of the National Environmental Research Program (NERP) Tropical Ecosystems Hub with the help from with community volunteers and the Great Barrier Reef Marine Park Authority's Mackay Local Marine Advisory Committee.

The Australian Government funds the NERP to inform evidence-based policy and sustainable management of the Australian environment.



Australian Government
Department of Sustainability, Environment,
Water, Population and Communities



Australian Government
Great Barrier Reef
Marine Park Authority



Figure 67: Flyer for the survey 3-day at Mercy College

Media monitor of radio interviews

MON 11 NOVEMBER 2013

Mediaportal Report



Burdekin and Mackay have been chosen to gauge public attitudes towards the ...

ABC North Queensland, Townsville, 06:30 News, Newsreader

11 Sep 2013 6:33 AM

Duration: 0 min 48 secs - ASR AUD 99 - QLD - Australia - ID: W00054515069



Burdekin and Mackay have been chosen to gauge public attitudes towards the conservation and recreational and commercial use of coastal areas bordering the Great Barrier Reef by the CSIRO.

Interviewees

Kathy Dickmon(*), Researcher, CSIRO

N/A ALL
N/A MALE 16+
N/A FEMALE 16+

Communities to help form coastal management policy

ABC Online, www.abc.net.au

11 Sep 2013 3:26 PM

168 words - ASR AUD 1,706 - ID: 212794314

[Read on source website](#)

198,635 UNIQUE DAILY VISITORS
2,681 AV. STORY AUDIENCE

Communities to help form coastal management policy

ABC Online, www.abc.net.au

11 Sep 2013 1:18 PM

168 words - ASR AUD 1,708 - ID: 212776179

[Read on source website](#)

198,635 UNIQUE DAILY VISITORS
2,681 AV. STORY AUDIENCE

Program preview:

- Discussion about the coastal survey that will be done by the CSIRO.

ABC Tropical North, Mackay, Mornings, Kim Kleidon

14 Oct 2013 9:06 AM

Duration: 0 min 50 secs - ASR AUD 103 - QLD - Australia - ID: W00054889329



Program preview:
- Discussion about the coastal survey that will be done by the CSIRO.

N/A ALL
N/A MALE 16+
N/A FEMALE 16+

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Figure 68: Media monitor of radio interviews and pickup thereof

Online survey front page



Identifying key objectives for the management of the Mackay inshore coastal area

Project Description

14%

How important is the coast to you? We want to know what you think is important for the future of your coast. Australia's national science agency, CSIRO is leading a study to find out how people living in Mackay would like to see the coast managed in the future. The study is entitled "Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)", and explores coastal management choices and priorities. We are aiming to understand the balance between local community needs, conservation and economic development, and where they all overlap. This survey is an opportunity to have your say.

Based on a bibliographic review and extensive consultation with stakeholders from the Mackay region, the project team developed a structured list of objectives which can all be considered in managing the inshore coastal area. This list is a tree with three main objective branches relating to (1) the protection and restoration of environmental assets; (2) improvement of governance systems; and (3) improvement of regional economic and social well-being. Each of these branches contains a number of sub-objectives.

The purpose of this survey is to obtain your views on the relative importance you think should be placed on these different objectives.

By clicking the "Yes" button below you indicate that you want to participate in the survey. We ensure your confidentiality by not making public the information you provide in this online survey. It will only take approximately 20 minutes to complete this online survey. The information will be kept at a secure location on the CSIRO network only accessible to a core team of people until Dec 2014.

The information you provide will be used for research purposes only, without reference to specific facts or events. For any reporting your individual information will not be presented - all information will be presented in summarised form based on collating all survey data. This summarised information will be from a large enough group that your individual data could not be inferred. The range of answers in this summarised form will also be represented rather than only the average or median.

The research team will provide feedback on how the collected information has been used through verbal and written feedback by the end of 2013.

It is your right to withdraw from the survey at any time and without having to provide a reason for the withdrawal if you wish to do so. However, if you have already submitted your anonymous response we will not be able to withdraw any submitted information from the study as we cannot identify individual responses.

Please exit this survey if you do not agree to participate in the research.

We can be contacted on GBR-MSE@csiro.au if you have any queries.

The research is funded through the Reef and Rainforest Centre by the Commonwealth Department of Sustainability, Environment, Water, Population and Communities; CSIRO, the Great Barrier Reef Marine Park Authority; and the Queensland State Departments of Agriculture, Fisheries and Forestry; Department of Science, Information Technology, Innovation and the Arts; Department of Environment and Heritage Protection.

Final project reports would be provided to the different funding agencies and will also be made publicly available online at the end of the project. Journal publications would also be published in the scientific literature.

*** 1. Do you agree to participate with the survey?**

☐ Yes
☐ No

Next

Figure 69: Online survey front page

Paper survey

Your details



Name:

Email:

Please choose the group that you mostly associate with by checking (✓) the appropriate stakeholder group

Stakeholder groups

Please tick ✓ only one

Commercial Fishing

Charter Fishing

Commercial seafood processing

Recreational Fishing

Diving

Tourism

Fisheries Management

Fisheries Compliance

Tackleshops, Recreational Service Industry

Marine Services Industry

Mining

Port Authority

Farmer

Grazier

Conservation organisation

Great Barrier Reef Marine Park Authority

Queensland Parks and Wildlife Service

NRM group

Local Government Councillors

State Government

Aboriginal & Torres Strait Islander

Local Resident

Scientists

Student - High School

Student - Tertiary

Other

Please indicate the region where you are located

Region **Please tick ✓ only one**

Torres Strait to Cairns

South of Cairns to Bowen

South of Bowen to Repulse Bay

Repulse Bay to Clairview (Mackay)

South of Yeppoon to Baffle Creek

South of Baffle Creek to Double Island Point

South of Double Island Point to Caloundra

Caloundra to the NSW Border

Other

Example

Please indicate the relative importance of three different objectives for playing sports.

The total score should be **equal to 100**.

The indicator score for the individual objective has to be **at least one** (1) and CANNOT be zero (0)

Objective		100 points	Explanation of objective
1	Get fit	30	You want to maintain a level of fitness to stay healthy
2	Interact with your friends	10	This is an important opportunity to be with your friends every week
3	Have fun	60	The physical activity provides a high level of necessary fun in your otherwise busy life
		TOTAL 100	

OR

If you rate two the same please give them the same number of points

Objective		100 points	Explanation of objective
1	Get fit	1	You want to maintain a level of fitness to stay healthy
2	Interact with your friends	1	This is an important opportunity to be with your friends every week
3	Have fun	98	The physical activity provides a high level of necessary fun in your otherwise busy life
		TOTAL 100	

High Level Objectives

Please indicate the relative importance of three different high level objectives. The total score should be equal to 100.

Objective		100 points	Explanation of objective
1	Protect and restore inshore environmental assets		Overarching environmental objective for the region
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
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
		TOTAL 100	

Protect environmental assets

Please indicate the relative importance of three different objectives for protecting environmental assets. The total score should be equal to 100.

Objective		100 points	Explanation of objective
1.1	Improve ecosystem connectivity		Connectivity between catchment, fresh- and salt-water habitats
1.2	Improve water quality		Reduce sediment and nutrient runoff into waterways and reefs
1.3	Conserve inshore living resources		Ensure long-term conservation of the inshore living resources and their support systems
		100	

Objective		100 points	Explanation of objective
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
		100	

Objective		100 points	Explanation of objective
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
		100	

Objective		100 points	Explanation of objective
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)		Minimise accidental strikes and kills of fauna and flora (e.g. dugongs,

species

turtles, quolls)



100

Improve governance systems

Please indicate the relative importance of three different objectives for improving governance systems. The total score should be equal to 100.

Objective		100 points	Explanation of objective
2.1	Increase management effectiveness		Increase the effectiveness of management systems by removing barriers to flexibility
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
2.3	Increase management integration		Improve integration of management in policy, regulation & implementation, at Local, State & Comm. levels
		100	

Objective		100 points	Explanation of objective
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 & unregulated activities, & encourage compliance with existing regulations
		100	

Objective		100 points	Explanation of objective
2.2.1	Increase management acceptability		Increase management acceptability through rational & proportional legislation, & increased info dissemination
2.2.2	Increase stakeholder		Increase stakeholder engagement

	engagement and community ownership/stewardship
2.2.3	Sustainable financial costs

100

through involvement of private developers / corporate responsibility and community involvement in management to foster community ownership/stewardship
Minimise industry compliance costs & govt enforcement costs, including recoverable and non-recoverable total management costs and infrastructure costs

Objective		100 points	Explanation of objective
2.3.1	Increase policy integration		Coherent & integrated policies across Local, State and Commonw ealth levels
2.3.2	Increase regulatory integration		Coherent & integrated regulations across Local, State and Commonw ealth levels
2.3.3	Increase implementation integration		Coherent & integrated management implementation across Local, State and Commonw ealth levels
		100	

Improve regional well-being

Please indicate the relative importance of three different objectives for improving regional well-being. The total score should be equal to 100.

Objective		100 points	Explanation of objective
3.1	Increase economic growth		Promotion of regional economic development, incl. natural resource based industries, to maintain / improve family livelihoods
3.2	Increase social cohesion		Increase regional community cohesion through minimising conflicts between stakeholders, conserving traditional activities & cultures and ensuring 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
		100	

Objective		100 points	Explanation of objective
3.1.1	Improve regional economic development and industry diversity		Increase the regional flow of human & financial resources, develop efficient & integrated infrastructure, increase local market opportunities for local 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
		100	

Objective		100 points	Explanation of objective
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
		100	

Objective		100 points	Explanation of objective
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 social capital at both individual (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
		100	

13.2.3 MANAGEMENT STRATEGIES: CREATING IMPACTS

Queensland fisheries review letter entitled “Regional input to fisheries management is important”

Written for the Mackay Local Marine Advisory Committee Reference Group that supported the project “Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)”

Background

The Mackay LMAC Reference Group (RG) was formed as a sub-committee of the Mackay Local Marine Advisory Committee³ (LMAC) to support a Department of Environment funded project that investigated factors driving inshore impacts on biodiversity and fisheries using an approach that allowed locals to provide input to coastal fisheries and biodiversity management

(<http://www.nerptropical.edu.au/project/mse-ghr>).

The project found that terrestrial activities such as urban and rural development, and other aquatic non-fisheries activities that include dredging have significant impacts on fisheries through changes to habitats, water flow, sediment and water quality. These impacts affect both fisheries productivity and fishers return with potential negative effects flowing to both commercial and recreational sectors (e.g. reduction in fish catches which affect industry profitability and also reduces the enjoyment from fishing for recreational fishers).

Most members of the RG were also Mackay LMAC members and included commercial fishers and traders, recreational fishers, council and port staff, and local farmers. Even though the RG may not be representative of all interest groups in the entire Mackay community, they are locals who are passionate about improving management in the Mackay region and who volunteered considerable time to support this project. The project team, led by CSIRO, included staff from DAFF, GBRMPA, DSITIA and DEHP who helped link relevant government agencies with the RG members. During an intensive 18 months investigating issues that affect the coastal zone, the RG developed possible management actions that could be undertaken to mitigate identified coastal zone risks. Throughout the deliberation process, the RG had access to experts on relevant topics such as the role of key habitats (seagrass, mangroves and inshore corals), urban and port development, and fisheries. They were also made aware of existing management arrangements in the region. Outlined below are the RGs key inputs to fisheries management in the Mackay region specifically, but these inputs are likely to be highly relevant to Queensland fisheries management and the reviewers of Queensland fisheries. Management options developed by this group for broader impacts not directly attributable to fisheries are not mentioned here as they are not managed by DAFF fisheries, but are an important context that should be kept in mind.

Major fisheries-related issues highlighted and suggested solutions:

1. Competition between the different industries and sectors is the primary issue of concern to fisheries management. This is especially the case in the coastal zone

³ LMACs are committees established by GBRMPA in GBR coastal regions to provide advice to GBRMPA, membership is by way of nomination for a 3 year period and they are broadly representative of relevant stakeholder groups although they may also contain independent members

where large changes to the coastal landscape are occurring through Port and Urban development and where most of the conflict occurs between the indigenous, recreational and commercial fishing sectors. Of special concern is the growing conflict between the recreational and commercial fishery, which is serious and at times very acrimonious in many local areas in Queensland.

- a. Allocation to different sectors would allow for more appropriate fisheries management. This should lead to more reasonable controls on recreational fisheries (rather than trying to manage through indirect tools only such as bag limits) and create transparency in the dialogue about which fisheries will be predominantly fished by one sector or the relative allocation to each sector. This may mean that recreational fishers have to contribute to a licence or tagging system as used in other States. The sectoral allocation proposition is of the highest priority.
 - b. Education about the relative merits of each sector is also important, but follows on from the above. Some aspects of the lack of mutual respect can be explained by a predominance of misunderstandings and can thus be addressed through targeted campaigns that explain, for instance, the strict management controls on the commercial fishery and how they contribute to locally eaten seafood, employment and the economy. Similarly, recreational fishing activity could be explained as an important pass-time for many families around having fun, enjoying family time together and getting some seafood, but not for semi-commercial purposes. Present education by DAFF concentrates mainly on explaining existing regulations. Although this is important it may overly concentrate on a single aspect of fisheries management.
2. Illegal and unregulated fishing is perceived to have increased here over time as the amount of compliance staff on the ground has decreased. This has meant that a sophisticated poaching system seems to be developing in various regions of Queensland. With few compliance staff in each location and the large geographic area they need to cover, there is a view that it is generally well known where compliance staff are patrolling on any given day and where they are not. Lack of investment in compliance staff and infrastructure is compromising good fisheries management both directly through decreased compliance and indirectly as a disincentive to comply by honest people.
- a. Increased investment in compliance is required. Ideally this investment should concentrate on increasing the number of people on the ground, rather than investing in assets or management positions.
 - b. In reality, more resources may not be possible, meaning smarter compliance is needed using current resources. Presently risk assessments are mainly undertaken on a Queensland wide basis. However, the RG felt strongly that local knowledge is crucial for effective compliance and they expressed frustration at their inability to input to compliance risk assessment and strategy development. Locals know where the issues are and because local conditions drive many fisheries (especially in the inshore, e.g. local rainfall and barramundi). It is therefore suggested that mechanisms are needed to enable local input into illegal activities through direct engagement for example, FishWatch, into compliance risk assessments in different Queensland regions.

3. Regional versus State-wide management is a major issue, especially as there is a perception in smaller regions that South-East Queensland (SEQ) issues dominate. The lack of flexibility to undertake local management is hampered by the governance system that requires State-wide processes such as access licences and representation. Some fisheries may benefit from the ability to relocate from one region to another to remain economically viable. However, in the inshore zone this movement of "outsiders" into an area can become a major source of conflict. Locals want the flexibility to manage the resources on their doorstep. Several space-time allocation agreements between local commercial and recreational fishers have been unsuccessful due to the inability of the governance system to accommodate these good suggestions and the apparent ability of non-locals to disproportionately influence sensible development of local solutions. A compromise needs to be reached between flexible local arrangements and State-wide standards. This is a high priority. Other priorities include:
 - a. undertake a review of which fishery would benefit from a full or part devolution of management activities,
 - b. develop a governance system for these fisheries that overtly addresses the importance of local arrangements in the management of fisheries,
 - c. trial these arrangements in key fisheries, and
 - d. develop a stakeholder engagement system that allows for better local input.
4. The current Government is perceived as lacking independence on the decisions that are made. There is presently no representative stakeholder engagement process and thus no clarity exists as to how management decisions are made (or not). It is therefore necessary to consider:
 - a. Re-introducing stakeholder engagement committees such as the Resource Assessment Groups and Management Advisory Groups. Although these require resourcing, the benefits are seen to far outweigh the cost. If these traditional structures are no longer appropriate, some independent process is nevertheless essential for stakeholder buy-in to fisheries management.
5. Research priorities in Queensland are perceived to be dominated by SEQ priorities. This is partly due to the inability of local research ideas to be input to the system as there is no clear mechanism to feed in ideas to the process (bearing in mind that many/most fishers are not club or industry body members).
 - a. Develop a research priority process that allows bottom up, local input to research priorities.
6. Empowering locals (not only for regional management purposes) through stewardship programs is important for successful management, both to make effective decisions and to obtain support for these decisions.
 - a. Support existing stewardship groups such as the Reef Guardian Programs and/or develop specific fisheries-centric groups in different regions. These fisheries-centric groups should be adequately resourced.
7. Many departments have overlapping activities. For example, Parks' compliance staff, not empowered to deal with fisheries compliance, travel in areas where illegal fishing could occur. On-ground staff in all State and Commonwealth

Government agencies are much reduced in number, and sharing resources and tasks would greatly progress mutual management needs. This also applies to communication with the public, which is generally also independently undertaken by each agency, yet clear co-ordination of marine resource management objectives and communication strategies would be of mutual benefit.

- a. Develop synergies between GBRMPA, Parks, QDAFF through Inter-government Arrangement and Agreements. This should initially concentrate on on-ground activities such as compliance, littering etc.
- b. Synergise common messages of fisheries and marine resource management through the different agencies, especially between GBRMPA and DAFF. The priority here is to undertake education campaigns that aim to generate voluntary compliance and address allocation and mutual respect of different users of the marine estate.

In summary

Regional input is crucial to the effective management of Queensland's fisheries. To achieve this, governance reform is required to stakeholder engagement, allocation, compliance and education processes. Some of these will require further resourcing, but others are more about being more cognisant of regional issues and benefits. However, it is essential that potential fisheries reform (especially in the coastal zone) should be seen in the broader context of multiple use management. Fishers are users of a socio-ecological system where they are often receivers of what others do. They are at the end of a catchment to coast system where other users can affect the system fishers rely on and they often are smaller industries compared to other more financially valuable interests. Open and constructive dialogue to create systems that cross into other's management processes are therefore essential for a vibrant fishing community – fisheries should not be seen as the lowest hanging fruit of ecosystem management.

Mackay Council letter

18/12/2014

Our Ref: Outcomes from the CSIRO Project: "Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)"

Barry Omundson
Mackay Regional Council CEO
Mackay Regional Council
Sir Albert Abbott Administration Building
73 Gordon Street
Mackay QLD

Dear Mr Barry Omundson,

This Letter was written for the Mackay Local Marine Advisory Committee Reference Group that supported the project "Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore (MSE-GBR)".

Background

The Mackay LMAC Reference Group (RG) was formed as a sub-committee of the Mackay Local Marine Advisory Committee⁴ (LMAC) to support a Department of Environment funded project that investigated factors driving inshore impacts on biodiversity and fisheries using an approach that allowed locals to provide input to coastal fisheries and biodiversity management (<http://www.nerptropical.edu.au/project/mse-ghr>).

The project found that, with respect to their coast, the Mackay community values their environment highly, followed by good management, and then social and economic well-being. Currently, activities under the jurisdiction of Mackay Regional Council, such as urban and rural development, have significant impacts on coastal fisheries and biodiversity through changes to habitats, water flow, sediment, water quality and accidental deaths of iconic species. It is the view of the RG that these impacts affect (i) both fisheries productivity and **economic** return with potential negative effects flowing to both commercial and recreational sectors (e.g. reduction in fish catches which affect industry profitability and also reduces the enjoyment from fishing for recreational fishers), (ii) the capacity of communities to use the coastal zone for recreation and aesthetic enjoyment, and (iii) tourism.

Most members of the RG are also Mackay LMAC members and included commercial fishers and traders, recreational fishers, council and port staff, and local farmers. Even though the RG may not be representative of all interest groups in the entire Mackay community, they are locals who are passionate about improving management in the Mackay region and who volunteered considerable time to support this project. The project team, led by CSIRO, included staff from DAFF, GBRMPA, DSITIA and DEHP who helped link relevant government agencies with the RG members. During an intensive 18 months investigating issues that affect the coastal zone, the RG developed proposed management actions that could be undertaken to mitigate identified coastal zone risks. Throughout the deliberation process, the RG had access to experts on relevant topics such as the role of key habitats (sea grass, mangroves and inshore corals), urban and port development, and fisheries. They were also made aware of existing management arrangements in the region. Outlined below are the RGs key inputs to the Mackay region related to Council. Management options developed by this group for broader impacts not directly attributable to matters related to Council are not mentioned here as they are not managed by Mackay Regional Council, but are an important context that should be kept in mind.

It is important to note that this project concentrated on the coastal zone and not on the upper catchment. Furthermore, although many of the solutions highlighted below are known, this group highlights them as an issue i.e. what they are describing are their personal experiences on-the-ground living in Mackay.

Major Council-related issues highlighted and suggested solutions:

⁴ LMACs are committees established by GBRMPA in GBR coastal regions to provide advice to GBRMPA, membership is by way of nomination for a 3 year period and they are broadly representative of relevant stakeholder groups although they may also contain independent members

1. Littering in the coastal zone of the Mackay region can be either through carelessness, such as plastic bags flying from boats on rough seas, and security helmets and pieces of coal falling into the sea, or deliberate, such as discarding of plastic bottles, cigarette butts and bags on land and in coastal waters. Littering affects habitat amenity and impairment, and has been linked to the deaths of iconic species. Littering occurs because of people's indifference about the effects of littering on the environment. Therefore behavioural changes are necessary to deal with littering in Mackay and the Council can play a key role in reducing littering through further direct actions and indirectly via changing people's behaviour. For example:
 - a. Emphasise the implementation of waste management strategies. Council can increase adequate signage for boats on the location of rubbish bins and responsible litter disposal and encourage green waste recycling to minimise the amount of litter being disposed. Education campaigns to minimise plastic bag usage is also an important action to reduce litter. Council should undertake stormwater studies to identify priority areas for Gross Pollutant Traps (GPTs) retrofitting/installation and build these new areas into the Council strategy. Another key measure that should be undertaken by Council is to maintain an asset register of GPTs and Water Sensitive Urban Design infrastructure after developers hand-over these to the Council, and undertake an analysis of their efficacy through establishing monitoring programs. This is critical in justifying investments in measures to reduce litter and improve water quality.
 - b. Custodianship. Mackay Regional Council could support and be part of regular beach clean-ups with volunteers and schools to remove litter/debris from the coast and also promote programs such as 'adopt a beach', for roads, parks, and drains to encourage individuals or groups to regularly clean particular areas in the Mackay region.

