Ecosystem Repair Prioritisation

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FITZROY BASIN ASSOCIATION

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Executive Summary

The Fitzroy Basin Association Inc. (FBA) aims to undertake actions that will reduce threats, restore condition, and improve the outlook of the Great Barrier Reef. The Reef Plan 2013 provides an urgency and direction for improving water quality to the Great Barrier Reef lagoon. 'No regrets' targets have been communicated through the plan that impact on the types of natural resource management (NRM) activities undertaken by the NRM regional bodies and other stakeholders. As part of the Water Quality Improvement Plan WQIP:2015, FBA are undertaking a prioritisation process to implement activities addressing systems repair to meet reef targets to improve aquatic habitat and wetlands.

This report outlines the development and application of several assessment and prioritisation tools for the FBA region, and their combination into a single prioritisation support tool. In 2015, the Fitzroy Basin Fish Barrier Prioritisation Project was revisited to account for remediation works to fish barriers since the original 2008 assessment. The re-assessment scored and prioritised the top 46 barriers to fish passage within the FBA region. The Department of Environment and Heritage Protection (EHP) Wetland Decision Support System (DSS) was applied to the FBA region, and prioritised the top 20 wetlands for management action. The Great Barrier Reef Marine Park Authority developed the Eco Calculator and Blue Maps to quantify change in the delivery of ecosystem services from modified coastal ecosystems since pre-European times, and to define the level of connectivity of coastal ecosystems with the Great Barrier Reef.

Each of these tools was applied to the FBA region, and their outputs standardised and combined to produce an overall score for each Neighbourhood Catchment (NC) within the region. The final prioritisation identified 61 out of 189 NCs that contain multiple ranking wetlands and fish barriers, with high connectivity to the reef. The high-scoring NCs in this combined output represent areas with the greatest potential for realising synergistic benefits from management actions, but should not be considered as a final prioritisation without careful consideration of the underlying complexities and issues with the individual tools, and those that arise from their combination into a single score.

"Decision Support Systems are support tools that help users document and quantify the intuitive decisions people make, rather than making decisions for you." (HLA Envirosciences 2007)

The key recommendation arising from this process is that the final integrated tool should comprise more than a single combined score. It should be based more directly on each of the individual sub-tools, and allow users to drill down or move between the outputs of each to fully consider interactions between different management options. No single number can capture the diversity of values an area may provide, and it is important to understand the impact of management goals and value judgements on the outputs of each individual tool.

1. Introduction

1.1. The GBR: "an icon under pressure"

The Great Barrier Reef (GBR) is an icon under pressure. Everyone's actions, whether big or small, to reduce threats and help restore its condition will improve its outlook. Combined, they will make the Reef more able to recover from the legacy of past actions and better able to withstand those predicted to threaten its future (Outlook Report 2014).

The Fitzroy Basin Association, through a number of initiatives funded by government to address Reef health, has endeavoured to do just that. Make a difference where the organisation can: by following the strategic direction of the Regional NRM plan informed by regional stakeholders. However, when it comes to Systems Repair, the organisation in the past has been able to guide its priorities through experience and a knowledge of the region's ecosystem services that contribute to Reef health.

The opportunity to revisit processes and include more robust prioritisation through the FBA Water Quality Improvement Plan makes sense. Enabling strategic selection of critical areas for targeting funding will achieve better outcomes in the longer term.

Intact coastal habitats (for example freshwater wetlands, flood plains and saltmarshes) are vital to a healthy Great Barrier