2. Introduced pests (weeds and animals) affect the abundance and composition of native species, which leads to ecosystem degradation resulting in habitat loss and impairment. Council can contribute to enhanced pest control via establishing pest surveys and monitoring programs to identify which species occur locally, understand if they are spreading and to where, and how they are affecting the environment. It is also essential that Council and stakeholders identify and agree on management options to deal with weeds and pests, supported by cost/benefit analysis. Council should work with farmers or other landholders to understand how weeds can be managed on their property as local conditions will influence the way pests are managed. These results should be communicated to the public.

3. Development: Coastal urban, industrial and aquaculture developments are causing ecosystem degradation in the Mackay region through sediment runoff and reduction of ecosystem connectivity. There are established and effective practices that can minimise effects of development on ecosystems, but in Mackay, wide knowledge about these practices is limited. The following actions were identified to support Mackay Regional Council deal with development:
 - a. Maintain an asset register for handover of sediment reduction infrastructure to Council from developers. Developers build infrastructure in

new developments to capture groundwater flows and reduce development impacts on the environment, but after a couple of years they hand over this infrastructure to Council who maintains them. It appears Council does not have the necessary information detailing which infrastructure was passed on from developers and their condition, so it appears that Council does not know what they own and what needs to be maintained. An asset register would be beneficial to assist Council to adequately budget to maintain such infrastructure. Funding for construction and maintenance of infrastructure could be sourced, for example, from the Australian Government water quality initiative program.

- b. Improve knowledge feedback to 'improve' best practices over time. It is essential that Council establishes research programs based on better monitoring and sampling to identify whether or not management actions are effective. Council should consider linking activities with existing surface water quality monitoring program from NQBP and identify in the State Planning Policy the objectives that are relevant to the region.
 - c. Commission flood studies to identify areas at risk and articulate these to the public for their information and comment as local knowledge of what happens in floods may add value to the reports. It is also important to promote knowledge of the role that low lying flood prone areas play in both the management of flood impacts as well as their environmental importance in ecological productivity i.e. fishery spawning and recruitment. The Council should also consider using freeware tools easily accessible by the community, such as Google Maps and Google Earth available on the Council web site, to show areas at risk from floods and inundation.
 - d. The Council should use water quality offset contributions to mitigate pollution from development. For example, via establishing monitoring programs and developing spatial tools to support management of water quality and quantity.
4. Improve resource management. Resource management in Mackay region is challenging because management processes and regulatory frameworks are disconnected and vary between Commonwealth, State and local governments in the Mackay region. Although progress has been made, much improvement is still possible. Disconnected and inconsistent management frameworks result in multiple and inconsistent approvals for activities, which reduces (i) environmental protection, (ii) fisheries resources and sustainability, (iii) habitat amenity, and (iv) species sustainability, and increases (i) habitat loss, degradation, and impairment, and (ii) risk of death or harm of iconic species. Mackay Regional Council can improve resource management through the following activities:
- a. Improve decision-making process by using fact-based decision-making. Council should invest in research about local solutions and apply lessons learnt from elsewhere: such as examples of cost-effective practices from around the GBR that are known to improve environmental conditions. The evaluation of the effectiveness of management actions (supported by a monitoring program) is also a key component of improving resource management. Council should pilot a project to demonstrate benefits of WSUD in developments to justify further investments. Benefits should be

- holistic by considering cumulative impacts (e.g. water quality, aesthetics, biodiversity, economic).
- b. Another key action from Council is to consider and adopt local knowledge in decision-making. There are cases in Mackay where improved and cost-effective practices used by farmers (e.g. riparian re-vegetation) were overruled by Council that decided to implement a hard solution (concrete channelization of stream) further upstream instead of supporting the local initiative. Council decision undermined the local initiative and also the investments made by NRM organisation to improve water quality through riparian vegetation.
 - c. Rather than create new legislation, enforce existing legislation within government and in the public especially those that deal with impacts of population growth, coastal development and aquaculture runoff on habitat loss. Mackay Regional Council should also increase resources to compliance and enforcement. It is important to identify how State and Council could better work together in terms of jurisdictions so that resources for compliance are optimised. For example, Council sometimes is better positioned to check compliance of State developments, but Council has no jurisdiction on State developments (e.g. roads).
 - d. Improve connectivity within the Mackay catchment. Council can commission studies to identify the type of bund walls and the need to improve connectivity through fish passages using basin assessments. Offsets can be used to address lack of connectivity through fish passages due to construction of bund walls and also to maintain mangrove community links to improve connectivity along the coastal and estuarine fringe.
 - e. Apply more widely existing urban design principles and soft solutions to reduce impacts of population growth/development on habitats. It can, for example further use the Internal WSUD working group in Council to identify problems and how they will be addressed in terms of better understanding effectiveness of wetlands, bio-retention, sediment basin, grass swales, grass pollution traps (GPT), vegetated drains, and establishment of drainage reserves and how to implement these actions in the Mackay region
5. Coordinated Education Campaigns. In the Mackay region, careless attitudes of some people towards the environment have been affecting fisheries and biodiversity in the coastal zone. Changing behaviour of some Mackay residents, government agencies and industry through educational campaigns is therefore paramount to improve water quality and reduce littering in the region. Council can promote change in cultural attitudes through the following actions:
- a. Educate community about the use of bike paths, walkways and alternative modes of transport as ways of substantially reducing traffic and the need to build new bridges and roads. Council already has a car-pooling system to reduce traffic in the roads that needs to be promoted and further used by the community (<http://www.mackayregioncarpool.org/>)
 - b. Develop an education program to change attitudes of society toward littering. For example, by including littering as an indicator of a regional report card system in the Mackay region. A regional water quality report card would be a valuable educational material to change cultural

attitude. Additionally Council can develop signage showing connection of rubbish impact on reef – stencils on drains, green waste signs.

- c. Assign a waste officer to go to schools and organise tours about how the Council manages littering. For example, display litter collected in gross pollutant traps and display information about how rubbish is recycled in the Mackay Libraries.
- d. Undertake education campaigns within different sections of the Mackay Council and link to successful programs in other Councils in QLD. Such campaigns should focus on education of Council staff about successful systems used elsewhere (e.g. Brisbane/Gold Coast), such as Water Sensitive Urban Design⁵, keyline planning⁶, wetlands bio-retention, sediment basin, grass swales, and vegetated drains to improve water quality. Mackay Council have established sediment control measures in the region as part of State Planning Policy and it would be beneficial to improve knowledge about other options available to reduce sediment runoff from development. Council should also promote education of compliance staff as they must be educated and diplomatic when dealing with the community. This is important because most people comply with legislation and courteous behaviour provides greater support of compliance activities. It is also important to promote compliance officer training in the legislation they are enforcing.

In summary

Regional input is crucial to the effective management of the coastal zone of Mackay. To achieve this, direct actions to minimise littering, sediment/nutrient runoff from development and to control pests are essential. Improved resource management and educational campaigns are also critical to support stakeholder engagement, improve compliance and change behaviour of some Mackay residents. Some of these will require further resourcing, but others are more about being more cognisant of regional issues and benefits.

A key finding of this project is that, although much action is already been undertaken, further on-the-ground work is still needed and Mackay Regional Council can support on-the-ground initiative to deal with multiple-use management in the coastal zone. The overriding view is that much of the legislation, plans and strategies are in place; however, there is room for improvement in the areas of implementation, compliance and education.

Regards,

⁵ Water Sensitive Urban Design (WSUD) is about integrating water cycle management into urban planning and design. It looks to manage the impacts of stormwater from development.

⁶ a technique for development of urban and rural landscapes that considers the topography to build infrastructure (hard or green) to maximise the beneficial use of water resources.

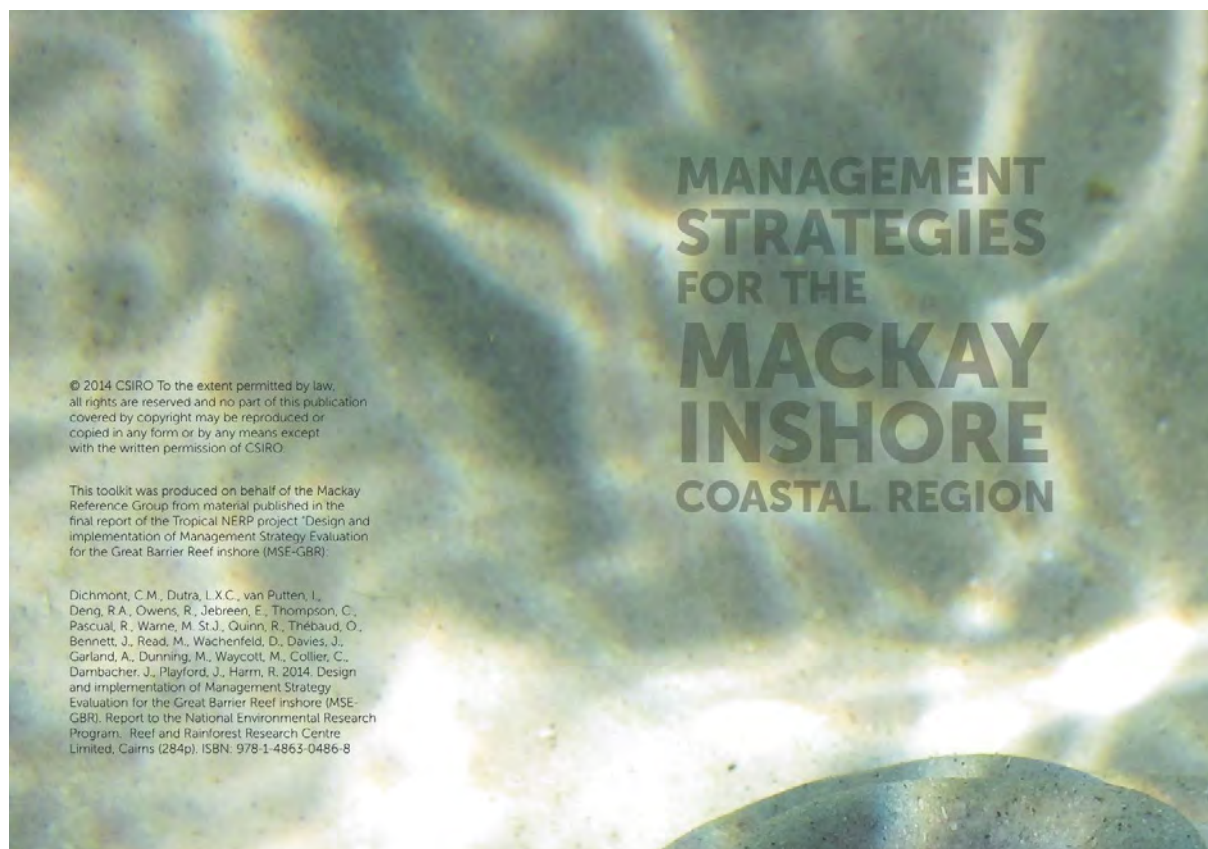
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Management strategy cards

MANAGEMENT STRATEGIES FOR THE MACKAY INSHORE COASTAL REGION

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)



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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., Darnbacher, J., Playford, J., Hamm, 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). ISBN: 978-1-4863-0486-8

INTRODUCTION

The inshore zone of Mackay contains key habitats that support biodiversity and fisheries, benefiting the local economy and community lifestyle. Cumulative impacts from mining, ports, agriculture and urban development influence habitats, and if not properly managed will cause adverse social and economic consequences.

This project has developed a Management Strategy Evaluation (MSE) framework with a community group and the Local Marine Advisory Committee (LMAC) from Mackay. This framework built understanding of the key human uses and drivers of change in the inshore Great Barrier Reef (GBR). Our objective is to inform GBR stakeholders of the likely consequences, costs and benefits of particular management decisions that aim to minimize the impacts on inshore biodiversity and fisheries.

This 4-year project found that, with respect to their coast, communities value their environment very highly, followed by good management, and then social and economic well-being. One key finding of the project is that local people should and can influence the management of their natural resources for future generations. Another finding is that, although much action is already being undertaken, much on-the-ground work is still needed.

RESEARCH NEED

The management strategies presented in this kit are useful to a range of stakeholder organisations including local, state and federal government bodies, the fishing industry and other sectors, and conservation planners/managers.

These organisations include the Great Barrier Reef Marine Park Authority, the Department of Environment, the Queensland Departments of Environment and Heritage Protection and Agriculture, Fisheries and Forestry, the Queensland Seafood Industry Association and the Mackay Regional Council.

THE MANAGEMENT STRATEGY KIT

This kit contains 12 cards that showcase the management strategies developed with a community group from Mackay.

Each card represents one of the management strategies, which consists of several actions. The strategies can be each read on their own or together, and are aimed at concerned members of Mackay community and at managers that make decisions in the region.

The overriding view is that much of the legislation, plans and strategies are already in place. However, there is room for improvement in the areas of implementation and compliance. A few people from Mackay are stepping way over the boundaries of acceptable behaviour, and as such it is affecting the community, the environment and government effectiveness and action in on-the-ground activities which are already stretched.

The management strategies address issues ranging from the cumulative impacts of littering, pests and weeds, fisheries management, protected species incidents, dredging, farming and urban and rural developments.

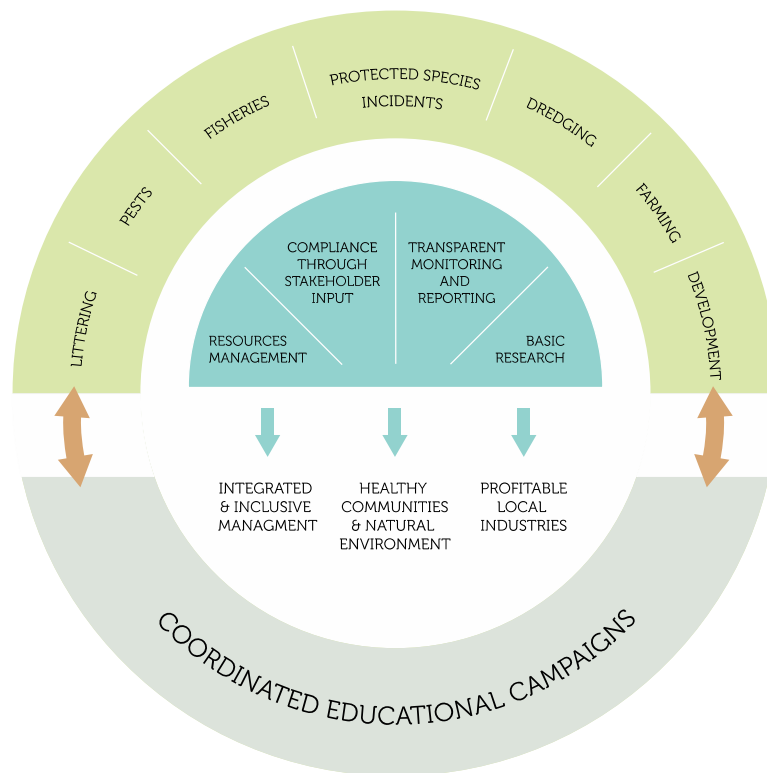
A key underlying theme is that all management actions can give rise to either **direct actions** on individual impacts, such as reducing littering and runoff from farms and development or through responses by means of **indirect actions** such as resource management, added compliance, and basic research.

Coordinated educational campaigns targeted at the local community, industries and government agencies is a key action that can help influence positive behaviour and attitudes towards inshore resources in the Mackay region. The final **outcomes** expected from the management strategies are:

- 1 Healthy communities and natural environment
- 2 Integrated and inclusive management
- 3 Profitable local industries

For easier visualisation, we created a diagram to represent the relationships between the direct actions, indirect responses, coordinated educational campaigns and desired outcomes. We like to call it **"THE WHEEL"**.

THE WHEEL



HOW TO USE THE CARDS

Management strategies are colour coded and divided in three categories according to **THE WHEEL**.

- **direct actions** in light green
- **indirect responses** in aqua-blue
- **coordinated educational campaigns** in grey

You can choose the strategies that you are interested in based on the colours of the cards.

Individuals and organisations will have different powers and jurisdictional responsibilities/abilities as to what they can do to achieve regional outcomes.

For example, with regards to littering, individuals can participate and coordinate beach clean-ups, with support from industry, government and non-government organisations. However, only Council can implement waste management strategies, but support from the public and industry is important.

Each card describes one of the management strategies presented in **THE WHEEL** and provides information regarding potential actions that can be undertaken to achieve regional outcomes.

This kit is essentially a communication device where the cards can be used as a tool to engage stakeholders to take on-the-ground actions.

Search through the cards, read the suggested actions and think about how you or your community group can engage in or facilitate one of the suggested activities today!

ACKNOWLEDGEMENTS

This work would not have been possible without the incredible input from the **Mackay people**. Most notably, those that helped us tirelessly in Mackay as **members of the Mackay LMAC Reference group**.

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 local traction.

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

BOOKLET PHOTO CREDITS

Pages 2+3: *Light Sand* by Manuela Taboada

CARDS PHOTO CREDITS

Littering

On Shore by Manuela Taboada

Pests

Water Lettuce by Reef Catchment / Mackay Region Natural Environment

Source: <https://flic.kr/p/c3pnEq>

Fisheries

Juvenile Barramundi by Tim Marsden / Mackay Region Natural Environment

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Protected Species

Marine Turtle by Klaus Stiefel | Source: <https://flic.kr/p/czC21m>

Dredging

Dredge Gear by Snthony DeLorenzo | Source: <https://flic.kr/p/da1a6B>

Farming

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Investment in Basic Research

Barriere Riff by Originalwanna, based on NASA ISS Imagery ISS007-E-14874 |

Source: <http://commons.wikimedia.org/wiki/File:Barriere-Riff.jpg?uselang=en-gb>

Coordinated Educational Campaigns

Joint Effort by Manuela Taboada

THE FINE PRINT

Published by

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

December, 2014

Art Direction and Graphic Design
Manuela Taboada



Australian Government

Department of the Environment



National Environmental
Research Program
TROPICAL ECOSYSTEMS hub



WHAT CAN WE DO TOGETHER TO MINIMISE LITTERING?

■ Implement waste management strategies

Enforce adequate signage on boats and boat ramps on location of rubbish bins and responsible litter disposal.

Encourage green waste recycling.

Reduce plastic bag usage through education campaigns.

Undertake stormwater studies to identify priority areas for Gross Pollutant Traps (GPTs) retrofitting/ installation and build into strategy.

Develop an asset register of GPTs and Water Sensitive Urban Designs (WSUDs), and undertake an analysis of their efficacy.

■ Custodianship

Continue promoting attendance at national clean-up days.

Undertake regular beach clean-ups with volunteers and schools to remove litter/debris from the coast.

Continue the GBRMPA Future Leader Eco Challenge program that encourages students to participate in projects about sustainable living and environmental protection.

Promote programs such as 'adopt a beach', for roads, parks, and drains to encourage individuals or groups to regularly clean particular areas in the Mackay region.

■ Better design of industrial & government operational procedures

Make the management of littering explicit in industrial management principles and design procedures to reduce littering during activities (e.g. security hats falling during works in the jetty of coal terminal).

Implement procedures found in Water Quality Improvement Plan on managing littering.

LITTERING

In the Mackay region, littering can be either deliberate (discarding of plastic bottles, cigarette butts, and bags on land and in coastal waters), or as a consequence of careless behaviour (plastic bags flying from boats on rough seas and security helmets and pieces of coal falling into the sea).

Littering affects habitat amenity and impairment, and also leads to deaths of iconic species. Littering occurs because of people's indifference about the effects of littering on the environment. Therefore behavioural changes are necessary to deal with littering in Mackay

On Shore by Manuela Taboada, 2013

WHAT CAN WE DO TOGETHER TO IMPROVE PEST MANAGEMENT?

■ Develop and implement regional weed and pest management plans while learning from existing programs

■ Establish pest surveys and monitoring programs

Undertake an analysis of which species occur locally, if they are spreading and to where, and how they are affecting the environment for more effective monitoring.

■ Improve soil health by re-using weeds

Replace present weed control with more environmentally friendly methods. For example weeds can be used to re-mineralise the soil (medium to long-term) as most weeds, especially water weeds, are a very beneficial addition to compost.

■ Identify and agree on management options to deal with weeds and pests that is supported by cost/benefit analysis

Work with farmers or other land holders to understand how weeds can be managed on their property.

■ Decrease use of chemicals

Reduce the usage of pesticides/herbicides.

Follow guidelines from Water Quality Improvement Plan.

Burn the weeds to ashes (peppering) and use the ashes as a spray.

Implement effective biological control, including micro-biotic control—not just bugs.

Understand ecosystem impacts from pest management to identify unwanted flow on effects.

■ Work together with GBRMPA and NRM groups to follow established guidelines and management plans

Promote partnerships between research organisations, local universities and businesses to develop and implement strategies to manage pests.

Use a collaborative approach to control weeds instead of blaming another party.

PESTS

Introduced pests—weeds and animals—affect the abundance and composition of native species, which leads to ecosystem degradation resulting in habitat loss and impairment.

Water Hyacinth by Reef Catchment / Mackay Region Natural Environment
Source: https://pic.twitter.com/...

WHAT CAN WE DO TOGETHER TO ENCOURAGE SUSTAINABLE FISHING?

■ Deliver consistent communication campaigns

Re-emphasise existing communication campaigns directed towards allocation issues in the inshore zone using facts about Mackay, the reasons for recreation fishing (enjoyment) and the role of fisheries for the people and the economy.

Link communication strategies between GBRMPA and QDAFF to send consistent and harmonised messages about regulation, management and best behaviour.

Improve targeted advertising on the above fishing messages by getting local support through interviews of local fishers and other community members on local radio programs.

Simplify ID discussions in web sites.

■ Improve coordination between local fishers and managers

■ Modify compliance risk assessments

Modify risk assessments so that they include local knowledge and environmental characteristics (e.g. seasonality of fishing).

Enhance the Fishwatch hotline so that it links to local offices in time and enhances the DAFF compliance risk assessment in order for compliance activities to be better focused.

■ Revisit bag and size limits

Tighten and simplify bag limits especially slot limits for iconic target species in similar groups (e.g. flathead and grunter).

Apply bag limits to the boat not just individuals; for example having a boat limit that is twice the individual limit.

Reduce upper slot size limits especially for king salmon and barramundi.

■ Promote flexibility in management to incorporate regional changes in permits, legislation, and zoning for trawling

Move the existing seagrass closure within Hillsborough channel to a nearby site as the seagrass bed has relocated.

Allow local input into management systems through clear and transparent communication processes and representation bodies.

■ Tackle illegal fishing

Increase the recreational fishery use fund (RUF) to enforce good rules.

Increase value of fines for illegal fishing so as to create a disincentive to fish illegally.

■ Promote environmental branding to sell and market commercial products that are sustainably harvested

FISHERIES

In Mackay, high numbers of recreational fishers, driven by the mining sector, have increased fishing effort. This growth in number of fishers, combined with greed and disrespectful behaviour of some individuals, has led to unnecessary competition and conflicts between commercial and recreational fishers.

Existing behaviour of some fishers toward each other and the environment has also led to illegal activities by fishers which affect fishery resources and sustainability. The perceived reduction in compliance presence, due to the decrease in the number of fisheries officers based in Mackay, has exacerbated this situation. In addition, some of the existing legislation is inadequate for the appropriate control of some species and habitats, which in combination with illegal fishing activities, increases effort on fishery resources (with negative long-term consequences on fishery resources and sustainability) and degrades coastal habitats in the Mackay region.

The present situation of narrow research funding focusing on iconic species (rather than the broader suite of species of interest to this sector) is also an important issue that needs to be addressed to maintain long-term sustainability of a range of important fishery resources in the region.

The Queensland Government is undertaking a wide-ranging independent review of fisheries management and compliance to deliver a better system for the state's commercial and recreational fishers. It is anticipated that the Government will receive the review in early December 2014.

WHAT CAN WE DO TOGETHER TO LOOK AFTER PROTECTED SPECIES?

■ Trial dugong friendly nets in Dugong Protected Area B

Conduct trials of dugong friendly nets that can inform industry about their use specific to local situations.

Investigate and collate existing industry changes to fishing gear that may already reduce capture of dugongs.

Use Reef Guardian Program to help improve net practices with industry.

Identify champion in local area to trial new gears to reduce deaths of protected species to see what works.

■ Trial new propeller designs to protect protected species

Trial folding up propellers—soft plastic propeller designed not to cut animals/people in accidents; won invention of the year prize.

Trial other methods of modification to the propeller to reduce turtle strikes.

■ Review the use of offshore gillnet use in Dugong Protected Area B

Especially with respect to bottom set nets and the use of mechanical reels allowing for shorter soak times.

■ Use lead core rope and refine float line loop to reduce entanglement potential

PROTECTED SPECIES INCIDENTS

Mackay is well endowed with a large number of iconic species, many of which are also declared as threatened, endangered and protected. Every year protected species such as dugongs, turtles and dolphins are killed. They can be accidentally caught in fishnets, illegally fished, or stricken by boats, causing loss of biodiversity in the region.

Indigenous fishing of protected species requires further investigation given issues related to (i) non-indigenous people claiming to be indigenous and therefore illegally fishing indigenous resources, and (ii) potential impacts of traditional fishing on stocks.

Marine Turtle by Klaus Stiefel | Source: <https://iucn.org/price/23m>

WHAT CAN WE DO TOGETHER TO BETTER MANAGE DREDGING?

■ Thorough and transparent assessments on locations for dumping spoil

Decision on disposal sites (inshore versus offshore) needs to be transparent to the public and thoroughly investigated.

Investigate alternatives to utilise dredge spoil.

Time dredge operations to make sure it does not coincide with other dredging operations nearby.

■ Avoid the need for dredging

Investigate options to avoid/minimise dredging.

Consider costs, location, environment, logistics of alternatives to dredging, such as barge to transport coal to ships.

■ Undertake an education and information program targeted at the local community to explain the activities of the Port and how these are being managed

Provide greater transparency to the community by providing greater access to information and data collected by the Port.

Undertake a science program that uses the monitoring data for modelling to investigate Port and cumulative impacts.

■ Research into land options for dredge spoil (although local options are limited)

Use modelling and cost benefit analysis to investigate options for depositing dredge spoil on land not in water (e.g. industrial estate in Mackay Harbour).

Investigate the use of spoil to back fill holes from the mines—train is empty on return.

■ Apply strategic management control systems to dredge when water clarity is low

Identify a trigger to control how long dredging can run—monitor turbidity while dredging is underway and use data to identify such trigger points.

■ Remove the existing window for dredge spoil dumping timing and investigate the optimal window time design that fits the local conditions adaptively but also consider the Port, environment and other users' needs

DREDGING

Dredging is an important activity to maintain access to Ports, which benefits the regional economy. However, dredging can directly remove species and re-suspend sediments, which increases turbidity, reduces light penetration and impacts benthic organisms (e.g. corals, sponges).

Prolonged sedimentation and turbidity can affect species composition and abundance and may also alter habitats such as coral reefs.

Impacts of dredging can be managed to improve environmental protection and minimise habitat loss.

Dredge Gear by Anthony Delorenzo | Source: <https://lic.kr/p/0a3a68>

WHAT CAN WE DO TOGETHER TO MINIMISE RUNOFF?

■ Improve on-farm procedures to minimise run-off

Provide information on target spraying of chemicals and/or bio-inputs (spray at the right time).

Establish buffer zones in crops to minimise spray drift and investigate the optimal design of such buffer zones, which includes minimal maintenance.

Use nutrient management techniques to manage application, timing and quantity of nutrients in crops.

■ Implement the Water Quality Improvement Plan (WQIP)

Use the WQIP as an educational tool to farmers as it provides valuable and clear guidelines, measurements and targets to be achieved, and also potential actions that farmers can use to reduce farm runoff.

■ Promote on-farm best practices

Use farm and crop specific tractor traffic management to reduce soil compaction.

Continue to use cane trash blanketing and its conversion to humus.

FARMING

In Mackay, coastal farming is important. Some farms in the lower catchments are even surrounded by suburbs as Mackay has grown in size. Sediment, nutrient, pollutant and chemical runoff from farms can affect fisheries and biodiversity in the reefs of the Mackay region. In recent years farming practices have improved in Mackay, which reduced runoff to coastal waters, but some on-farm practices can still be improved.

The main causes of farm runoff are: a) the agriculture activity itself which requires land clearing and use of chemicals, and b) lack of knowledge about (i) dosage of chemicals and (ii) on-farm best practices to minimise runoff.

Sugar Cane Afternoon ©Stock.com/Ta

WHAT CAN WE DO TOGETHER TO MANAGE DEVELOPMENT?

■ **Maintain an asset register for hand-over of infrastructure to Council from developers**

Create an asset register of infrastructure passed on from developers to Council. Developers build infrastructure in new developments to reduce impacts on the environment. After a couple of years developer hand-over this infrastructure to Council who maintains them. At the moment the Council does not have the necessary information to know exactly which infrastructure was passed on from developers and their condition.

Investigate alternatives to maintain infrastructure built by developers and handed over to Council to minimise impacts on ecosystems. An asset register would be beneficial to assist Council to adequately budget to maintain such infrastructure. Ongoing investment in the register is needed.

■ **Target Australian Government water quality initiative program to enhance water quality in waterways of Mackay**■ **Improve knowledge feedback to 'improve' best practices over time**

Understand whether and how practices and ideas from places with different climates could work in Mackay.

Create conditions for groups to share data and knowledge and provide feedback to each other.

Establish research programs based on better monitoring and sampling to identify whether or not management actions are effective. Consider linking with existing surface water quality monitoring program from NQBP.

Identify State Planning Policy objectives that are relevant to the region and investigate how these could be implemented.

■ **Commission flood studies to identify areas at risk and articulate to public for inclusion of local knowledge**

Promote knowledge on the role that low lying flood prone areas play in both the management of flood impacts as well as their environmental importance in ecological productivity i.e. fishery spawning and recruitment.

Consider using freeware tools easily accessible by the community, such as Google Maps and Google Earth, to show areas at risk from floods and inundation.

■ **Use water quality offset contributions to mitigate pollution from developments**

DEVELOPMENT

Coastal urban, industrial and aquaculture development are causing ecosystem degradation in the Mackay region through sediment runoff and reduction of ecosystem connectivity. There are established and effective practices that can minimise effects of development on ecosystems, but in Mackay wide knowledge about these practices is limited.

Reef Catchment / Mackay Region Natural Environment / JRC 01/13/2014

WHAT CAN WE DO TOGETHER TO IMPROVE RESOURCE MANAGEMENT?

■ **Improve connectivity within the Mackay catchment**

Identify location and type of bund walls and the need to improve connectivity through fish passages using basin assessments.

Use offsets to address lack of connectivity due to construction of bund walls.

Maintain mangrove community links to improve connectivity along the coastal and estuarine fringe.

■ **Enforce existing legislation**

Within government and in the public especially legislations that deal with impacts of population growth, coastal development and aquaculture runoff on habitat loss.

Increase resources to compliance and enforcement, or provide local input into risk assessments.

■ **Improve decision-making process**

Use fact-based decision-making

Consider local knowledge in decision-making.

Apply lessons learnt from elsewhere such as examples of cost-effective practices from around the GBR that have been known to improve environmental conditions.

Achieve holistic outcomes from actions by considering cumulative impacts (e.g. water quality, aesthetics, biodiversity, economic).

Improve coast-wide understanding of cumulative impacts related to multiple dredging and seasonal river runoff in the Mackay area.

Move towards a code of practice that can be either regulatory or non-regulatory.

Pilot project to demonstrate benefits of WSUD in developments and justify further investments.

Fund the implementation of a monitoring program to measure effectiveness of management actions (e.g. installation of artificial wetlands) aimed at improving, for example, water quality. This will allow management agencies to justify further investments.

Fund and undertake research about alternative solutions to improve water quality and their impacts to support decisions.

RESOURCE MANAGEMENT

Resource management in Mackay region is challenging because management processes and regulatory frameworks are disconnected and vary between Commonwealth, State and local governments in the Mackay region. Although progress has been made, much improvement is still possible.

Disconnected and inconsistent management frameworks result in multiple and inconsistent approvals for activities, which reduces (i) environmental protection, (ii) fisheries resources and sustainability, (iii) habitat amenity, and (iv) species sustainability, and increases (i) habitat loss, degradation, and impairment, and (ii) death of iconic species.

Reef Catchment / Mackay Region Natural Environment / JRC 01/13/2014

WHAT CAN WE DO TOGETHER TO IMPROVE COMPLIANCE?

■ Enforce existing rules/legislation

Ensure compliance risk assessments include local knowledge on key compliance priorities across all fisheries in the region.

Identify how State and Council could better work together in terms of jurisdictions so that resources are optimised. For example, Council sometimes is better positioned to check compliance of State developments, but Council has no jurisdiction on State developments (e.g. roads).

■ Increase the number of compliance staff in State Government

Direct funds from other areas to increase number of compliance staff in State Government. In Queensland State it is not possible to have self-funded compliance staff positions as no incentive-based positions are allowed.

■ Increase resources for compliance as a whole, not only number of staff, but also boats, cars, etc.

■ Establish and promote a community-based reporting system

Establish a reporting hotline for Council, similar to FishWatch, which could be used for reporting people that do not comply with legislation. The community reporting system can be done via advertisement of hot lines on the council website. This action needs to consider costs of an officer on call after hours (nights, weekends), plus costs associated with mobile phone and maintenance of website compared to the benefit of potentially increased compliance.

Similar to already undertaken by some agencies, publish names of non-compliant people in the newspaper.

COMPLIANCE THROUGH STAKEHOLDER INPUT

Existing rules and legislation are effective to deal with fisheries resources, habitat loss associated with fisheries activities, and industrial and coastal development. However, these rules and legislations are not always enforced, which may increase illegal fishing, sale of products on the black market and increase runoff from developments. These illegal activities can affect fishery resources and sustainability, and degrade or impair coastal habitats.

The current small number of compliance staff within governments poses a big challenge to resource and habitat sustainability. For example, illegal fishers follow the movements of compliance staff and know where they are, so they can break the laws without being caught. It is necessary to improve compliance through local stakeholder input on risk assessments so compliance efforts can be better planned and tailored to local conditions even within existing budgets.

School of Big Eye Trevallies by Fugr10 | Source: <https://flic.kr/p/7d1uon>

WHAT CAN WE DO TOGETHER TO ENCOURAGE TRANSPARENCY?

■ Promote information and data sharing with public

Facilitate information and data sharing between industries and with the public so as to improve management of the inshore GBR, to influence perceptions related to development and to support a more evidence-based decision making process. Knowledge sharing should be mandatory and independently managed.

Make data sharing conditional to approval processes. The big problem involved in accessing and sharing data/information from Environmental Impact Assessments and Consultancies is related to IP and commercial in-confidence contracts.

■ Establish a report card system for water quality

Use a report card system with clear and consistent methods to support more transparent dissemination of information to the public.

■ Understand expectations and public perceptions about coastal issues

Run surveys with the broader community to understand their perceptions and expectations about the coast, for example with regards to the perception of communities in relation to risks of shipping in the GBR.

TRANSPARENT MONITORING & REPORTING

There are several programs collecting data in the inshore coastal zone of Mackay as part of environmental licences (e.g. air quality and marine data for Port activities) and research. Collecting data is expensive and therefore often subject to IP and commercial-in-confidence contracts, which hinders data sharing between organisations and the general public. Developers are cautious in making data publicly available because it can get 'twisted' or misinterpreted depending on who is doing the analysis.

Most data and information from existing monitoring programs in the Mackay region is not easily accessible by the general public, which causes perception problems about the actual impacts of development in general.

The public needs transparent and coordinated access to monitoring reporting as a way of understanding what the issues really are and their magnitude. This is important in dealing with issues related to multiple and inconsistent approval processes, public perception and misconception, and cumulative impacts.

Searching for Shipwrecks by NOAA National Ocean Service
Source: <https://flic.kr/p/7d0XCm>

WHAT CAN WE DO TOGETHER TO STIMULATE BASIC RESEARCH?

■ Undertake more basic research on...

Fish aggregation areas (e.g. king salmon)

Species that are not presently iconic or high profile as these are increasingly targeted and little is known about their biology, distribution and the fisheries' catch and effort. These species may become important in the future (e.g. grunter and abalone in WA).

Stocking of marine species and evaluate the role of existing stocking contributions to catch.

Spawning size of the grunter species as they are heavily targeted in North QLD.

■ Facilitate a process where local input could be obtained to influence research priorities of the QLD Fisheries Research Advisory Board (FRAB), which needs to consider local views

Write up submissions for next FRAB call, which incorporates local views from Mackay, focusing on the following legislation changes:

- Revisit bag and size limits.
- Tackle illegal fishing.
- Increase the recreational fishery use fund (RUF) to enforce good rules (e.g. enforcement of legislation against illegal fishing activities).
- Increase value of fines for illegal fishing so as to create a disincentive to fish illegally.

■ Promote flexibility in management to incorporate regional changes in permits, legislation, and zoning for trawling

Move the existing seagrass closure within Hillsborough channel to a nearby site as the seagrass bed has relocated.

Provide input to reviews that affect the local community to promote the importance of local engagement and regional management in fisheries.

■ Fund research to support decisions about how to allocate resources to different sectors and how to realistically apply it

INVESTMENT IN BASIC RESEARCH

Predicted population growth in Mackay and associated expansion of fish markets (more people buying fish) could threaten fishery resources and sustainability. More coordinated basic research is therefore needed to increase fishery sustainability, but this is particularly challenging because current funding for research is small, highly competitive, and focuses mainly on iconic and high profile species. Basic research on non-iconic species is also important because these may become important in the future.

Barriere Reef by Originalwanna, based on NASA's Image (ISS007-E-14874) | Source: <http://commons.wikimedia.org/wiki/File:Barriere-Reef.jpg?uselang=en-gb>

WHAT CAN WE DO TOGETHER TO EDUCATE THE COMMUNITY?

■ Promote change in cultural attitude

Emphasise that recreational fishing is about enjoyment through, for example, fishing shows and the Reef Guardian program.

Use regional radio for local stories about enjoyment in recreational fishing and importance of commercial fisheries.

Stimulate the use of bike paths, walkways and alternative modes of transport as ways of reducing traffic and the need to build new bridges and roads.

Promote the Council online system already in place for car-pooling: mackayregioncarpool.com

Develop an education program to change attitudes of society toward littering.

Produce education newsletters and editorials about adequate disposal of litter.

■ Educate public, especially youth, about the need for responsible resource allocation

Provide educational material to students from across different domains (engineering, planning, natural resources management etc) on existing understandings about downstream impacts of management actions and their consequences on natural systems; provide case studies of major failures and successes for discussion.

Start education programs at schools about the importance of seafood and fishing.

Educate fishers and the broader community about the need for different allocation for different fishing sectors as a way of reducing competition for fish resources.

Educate the recreational sector and public about the commercial fishery and the extent of fishing controls already in place.

■ Create education campaigns to reduce accidental deaths of protected species

Use Reef Guardian program to facilitate education campaign focusing on improved fishing practices to minimise accidental deaths of protected species.

Educate population about new technologies to minimise injury/deaths from boat strikes— such as plastic propellers— and develop a funding program to test these.

■ Undertake an education and information program targeted at the local community to explain the activities of the Port and how these are being managed

Provide greater transparency to the community by providing greater access to information and data collected by the Port.

■ Integrated educational and communication campaigns using traditional and social media

COORDINATED EDUCATIONAL CAMPAIGNS

In the Mackay region careless attitudes of some people towards the environment, unnecessary competition between commercial and recreational fishers and unawareness of improved farming practices to reduce runoff have been affecting fisheries resources and sustainability (e.g. buying from black market, excessive fishing pressure and conflicts), and degrading coastal habitats.

Changing behaviour of some Mackay residents, government agencies and industry through educational campaigns supports all management strategies described above and is therefore paramount to reduce conflicts and competition between and within fishing sectors, improve water quality and reduce littering.

Joint Effort by Manu and Roboada

13.2.4 DISCUSSION

In terms of obtaining information as to which of the many methods of obtaining survey respondents, word of mouth was a common way that people in Mackay got to hear about the survey (Figure 70). Other successful methods was using email from various interested parties such as within Council and Ports, and conservation groups – in way very similar word of mouth.

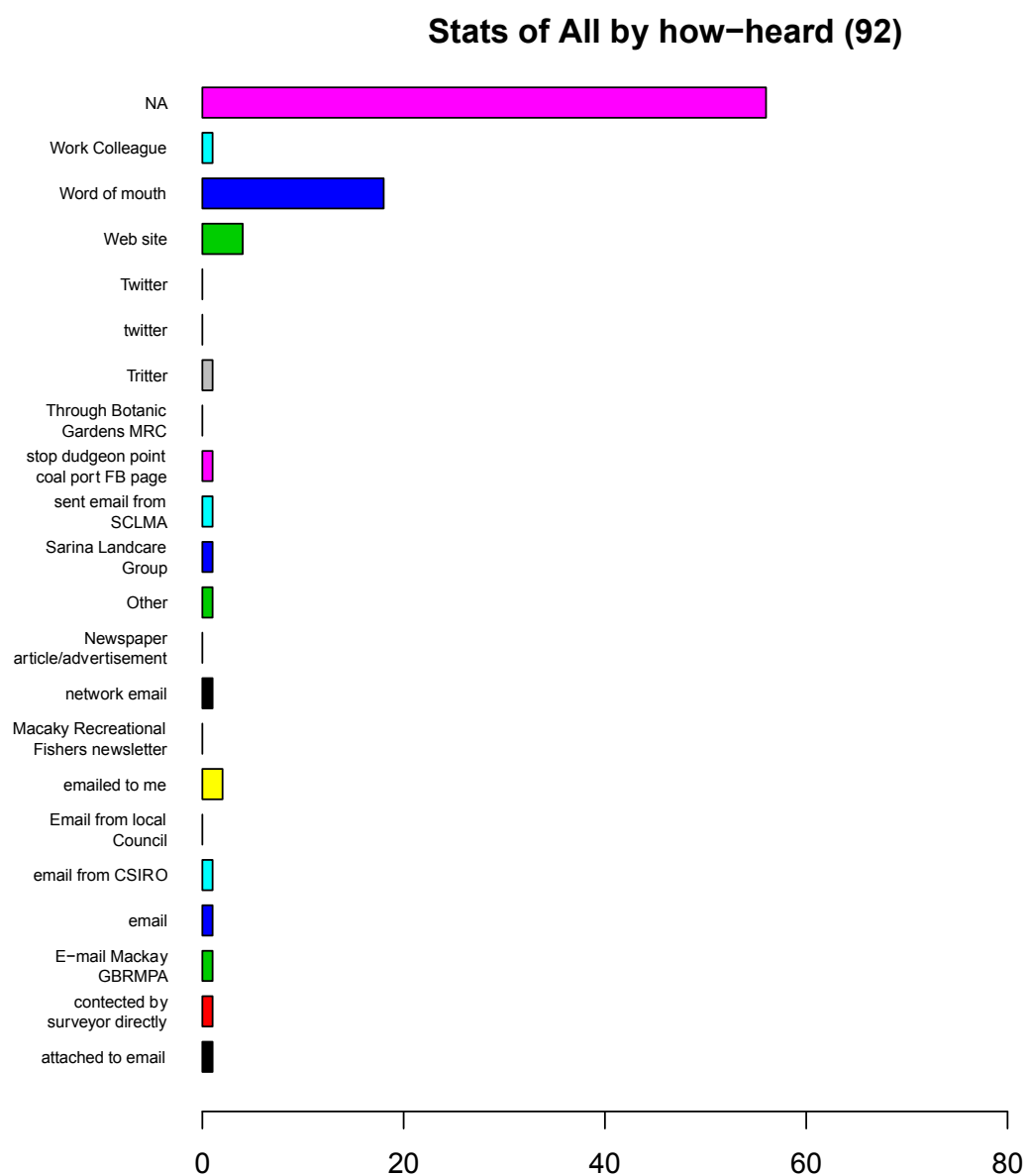
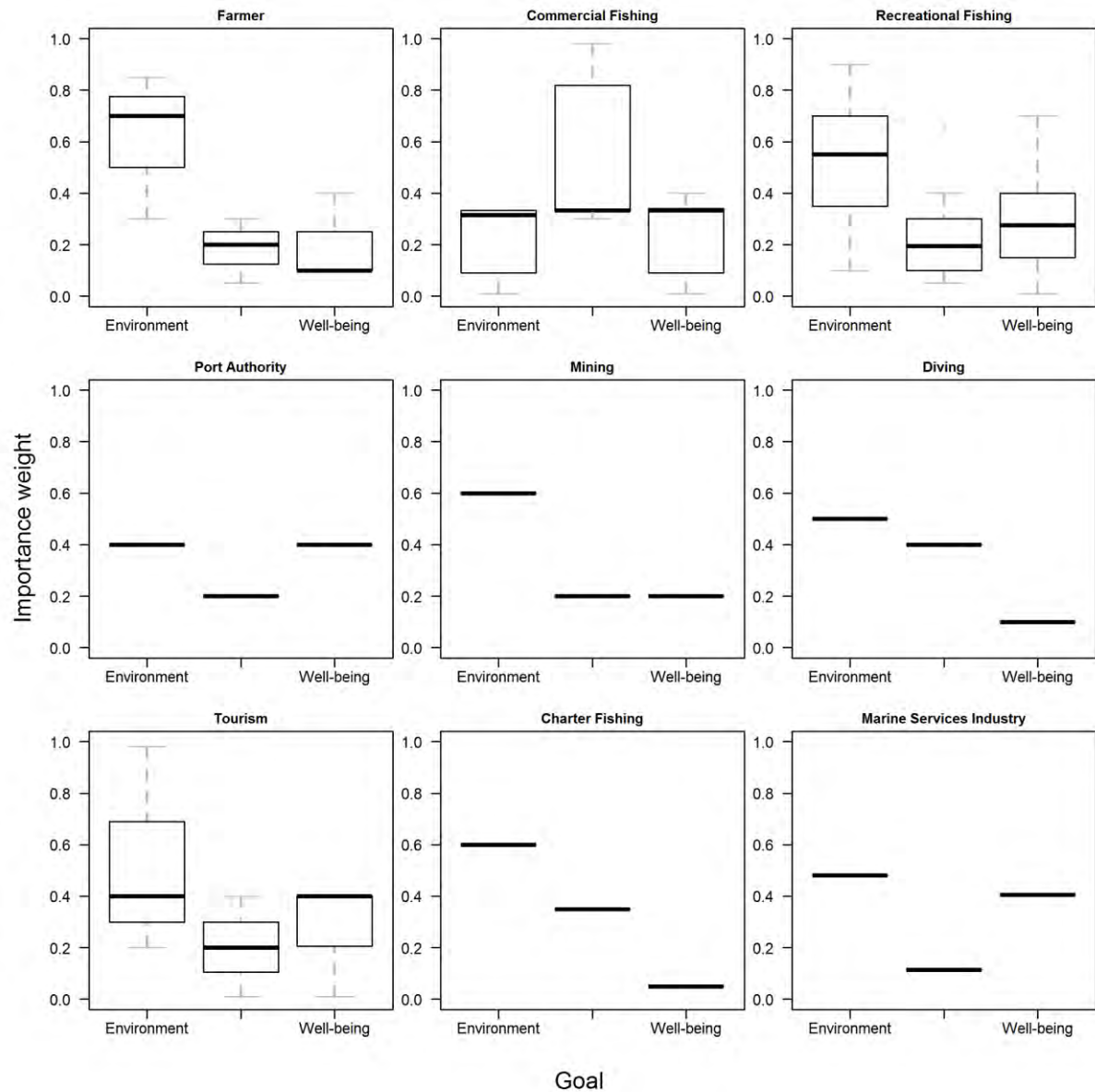


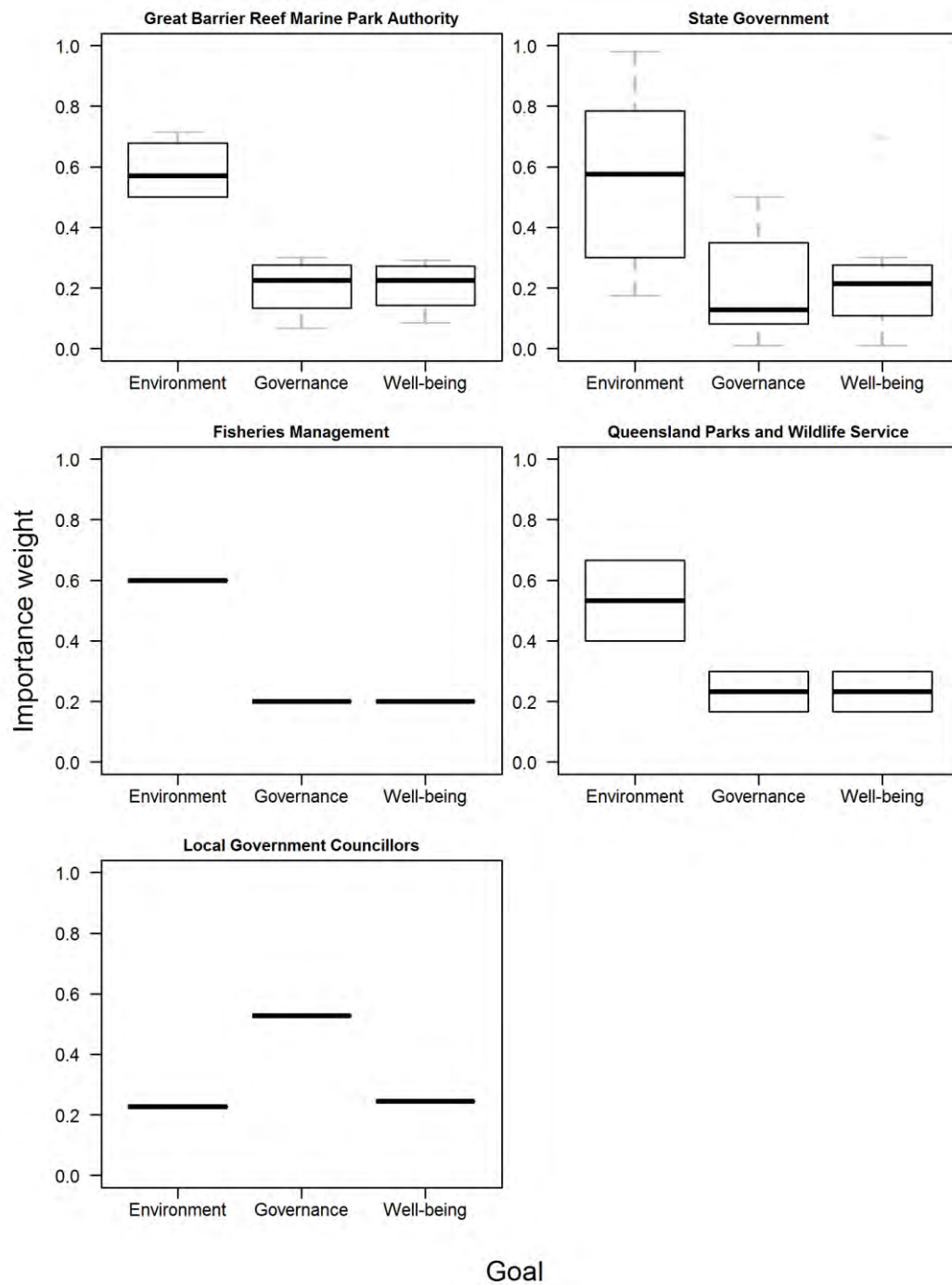
Figure 70. Number of Mackay respondents in the objective weightings survey with respect to how they heard about the survey.

14Appendix A: Relative weights of goals per individual stakeholder groups.

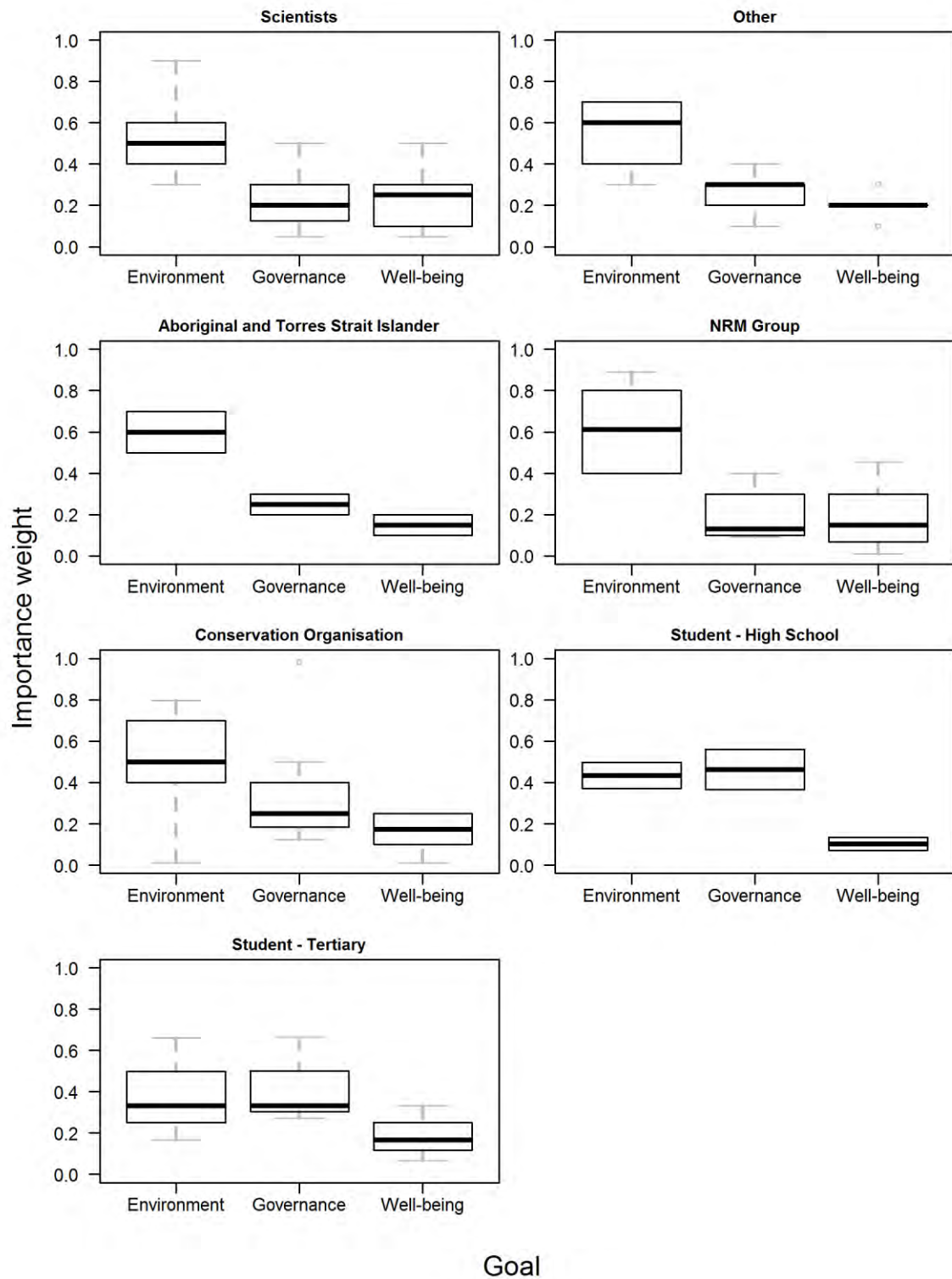
1. Resource Users



2. Government



3. Other



15Appendix B: Supplementary material of Mackay process

15.1 LMAC RG Membership

Table S.1: Membership (without names) of the Mackay Reference Group RG. Those in bold were regular members; others were invited members with few or no attendances

Position/Affiliation
Conservation Volunteers; LMAC member
Great Barrier Reef Marine Park Authority; LMAC member
Councillor Mackay City Council; LMAC chair
Queensland Department of Agriculture, Fisheries and Forestry
Recreation in inshore and offshore; cane farmer; LMAC member
Queensland Department of Agriculture, Fisheries and Forestry
Mackay Turtle Watch Association; LMAC member
Sustainability Officer - Mackay City Council (left Council)
Canegrowers Mackay; LMAC member
Farmer; cattleman; LMAC member
Great Barrier Reef Marine Park Authority
Great Barrier Reef Marine Park Authority
Reef Catchments; LMAC member
Queensland Bulk Ports environmental officer; LMAC member
Retired; Previously - state management roles; recreational fisher; LMAC member
Environmental officer - Mackay City Council
Commercial fisher; Seafood distributor; LMAC member
Great Barrier Reef Marine Park Authority
Queensland Department of National Parks, Recreation, Sport and Racing
Indigenous representative (resigned membership)
Agronomist; LMAC member (recently deceased)
Aquarium trade commercial fisher

15.2 Supplementary methods

Table S.2: Example impact assessment scoring sheet for managers' workshop against high-level goals for some of the management strategies

Objectives	Address littering through education, legislation and operating procedures	Develop and implement weed and pest management plans for regions	Education - best development practices	Education - farm best practices	Education - fishery campaign	Education - improving governance	Improve compliance	Improve governance through better planning, assessment and regulation	Legislation changes of allocation and sustainability of fishery issues	Management for dugong
1.1.1 Reduce direct impacts of infrastructure and development										
1.1.2 Minimise human induced changes in water flow regimes										
1.2.1 Ensure Reef Plan water quality targets are met										
1.2.2 Increase feral animal control and environmental friendly weed control strategies										
1.2.3 Reduce influx of pollutants										
1.3.1 Sustainable human use of marine resources										
1.3.2 Maintain habitat function and structure										
1.3.3 Reduce impacts on Threatened, Endangered, Protected (TEP) species										
2.1.1 Remove regulatory barriers to flexibility (alternative harvesting techniques, zoning, diversification in the economy)										
2.1.2 Increase compliance with environmental and resource use regulations										
2.2.1 Increase management acceptability										
2.2.2 Increase stakeholder engagement and community ownership/stewardship										
2.2.3 Sustainable financial costs										
2.3.1 Increase policy integration										

2.3.2 Increase regulatory integration										
2.3.3 Increase implementation integration										
3.1.1 Improve regional economic development and industry diversity										
3.1.2 Improve family livelihoods in the region										
3.1.3 Ensure that natural resource based industries are profitable and sustainable										
3.2.1 Minimise conflicts between stakeholders										
3.2.2 Conserve traditional activities and cultures										
3.2.3 Ensure community equity										
3.3.1 Improve workplace and family health and safety in the region										
3.3.2 Improve education, training, social infrastructure and networks										

Scale	-3: Considerably worse than current situation	-2: Moderately worse than current situation	-1: Slightly worse than current situation	0: Same as current situation	1: Slightly better than current situation	2: Moderately better than current situation	3: Considerably better than current situation
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Confidence score (1-5)	1: Very unsure	2: Fairly uncertain	3: Moderately certain	4: Fairly certain	5: Certain		
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Table S.3: Impact assessment scoring sheet for managers' workshop against high-level goals

Management Strategies	Ecological	Governance	Social	Economic
1. Address littering through education, legislation and operating procedures				
2. Develop and implement weed and pest management plans for regions				
3. Education - best development practices				
4. Education – on farm best practices				
5. Education - fishery campaign				
6. Education - improving governance				
7. Improve compliance by obtaining local stakeholder input				
8. Improve resource management through better planning, assessment and regulation				
9. Legislation changes to allocation and sustainability of fishery issues				
10. Management for protected species				
11. Reduce impacts of dredging				
12. Support, facilitate and coordinate basic research				
13. Transparent (to public) and coordinated monitoring reporting				
Confidence (score 1-5)				

Scale	-3: Considerably worse than current situation	-2: Moderately worse than current situation	-1: Slightly worse than current situation	0: Same as current situation	1: Slightly better than current situation	2: Moderately better than current situation	3: Considerably better than current situation
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Confidence score (1-5)	1: Very unsure	2: Fairly uncertain	3: Moderately certain	4: Fairly certain	5: Certain
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15.3 Supplementary results

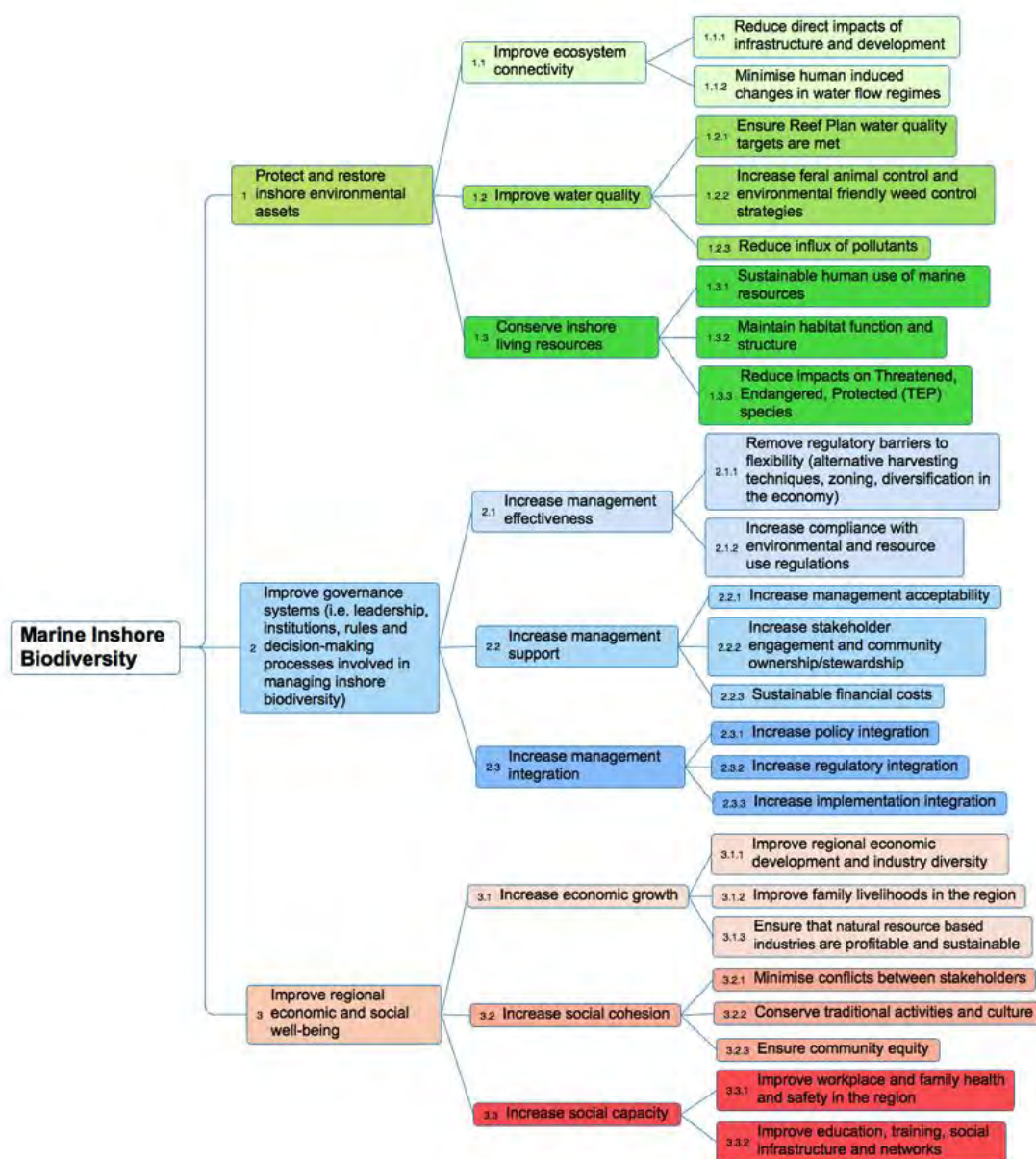


Fig S.1: Objective hierarchy for inshore biodiversity management in the Mackay region, based on input from the Mackay Reference Group and LM AC.

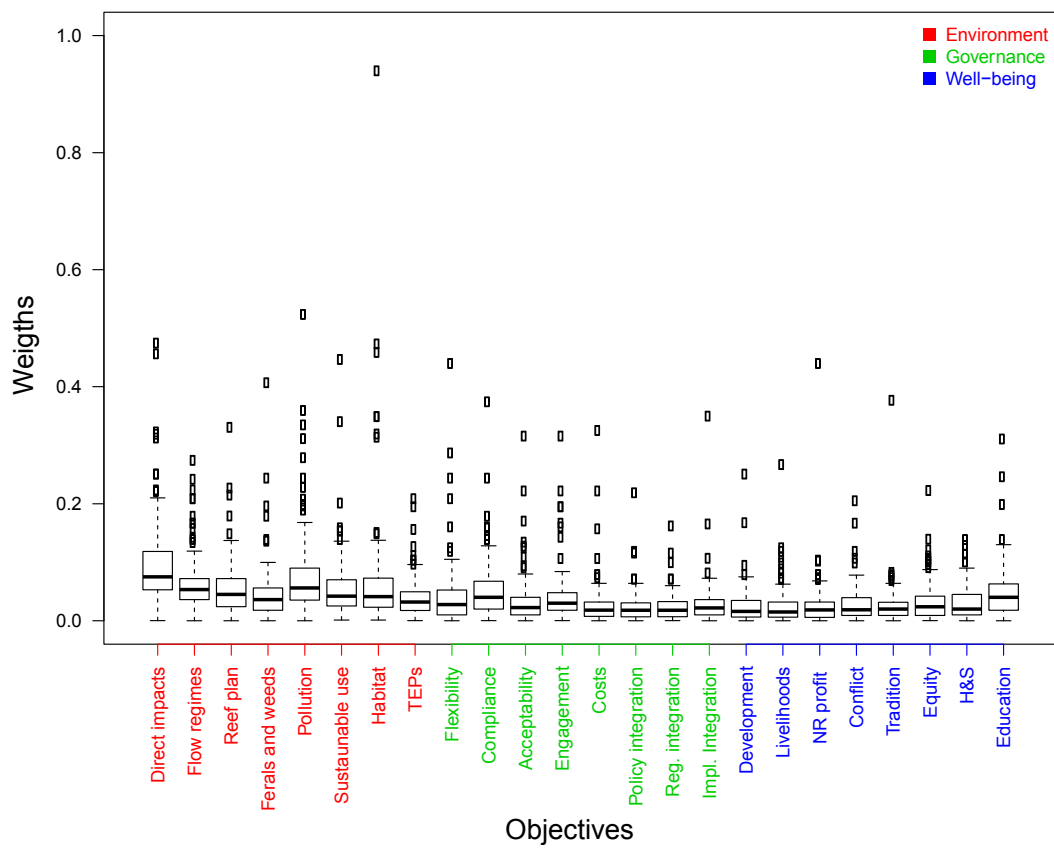


Fig S.2: Box and whisker plot of the objective weighting results from all respondents.

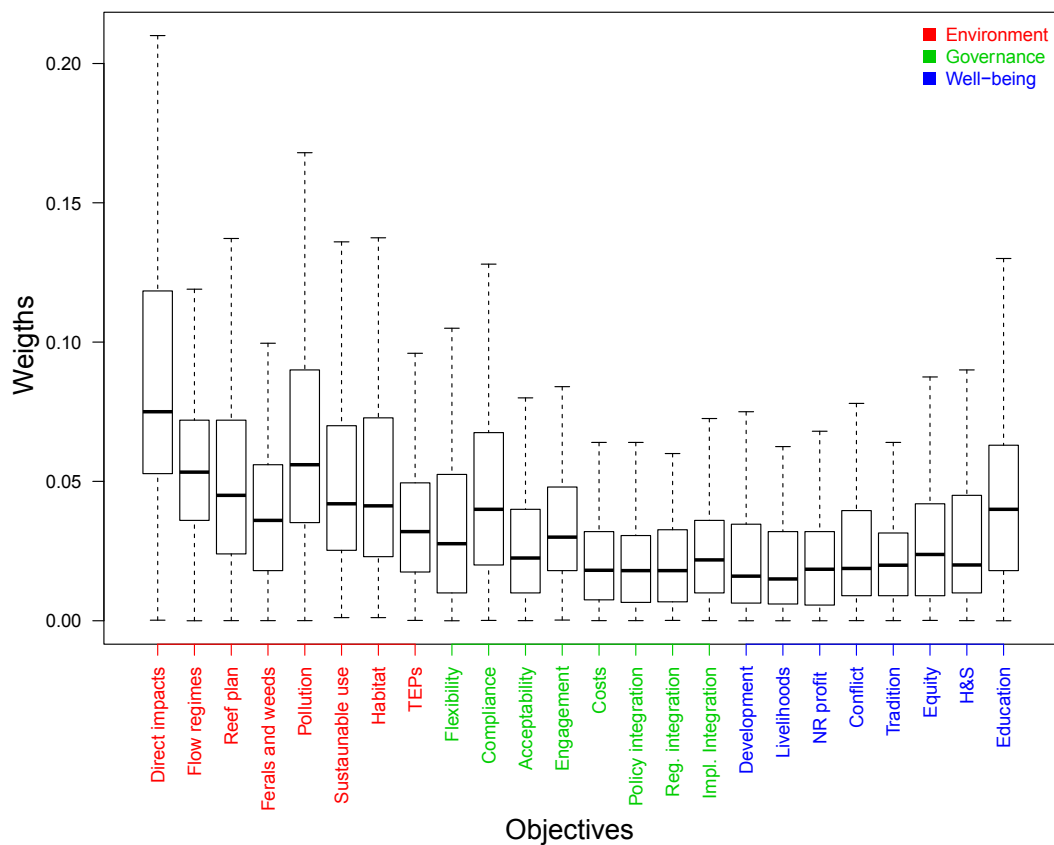


Fig S.3: Box and whisker plot of objective weighting from all respondents but without the extreme value outside the whisker shown, for clarity

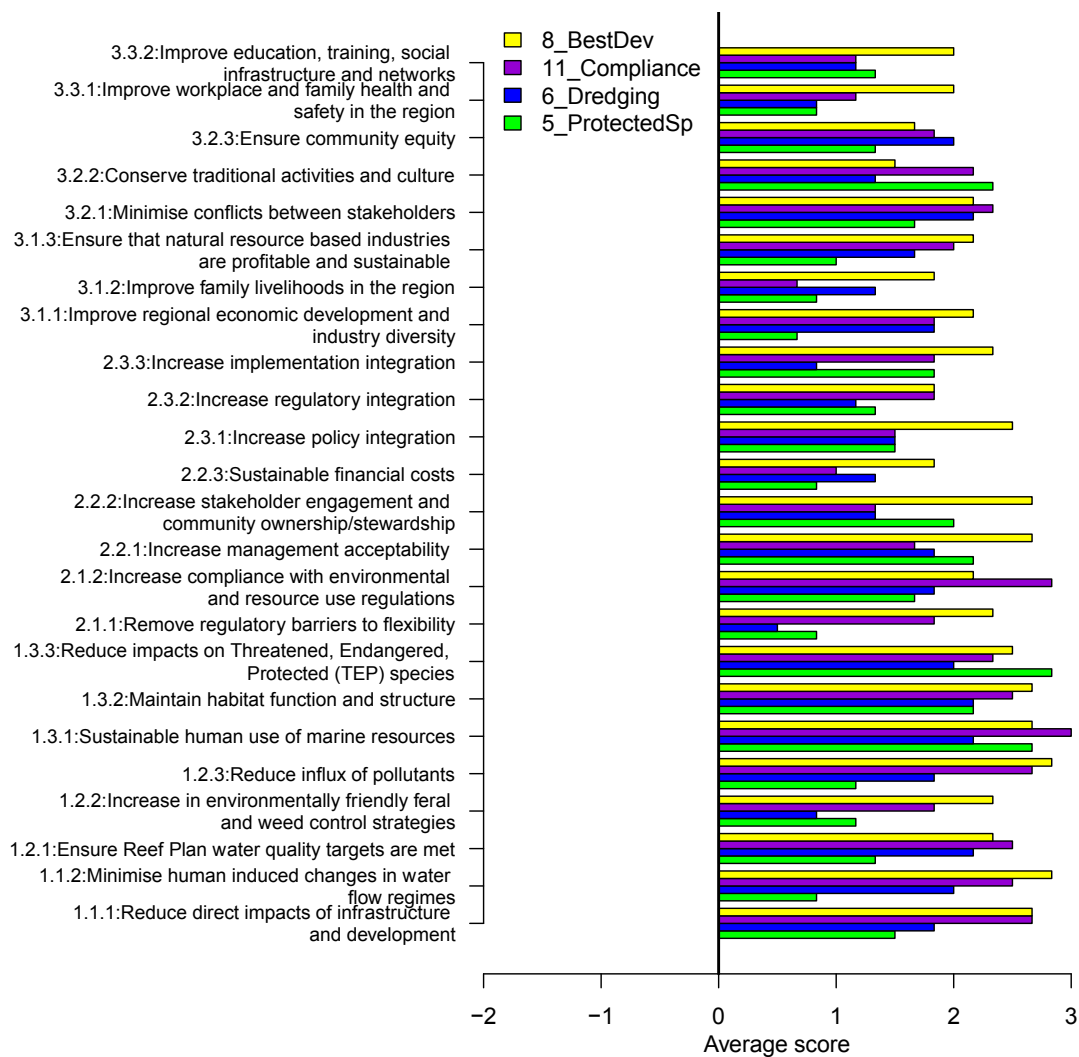


Fig S.5: Average impact score by the RG at objective level for the top two most important and the worst rated management strategies.

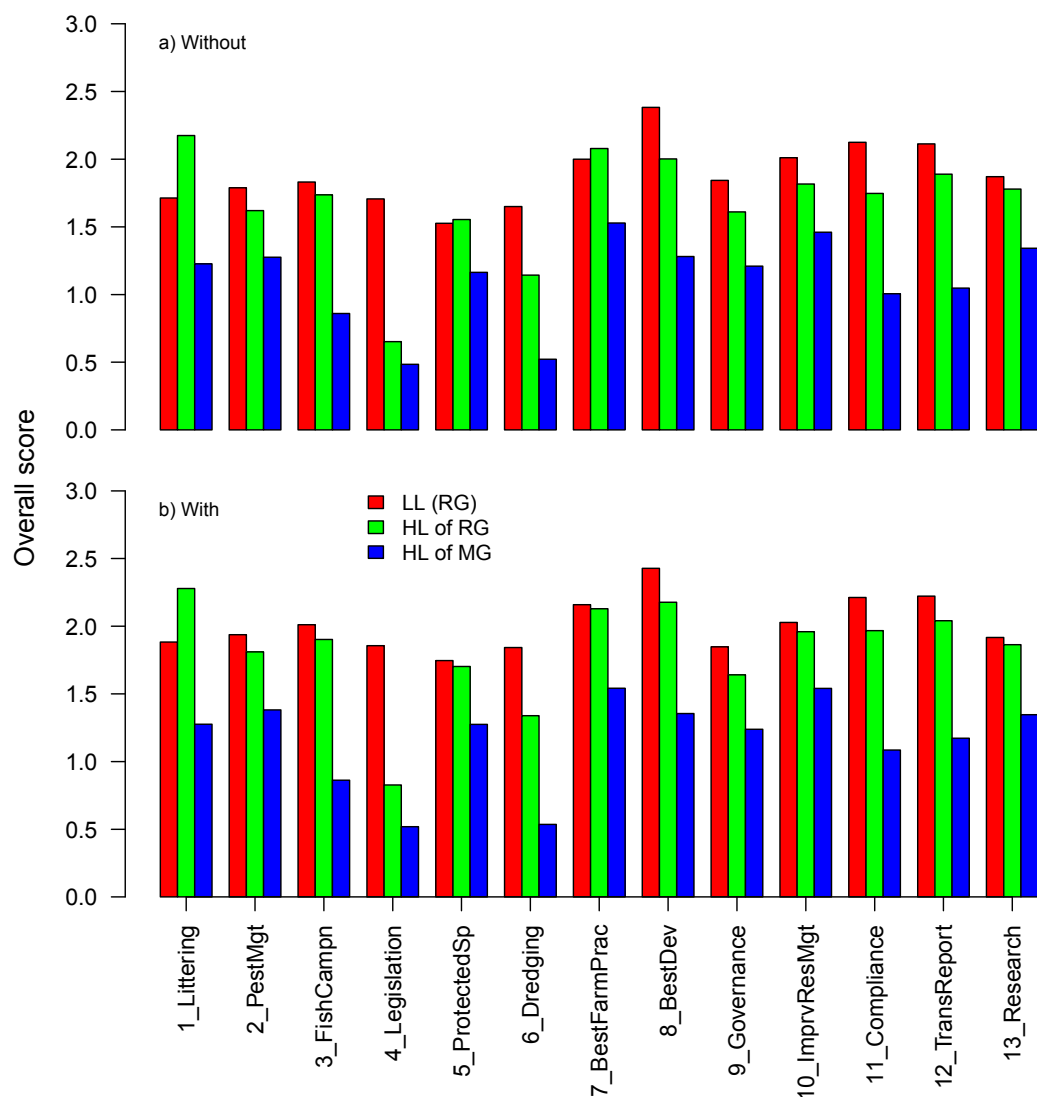


Fig. S.6: Average impact assessment scores (-3 to +3) without considering Confidence scores (top) and with confidence scores (bottom) formed from i) the scores undertaken at the objective level (LL) prior to the management workshop by the RG, ii) the RG scores undertaken at the goal level (HL) at the management meeting, iii) HL scores of the managers at the management meeting.

16 Appendix C: Generic survey from generic objectives

Your details

Name:

Email:

Please choose the group that you mostly associate with by checking (✓) the appropriate stakeholder group

Stakeholder groups	Please tick ✓ only one
e.g. Commercial Fishing	
Other	

Please indicate the region where you are located

Region	Please tick ✓ only one
E.g. Mackay	
Other	

High Level Objectives

Please indicate the relative importance of three different high level objectives. The total score should be equal to 100.

Objective		100 points	Explanation of objective
1	Maintain and improve environmental assets		Overarching environmental objective for the region
2	Improve management effectiveness to ensure long term sustainable resource use and availability		Improve leadership, institutions, rules and decision-making processes involving government, citizens, public associations, private businesses, and non-governmental organisation, for the management of ins hore biodiversity and its uses
3	Improve regional economic and social well-being now and into the future		Improve the long-term well-being of the region's people by promoting economic growth, increasing social cohesion and increasing social capital
		TOTAL 100	

Maintain and improve environmental assets

Please indicate the relative importance of three different objectives for protecting environmental assets. The total score should be equal to 100.

Objective		100 points	Explanation of objective
1.1	Improve biodiversity		Improve connectivity between catchment, fresh- and salt-water habitats and reduce impacts
1.2	Conserve coastal living resources and their use		Ensure long-term conservation of the ins hore living resources and their support systems
1.3	Improve water quality and ensure adequate water quantity		Reduce sediment and nutrient runoff into waterways and reefs and efficient water use.
		100	

Objective		100 points	Explanation of objective
1.1.1			
1.1.2			
1.1.3			
		100	

Objective		100 points	Explanation of objective
1.2.1			
1.2.2			
1.2.3			
		100	

Objective		100 points	Explanation of objective
1.3.1			
1.3.2			
1.3.3			
		100	

Improve management effectiveness

Please indicate the relative importance of three different objectives for improving governance systems. The total score should be equal to 100.

Objective		100 points	Explanation of objective
2.1	Encourage and improve community participation and create co-management solutions		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	Implement and increase flexible and pro-active approach to natural resource management		Increase the effectiveness of management systems by removing barriers to flexibility
2.3	Increase support for management solutions and increase the effectiveness of management integration		Improve integration of management in policy, regulation & implementation, at Local, State & Commonwealth levels
		100	

Objective		100 points	Explanation of objective
2.1.1			
2.1.2			
2.1.3			
		100	

Objective		100 points	Explanation of objective
2.2.1			
2.2.2			
2.2.3			
		100	

Objective		100 points	Explanation of objective
2.3.1			
2.3.2			
2.3.3			
		100	

Improve regional well-being

Please indicate the relative importance of three different objectives for improving regional well-being. The total score should be equal to 100.

Objective		100 points	Explanation of objective
3.1	Promote sustainable growth of industry sectors and create local employment		Promotion of regional economic development, including natural resource based industries, to maintain / improve family livelihoods
3.2	Increase social capacity and sense of ownership		Increase social capacity to act, through health improvement and investment in social capital development
3.3	Increase equity and improve access		Increase regional community cohesion through minimising conflicts between stakeholders, conserving traditional activities & cultures and ensuring equitable access to inshore areas and resources
		100	

Objective		100 points	Explanation of objective
3.1.1			
3.1.2			
3.1.3			
		100	

Objective		100 points	Explanation of objective
3.2.1			
3.2.2			
3.2.3			
		100	

Objective		100 points	Explanation of objective
3.3.1			
3.3.2			
3.3.3			
		100	

17 Appendix D: Analytical Hierarchical Process (AHP) versus Hierarchical point allocation (HPA)

17.1 Introduction

AHP (119) is based up on the construction of a series of pairwise comparison matrices, which compare goals, sub-goals and objectives to one another. The Hierarchical Point Allocation method (HPA) (108, 115) uses a combination of the Point Allocation (PA) (124, 125) method and AHP. The AHP is a pairwise comparison of all combinations at each level of the objective hierarchy. In order to ensure that the responses conform to basic logic (e.g. if $A > B$ and $A > C$ then C can not be greater than A), a test for this is required. If the respondents are inconsistent by more than 10% they have to change their score until this value was less than 10%. This conforms to the AHP method.

17.2 Method

The AHP method was first tested on a group of scientists in Brisbane. The code was simplified in terms of its look and feel, and was seen as optimal. The RG were asked to undertake the AHP survey.

To obtain the relative importance scores (weighting scores) of the objectives from the Mackay community, the AHP method was used in the early part of the objective weighting survey where a 3-day in person session was held at Mercy College, Mackay. This was to allow the team to get direct feedback from the respondents on how well they understood the survey and whether the use of a computer based system (the AHP was undertaken in Excel™) was a problem.

1. During the first night, the team found that there was strong negative reaction from the respondents about the survey method. The main issue was that the respondents felt the AHP method was manipulating them into providing a result by design rather than using their own original score. Some left the survey incomplete whereas others completed it but felt the score did not reflect their views. The team helped the latter group by enabling them to understand how to achieve their wanted score and remain consistent.
2. A second issue was that the Excel™ platform was perceived as tedious and long-winded. The team also found that the macros did not work on all Excel™ platforms particularly on Apple™ machines.
3. In all cases, the survey took more than 30 minutes, which was reasonable given the size of the hierarchy. However this was still seen as a big commitment.

It should be noted that there were also some respondents that found the survey reasonably easy to us.

The next day the team decided to change the method altogether. Although the PA method is well known, it does have another issues if there are many objectives i.e. that of repeatability (124, 125). Since there were 24 objectives, it was clear that the PA method applied to this survey would likely suffer from lack of repeatability, which means the scores were more reflective of opinions of the person for that moment.

A new method was developed that was a combination of the AHP and PA – called Hierarchical Point Allocation. It uses the PA allocation method (here we used 100 points) but these are applied to each part of the hierarchy rather than only at the objectives level. Mathematically this is analysed exactly the same as the AHP except for the very first step where the comparison scores are turned into a proportion.

A paper version and a web version of HPA were introduced the next few days with great success in terms of respondent's happiness with their scores, their time commitment (about 10 minutes) and the ease of the technology. People were asked whether they would volunteer to also undertake the AHP survey straight afterward. Most understood the mathematical similarity and could transcribe their HPA scores directly into the AHP. This meant they were always consistent. Due to this turn around in the method being widely accepted, all surveys thereafter were this method and technology. This means that the majority of importance surveys were conducted by using this method. To test the second method the RG was asked to complete the HPA paper survey.

This means that in the Mackay region, some respondents did AHP or HPA only and others did both (either directly after each other or with a month gap in the case of the RG), which allowed for in-depth analysis of the two methods. Furthermore, in order to investigate the factors of influence on the survey results and provide more experimental design into the process, extra surveys were conducted internally by a small group of people from CSIRO. Some staff always undertook the AHP before the HPA; whereas others did it the other way. They did not know which sequence they would get before hand. In addition, to test for temporal consistency some staff repeated the same method on the same survey over took.

To be able to compare the results of the two methods, all survey results were collated regardless of the methods used. Each of the survey was scrutinized to identify its respondent, date/time and method used to pair up the groups in three sequences: 1) AHP first and then HPA ("AHP2HPA") next but with a time gap of a few days to a few weeks; 2) HPA first and then AHP immediately thereafter ("HPA2AHP"); 3) AHP to HPA ("AHP2HPA") immediately thereafter.

The following analyses were conducted:

- 1) Boxplot of the importance weighting scores for objectives/ goals in pairs of two methods for each group - looking the patterns similarity;
- 2) Score differences – vertical plots for objectives between the methods for each group – looking at what the differences related to the groups.
- 3) Cumulative score differences for the goals and objectives – looking at the differences related to the groups and sequences of the objectives.
- 4) Variance analysis for all objectives per people by groups – looking at the all the scores variances of the two methods from each participant
- 5) Objective analysis of part of the hierarchy where there was one pairwise comparison i.e. two branches – looking at variances and cumulative score differences
- 6) Three-branch objectives analysis – focus on the objectives which have a three branch structure. Looking at variances and cumulative score differences

- 7) Multiple surveys both with AHP and HPA on single people – looking at the factor of time/date influences
- 8) Multiple surveys with HPA on two people at different time – looking at the factor of time and people influences.

17.3 Results

17.3.1 IMPORTANCE WEIGHTING SCORES.

Figure 71, Figure 72 and Figure 73 show the box-plots of the importance scores for the objectives, whereas group HPA2iAHP exhibits least deviation between AHP. Figure 74, Figure 75, Figure 76 show the box-plots of the importance scores for the goals. These figures show quite consistent results in terms of trends from the weighting scores.

17.3.2 IMPORTANCE WEIGHTING SCORE DIFFERENCES BETWEEN THE TWO METHODS

Three group's results for lower level objectives are illustrated in Figure 77. It demonstrates that HPA2iAHP has fewer differences, which suggests that HPA would be helpful to guide people doing AHP survey without feeling manipulated. Other groups' results show large differences between scores showing that there are contradictory opinions of the same objectives depending on method used. This is most likely because of the difficulties in balancing the scores when doing AHP.

It is possible that sequence of the objectives also could contribute to the differences. The cumulative differences curves for objectives are steep in the beginning and tend to stabilise towards the end of the survey for most of the participants (Figure 78). This might be due to the participants' learning to balance the AHP over time (and therefore objective). However the curves (Figure 79) show that there are fewer differences for the group HPA2iAHP and bigger deviations on the "Governance" and "Well-being" for the other two groups.

17.3.3 VARIANCE ANALYSIS CONDUCTED TO LOOK AT THE SCORES GIVEN BY PARTICIPANTS

The variance in this case represents the range of the scores of objectives for each of participants. Big variance could be due to the participant's extreme opinions on different objectives and also may come from the influence of the different survey platforms. Figure 80 shows the variances of the important scores of all objectives from two survey methods for each of participants. In most cases, the variances from the AHP method are consistently higher than those from the HPA. It suggests that the higher variances may be influenced by the AHP method. Interestingly to see, in the group AHP2iHPA, all variances are lower than other groups. It might be because these group people are mostly scientist and they are more familiar with the methods and therefore less diversified on the opinions to the objectives.

To test whether undertaking the more simpler pairwise comparison in the AHP (which will always be consistent) scores similar to the HPA, a comparison of two-branch and three-branch scores were made. Figure 81 shows the variances of the importance

scores of the two-branch lower level objectives. Most notable are that the values from group of AHP2iHPA almost always have the AHP positive. The cumulative two-branch objective score difference curves (Figure 82) also indicate there are big differences in the group of AHP2iHPA. These results suggest that the AHP is also influential on the scores for two-branch objectives.

Figure 83 shows the variances of importance scores of the three-branch objectives. The variances from AHP look consistently similar to that of the HPA for most participants (with a few of exceptions) and the variances in the group of AHP2iHPA are mostly lower than that from other groups. The cumulative three-branch objective score difference curves (Figure 84) exhibits very similar trends as that for all objectives (Figure 78).

17.3.4 TIME FACTOR INFLUENCES ON THE SCORE.

To test whether time was influential on the scores, Figure 85 shows the results from a suite of surveys on single project member at different time using the different methods. The plots compare the differences between each survey objective score and the mean values of all the surveys within the same methods. Generally, the differences are reasonably small considering the time interval being a day, a week and some more than a month. For HPA method it shows almost perfect consistency whereas AHP drifted over time especially at the beginnings of the objectives. It could be due to the unfamiliarity of AHP platform at start of the use of this method but may also be due to being unclear of the respondent's opinions at the start and these becoming more consolidated with time.

Two people from the project team participated in a series of multiple surveys using the HPA method. In Figure 86, the scientist on the right hand side exhibited a small degree of deviation from mean value of the multiple surveys for the objectives, which suggests the opinions changing following time line, but due to the small degree of differences the results may not be conclusive. On the left panel, the person shows a very consistent and persistent opinion. In general the differences are not considered significant.

17.4 Conclusions

1. It is easier and quicker to fill the survey questionnaire of HPA;
2. There was higher stakeholder trust of the HPA results and balancing the AHP means many people feel they are being manipulated;
3. Technology is easier for HPA whether scoring on paper or using the web form, whereas the AHP required a bit more computer skills especially if balancing is required;
4. No consistent bias in the difference of score irrespective of method or objective;
5. There are consistently bigger score variances for AHP method, which indicate the AHP methods consistently making people fill a bigger range of the scores;
6. Some individuals have different outcomes (even at the goal level) in terms of priorities but there is a smaller difference between the two methods in the outcomes if people do the HPA first;
7. There was no significant influence on the importance weighting scores for either method due whether there were time gaps of a day or weeks among

the multiple surveys experiment; however, the HPA method results exhibit more stable properties than that of the AHP, and the HPA method would be helpful to guide AHP survey.

8. Two-branch objectives comparisons suggest the different scores of the AHP and the PHA was quite similar as no balancing was required for the AHP irrespective of the sequence of methods (AHP2HPA or HPA2AHP). On the other hand, the three-branch objective scoring was much easier with the HPA and resulted in bigger variances with the AHP method. Although variance increases, the relative weighting pattern is not affected as the three-branch results exhibited a similar pattern as that from all the objectives. It should be noted that most of the hierarchy consisted of three branches (18 out of 24) in this case study; and
9. The HPA is a good replacement and for the hierarchy we tested was superior to the AHP. The HPA only is therefore recommended as it is mathematically the same as the AHP, is more accepted, and easier and quicker to undertake).

17.5 Figures

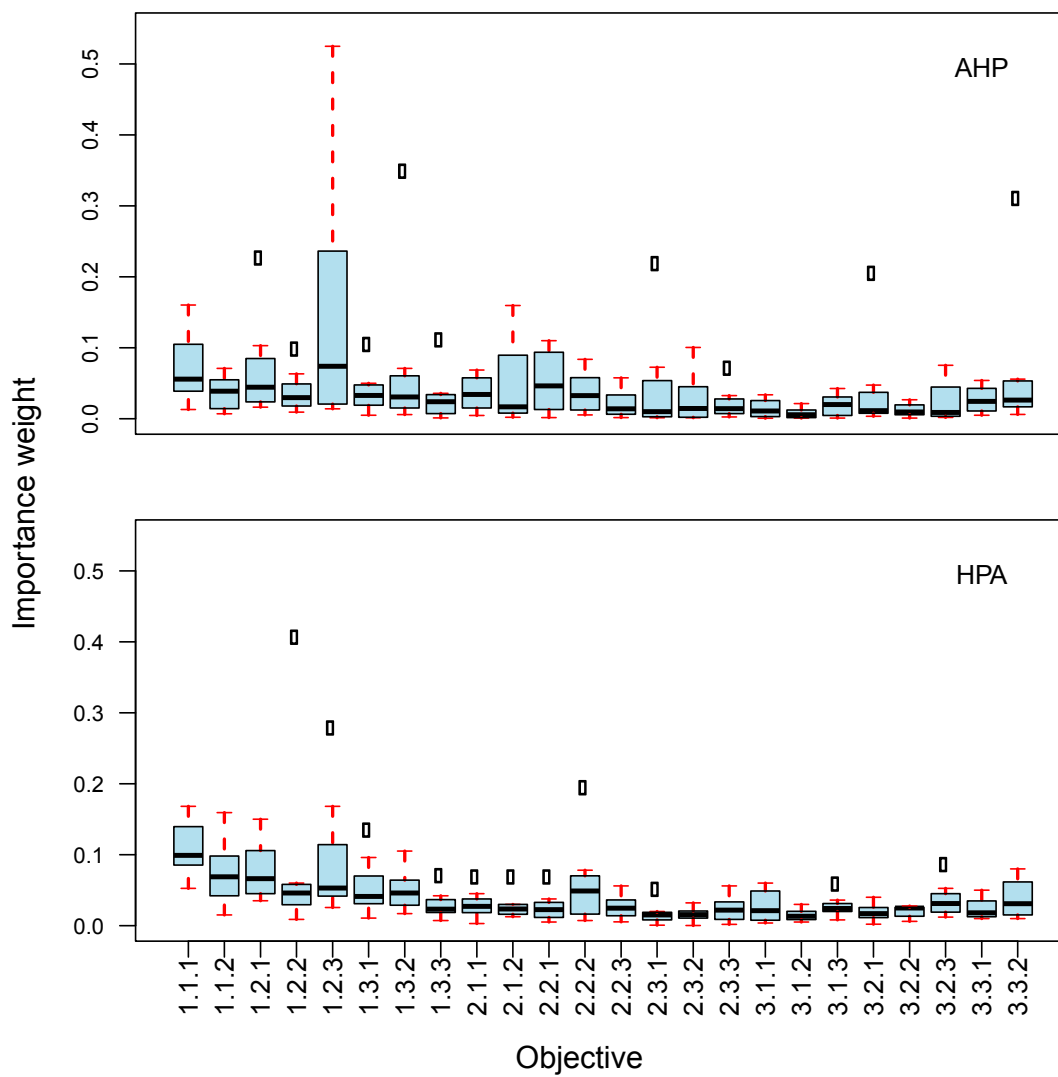


Figure 71: Boxplot of objective importance weighting scores AHP2HPA

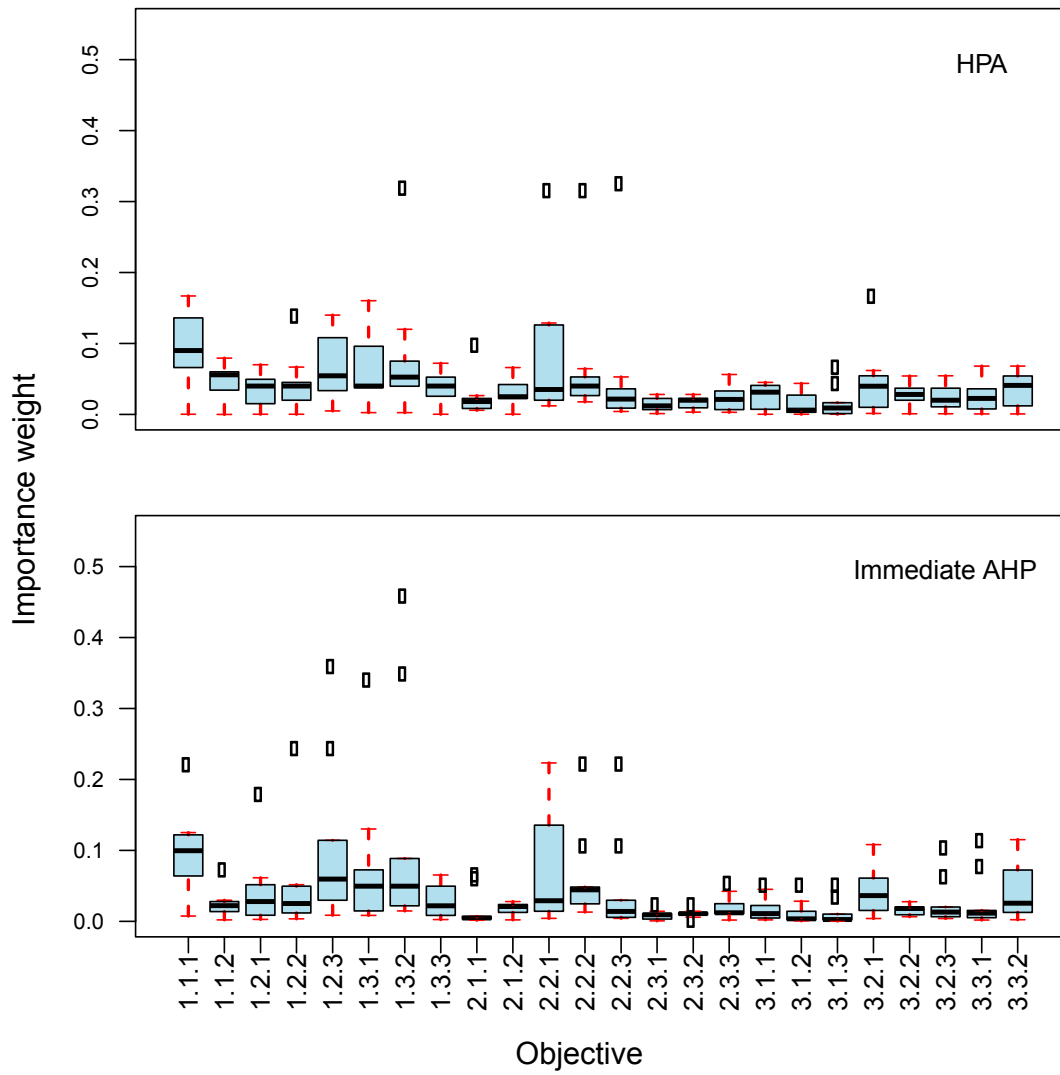


Figure 72: Boxplot of objective importance weighting scores HPA2iAHP

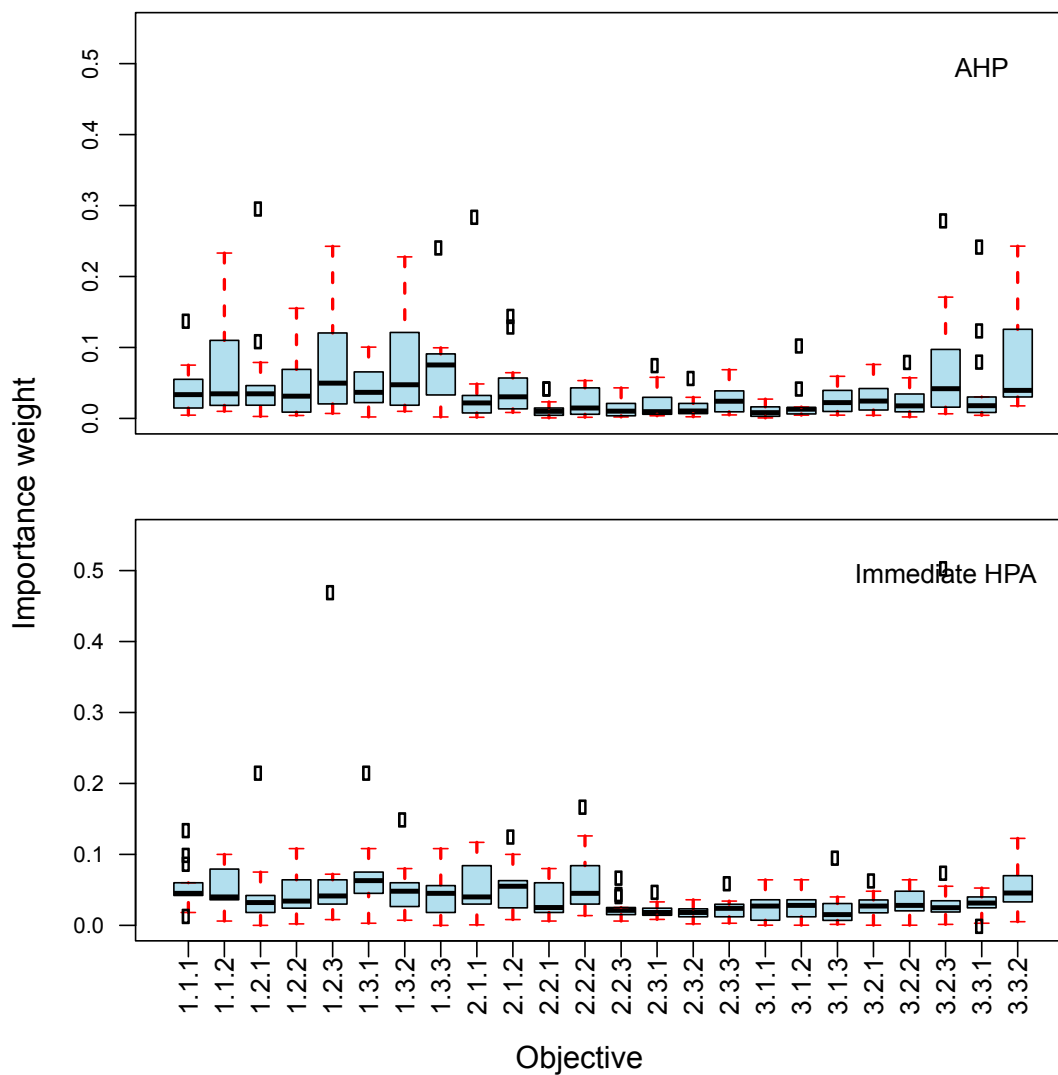


Figure 73: Boxplot of objective importance weighting scores AHP2iHPA

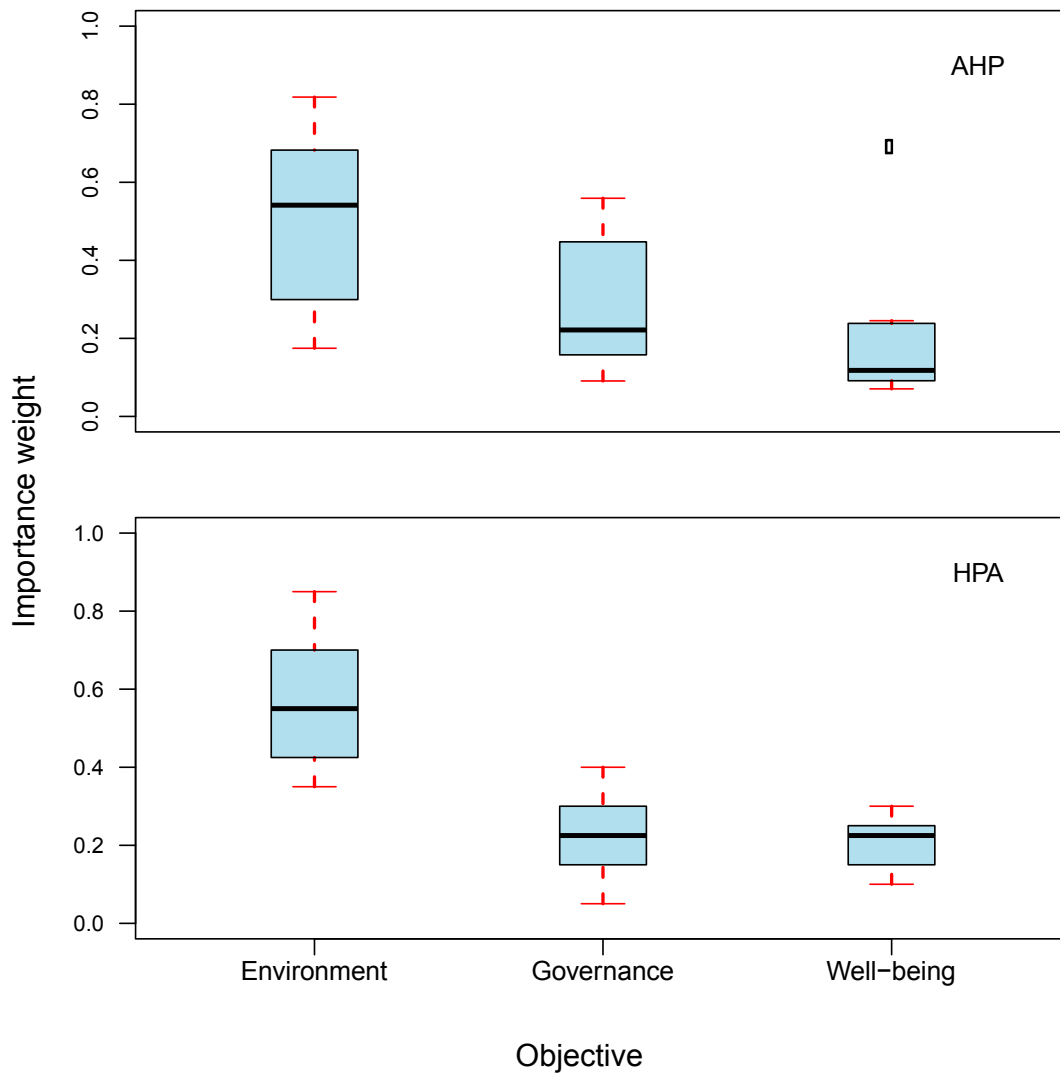


Figure 74:Boxplot of goals importance weighting scores AHP2HPA

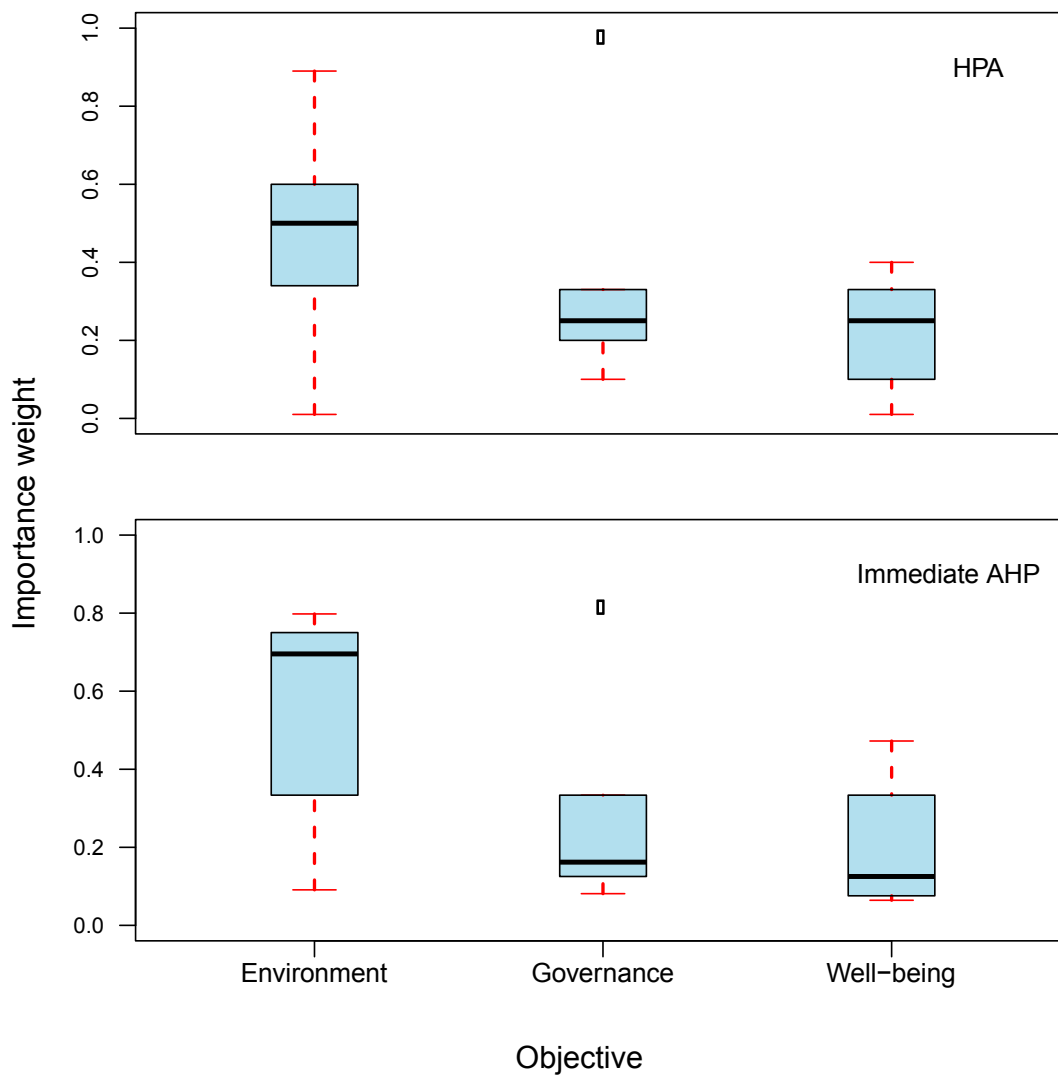


Figure 75: Boxplot of goals importance weighting scores HPA2iAHP

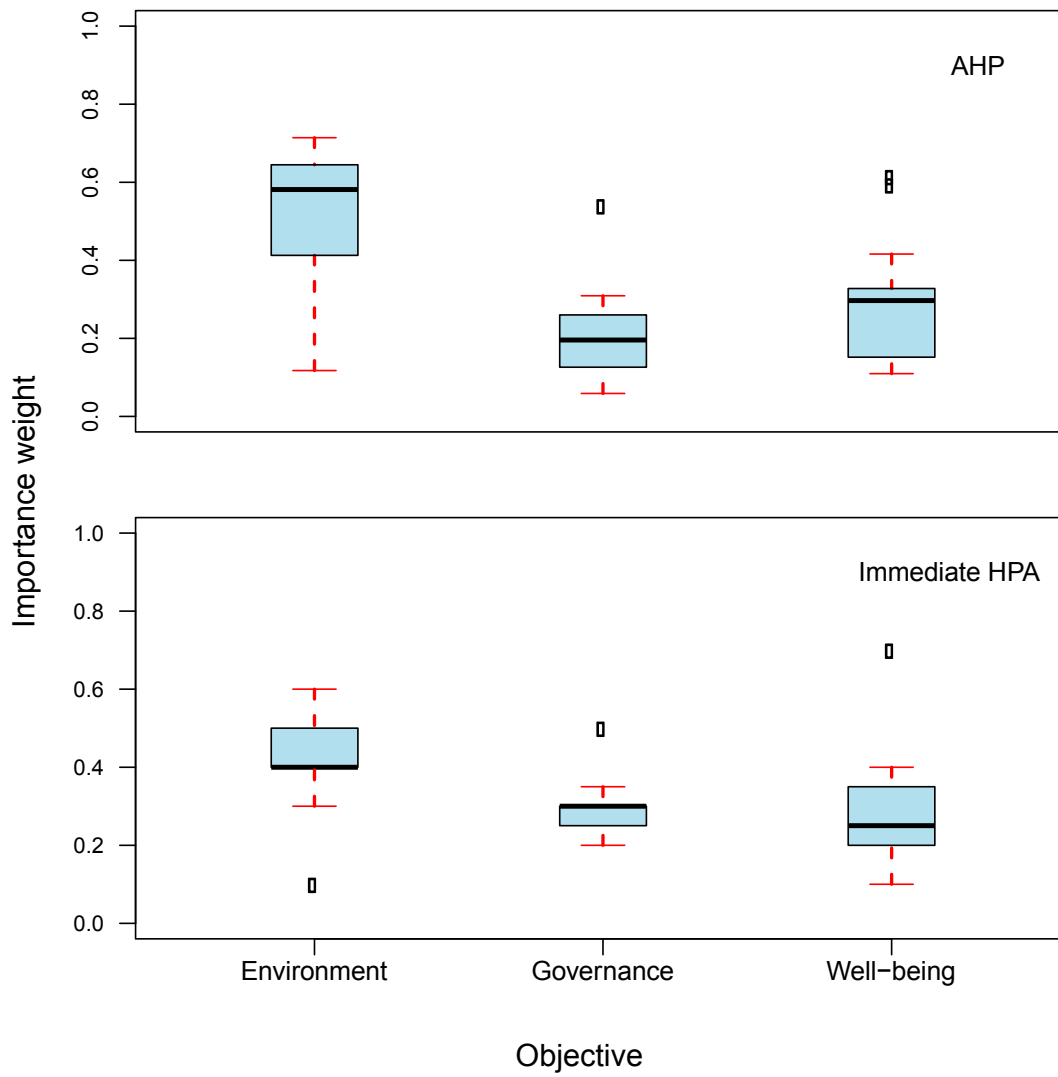


Figure 76: Boxplot of goals importance weighting scores AHP2iHPA

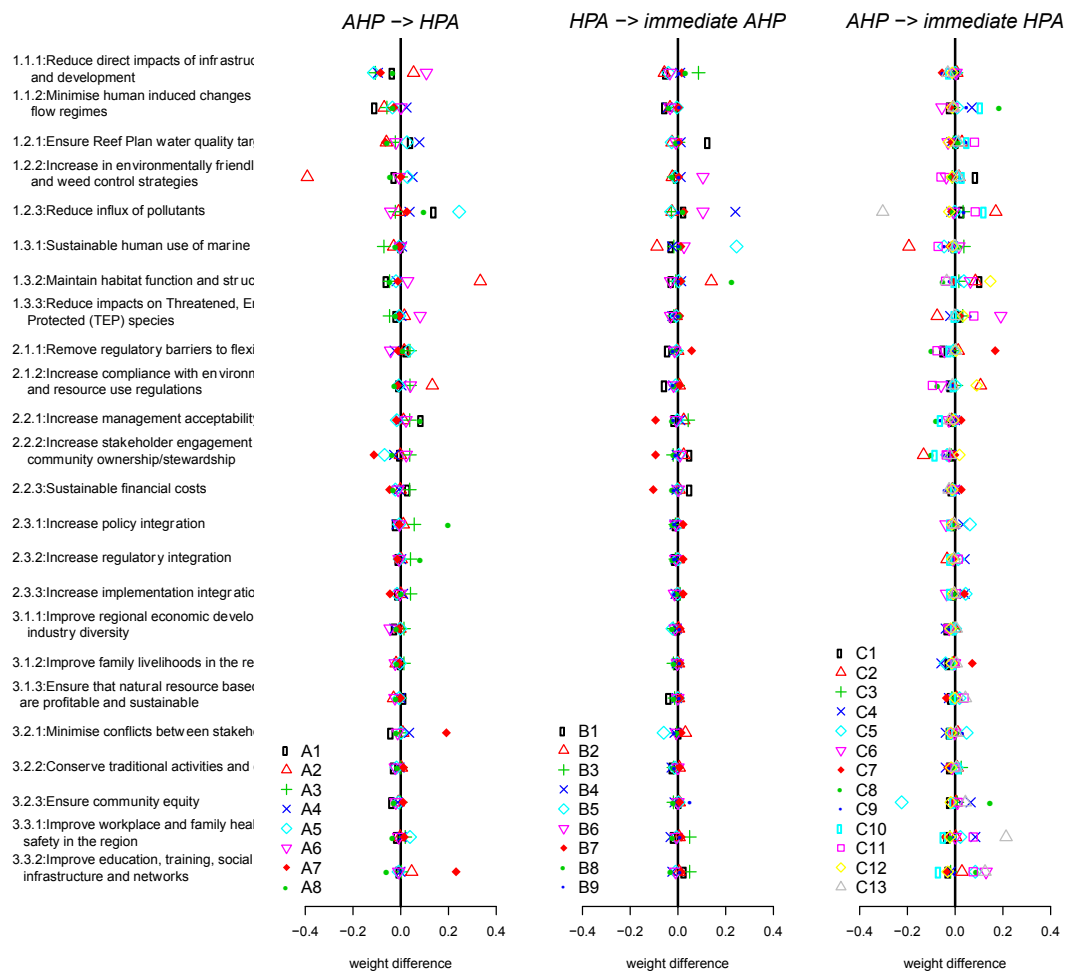


Figure 77: Objective importance weighting score differences ($W_{ahp} - W_{hpa}$) between the survey pairs of 1) AHP2HPA; 2) HPA2iAHP and 3) AHP2iHPA

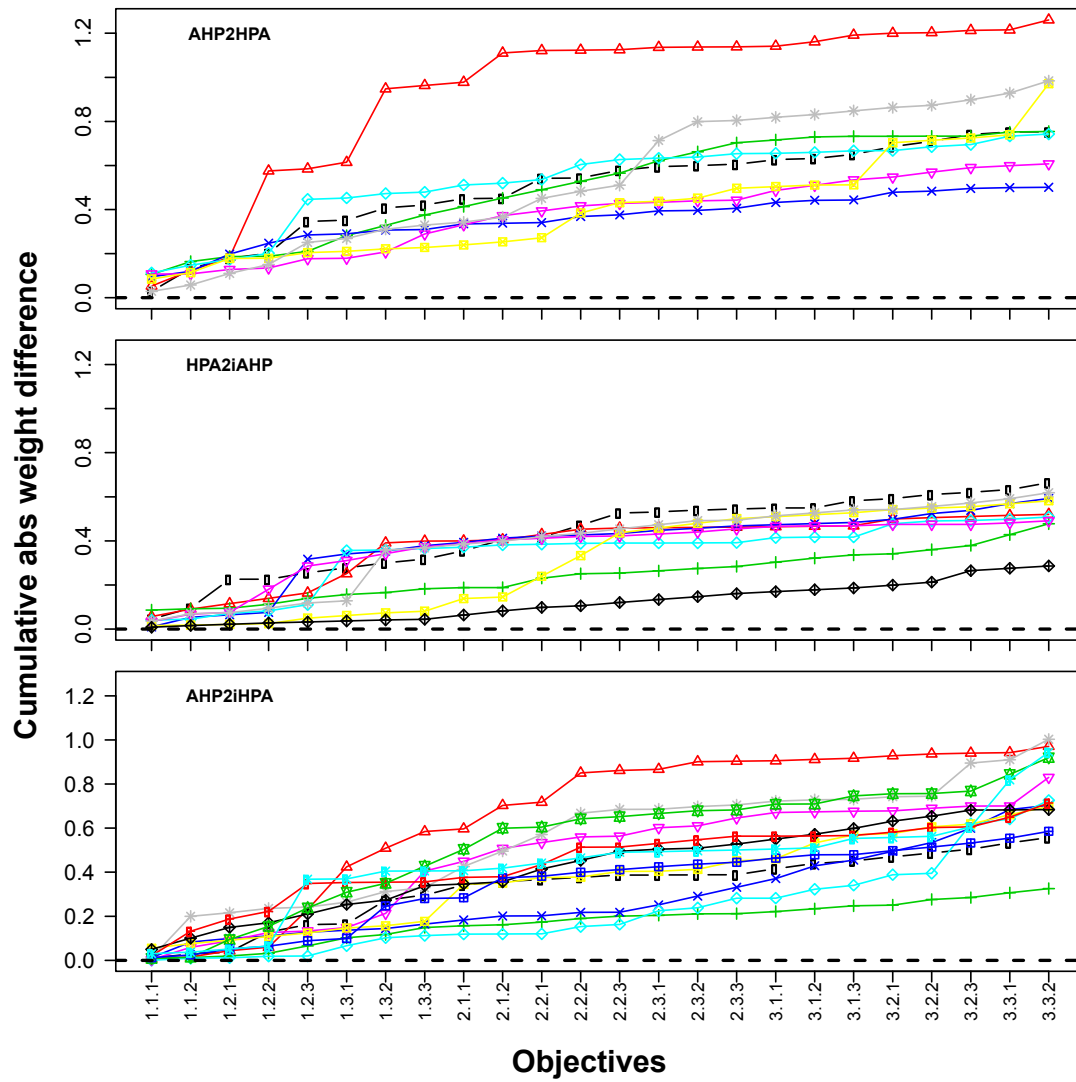


Figure 78: Objective cumulative absolute importance weighting score differences between the survey pairs of 1) AHP2HPA; 2) HPA2iAHP and 3) AHP2iHPA. Colors represent the respondents.

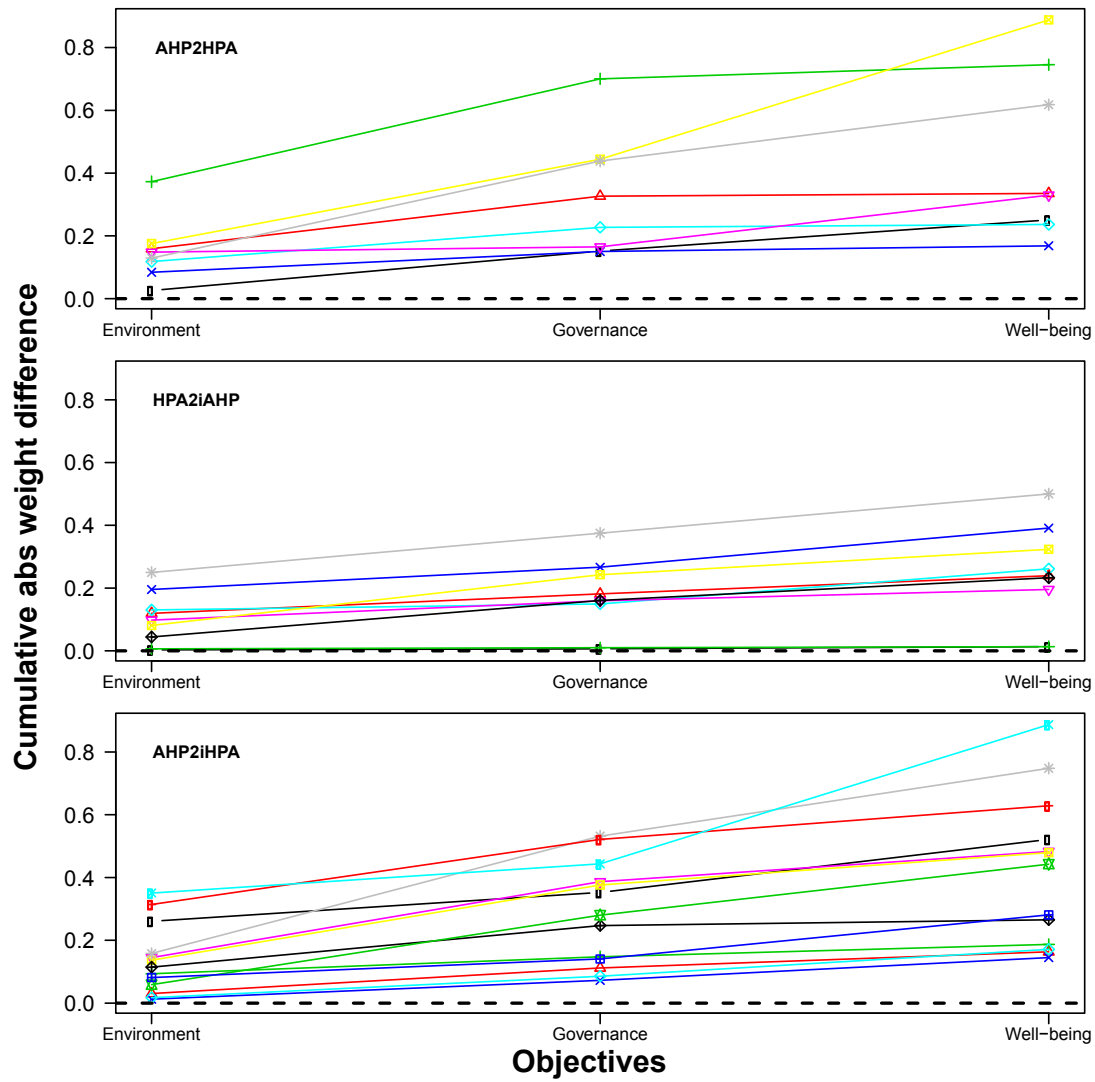


Figure 79: Goal cumulative absolute importance weighting score differences between the survey pairs of 1) AHP2HPA; 2) HPA2iAHP and 3) AHP2i HPA. Colors represent each respondent.

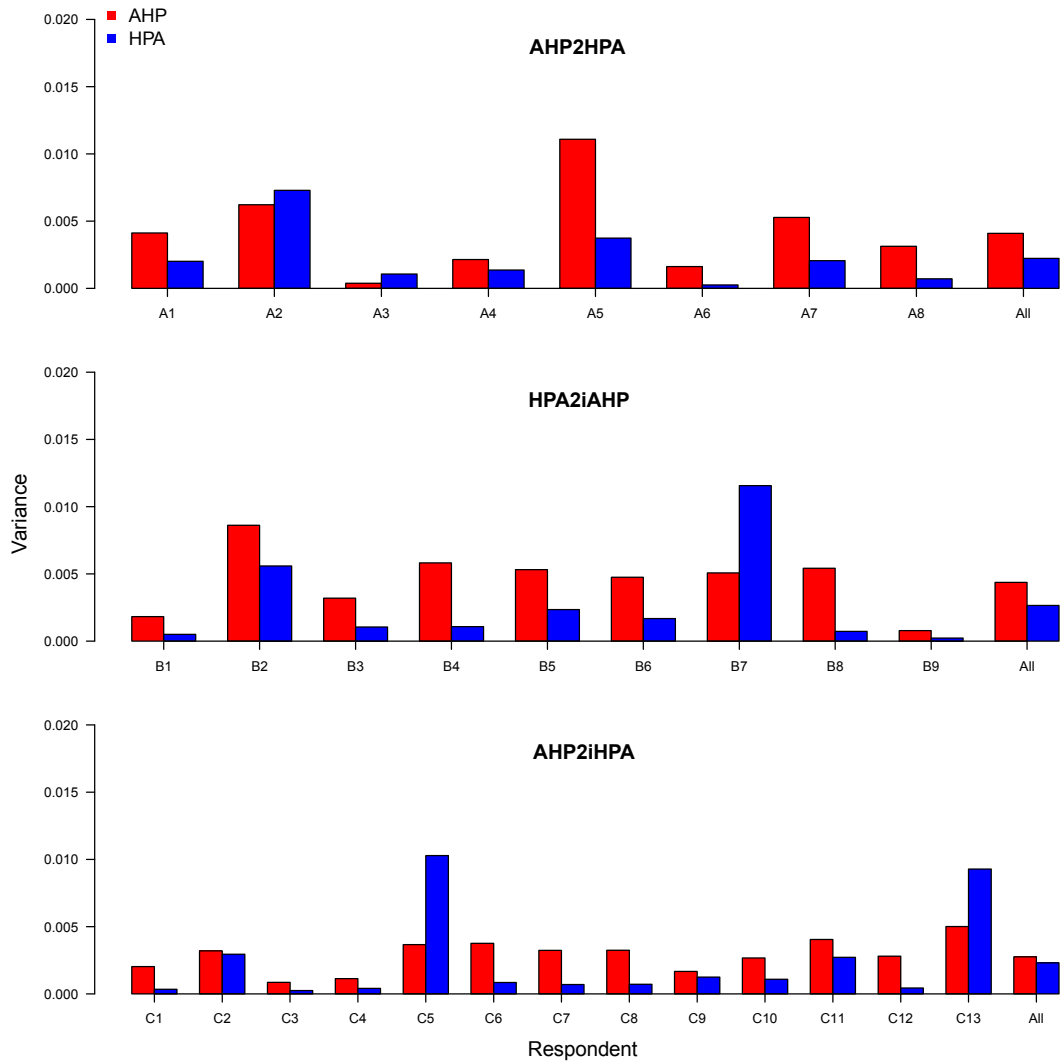


Figure 80: Variances of all objectives importance weighting score against each respondents for the survey pairs of 1) AHP2HPA; 2) HPA2iAHP and 3) AHP2iHPA.

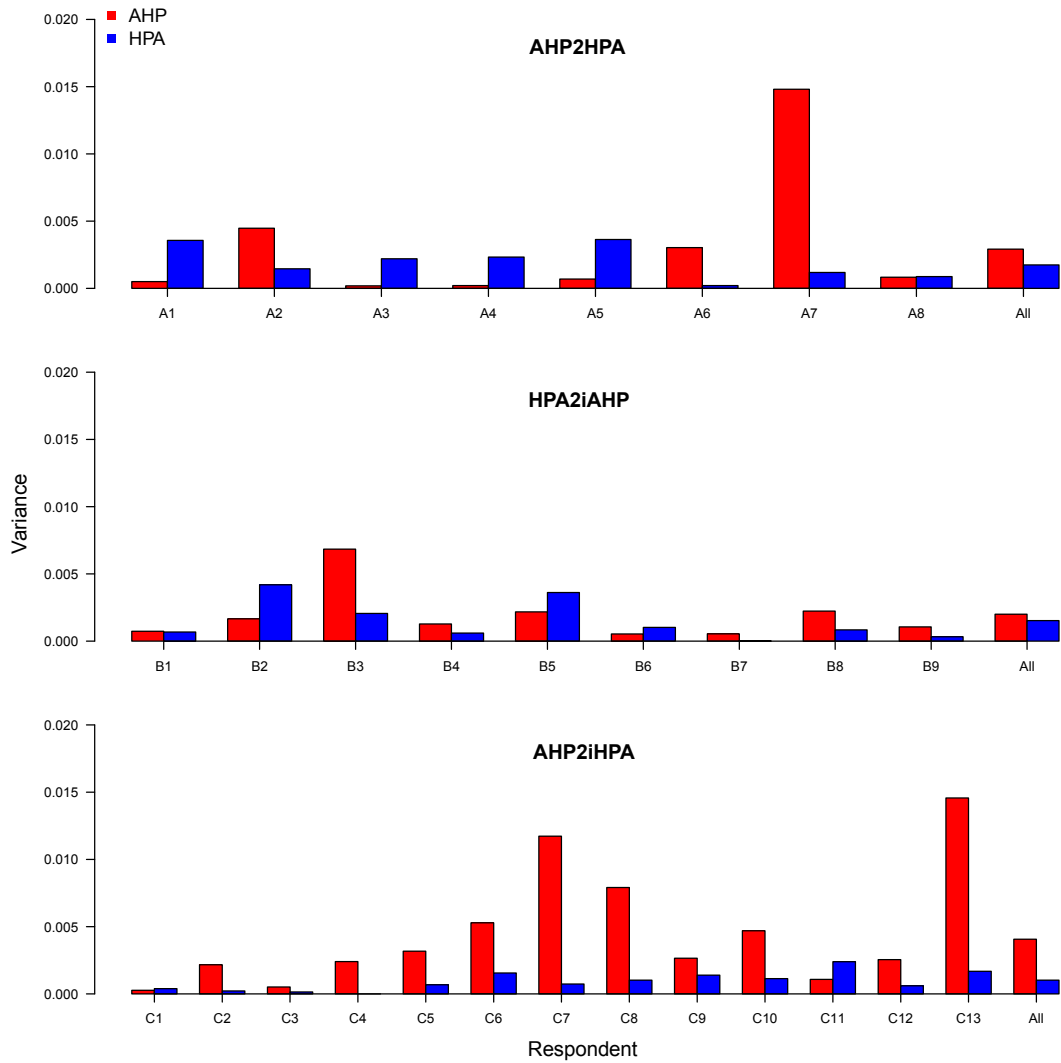


Figure 81: Variances of two-branch objective importance weighting score against each respondent for the survey pairs of 1) AHP2HPA; 2) HPA2iAHP and 3) AHP2iHPA.

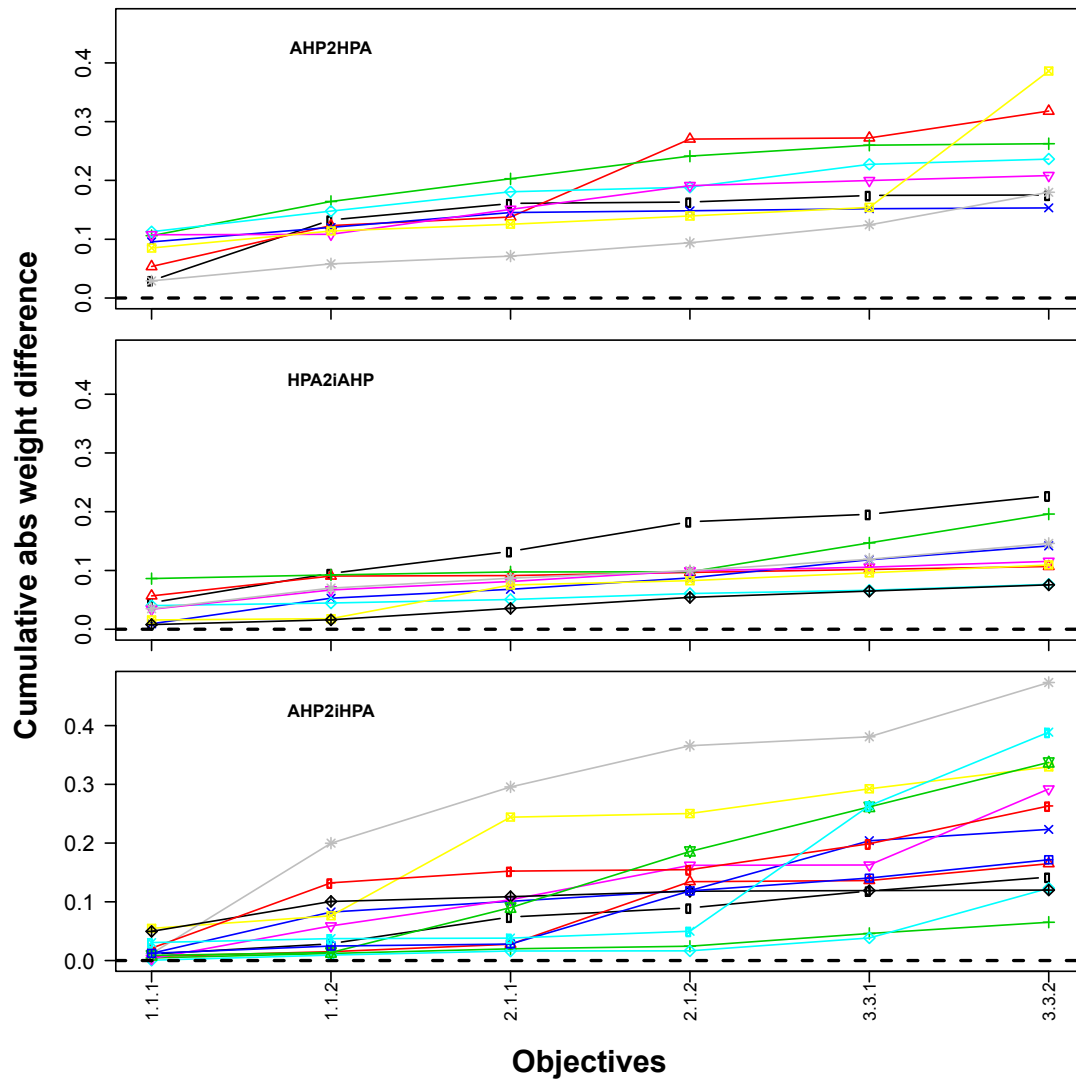


Figure 82: Cumulative two-branch objectives importance weighting score differences between the survey pairs of 1) AHP2HPA; 2) HPA2iAHP and 3) AHP2iHPA.

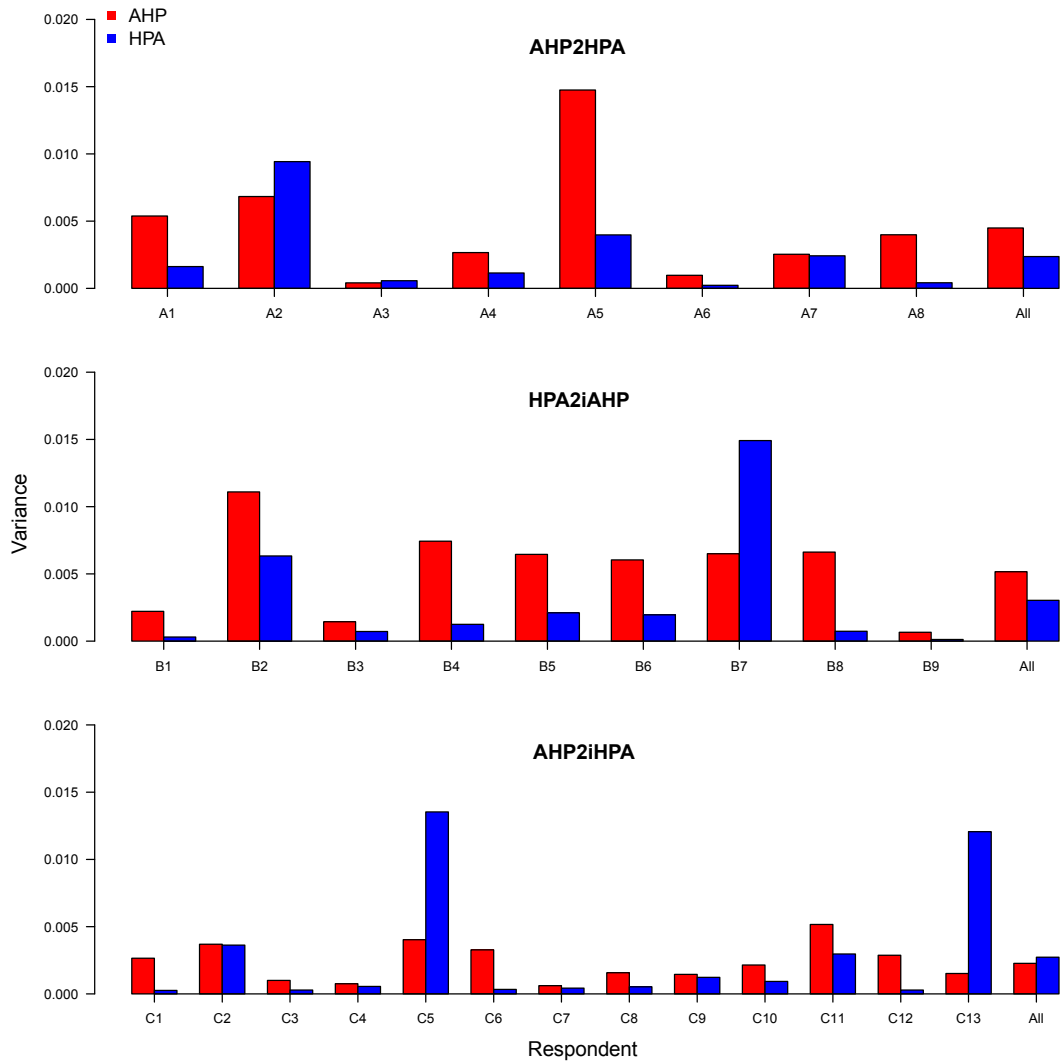


Figure 83: Variances of three-branch objective importance weighting score against each respondents for the survey pairs of 1) AHP2HPA; 2) HPA2iAHP and 3) AHP2iHPA.

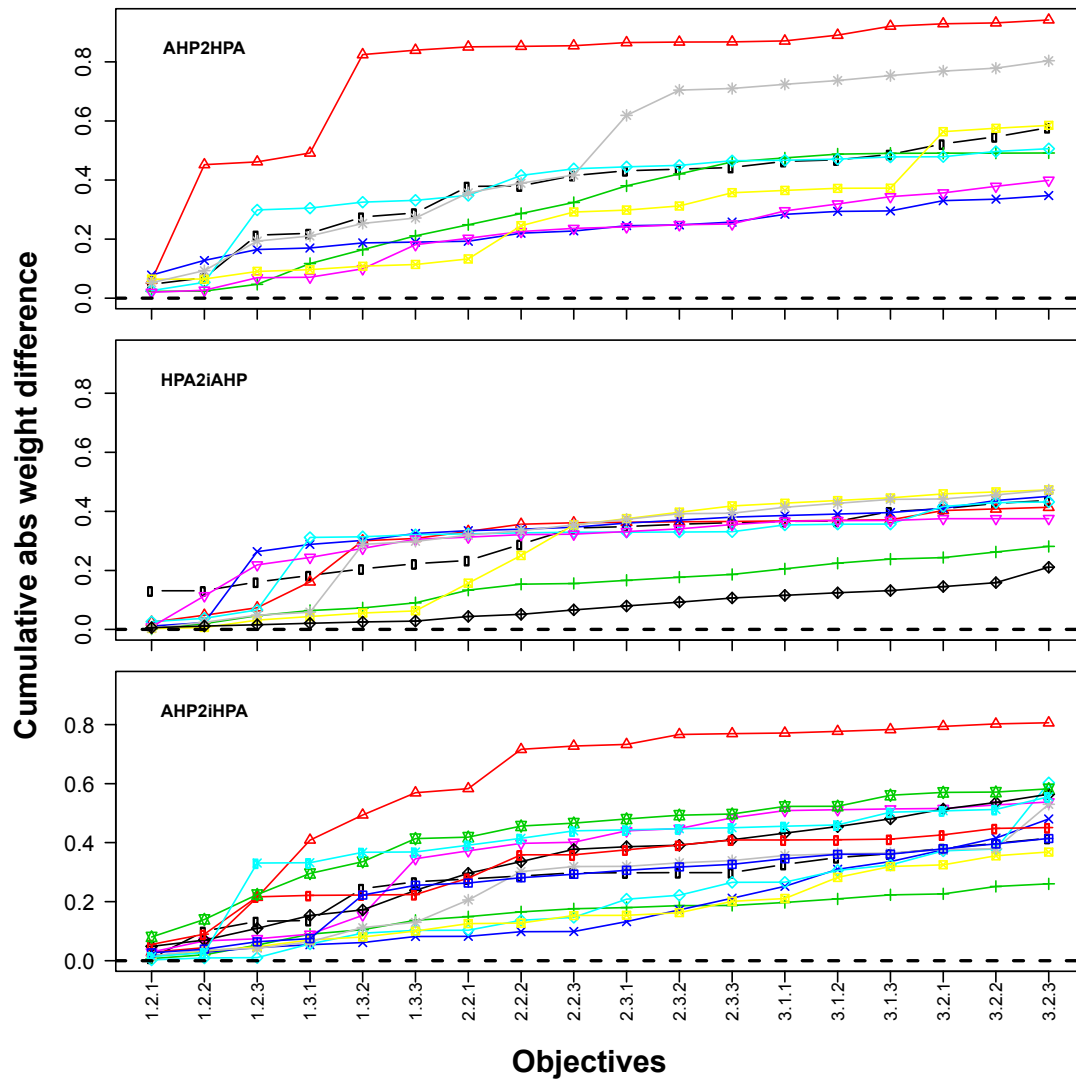


Figure 84: Cumulative absolute three-branch objectives importance weighting score differences between the survey pairs of 1) AHP2HPA; 2) HPA2iAHP and 3) AHP2iHPA.

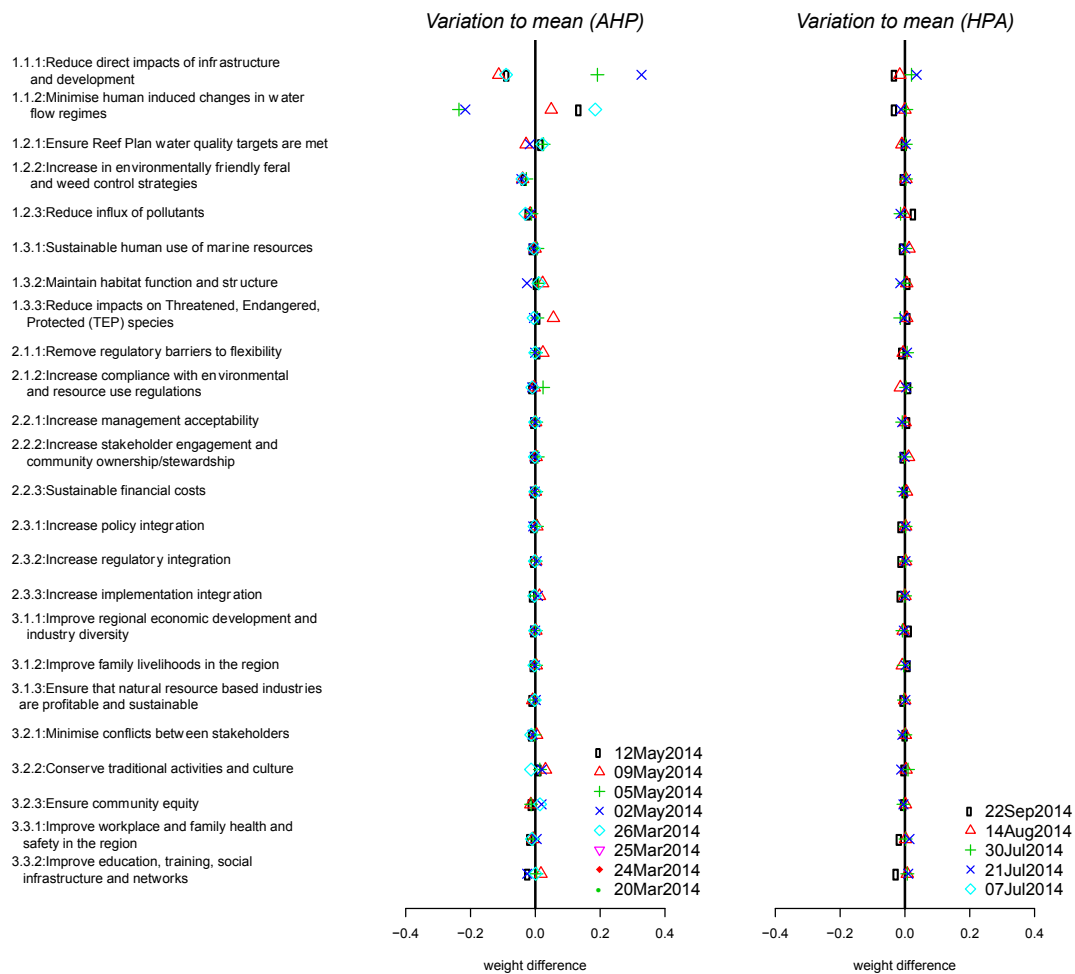


Figure 85: Variation to the mean scores from two different kinds of multiple surveys at different times by one project team member

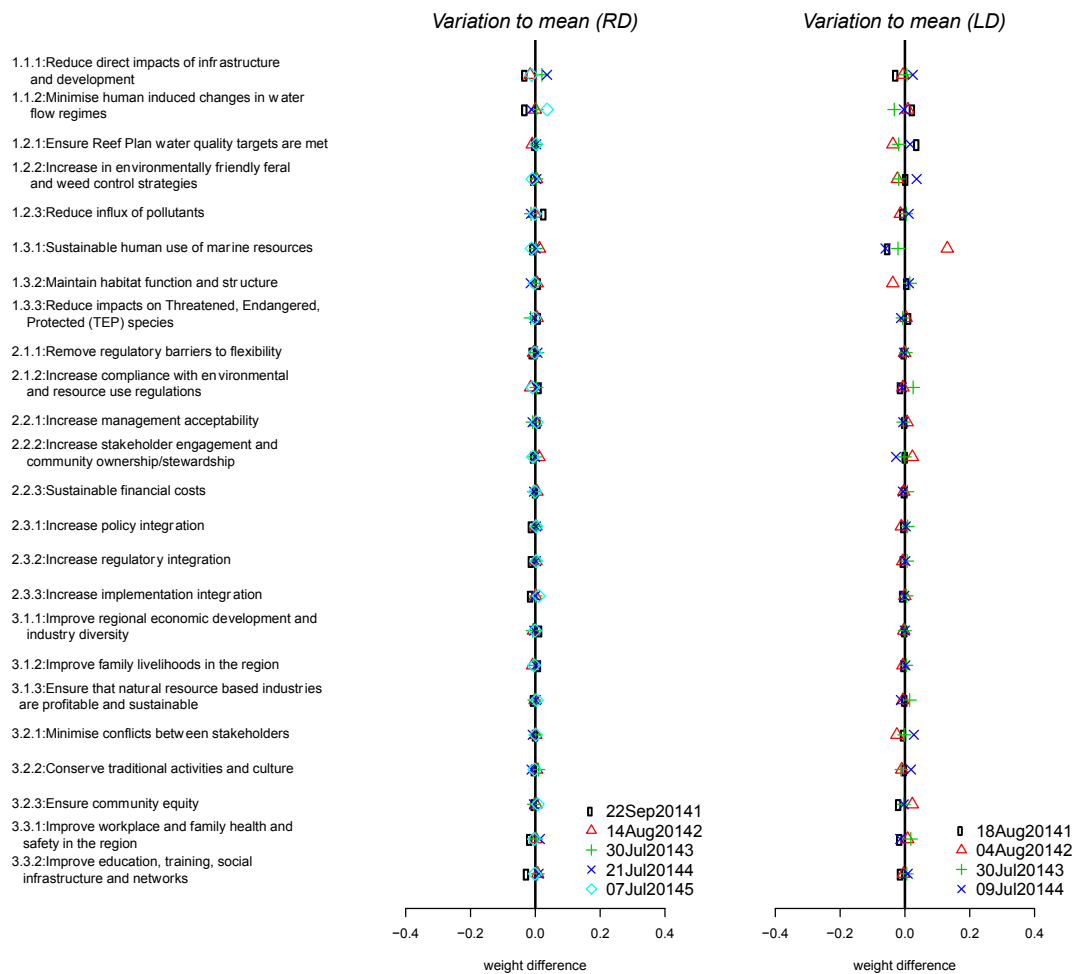


Figure 86: Variation to the mean scores from the multiple HPA surveys at different times by two project team members

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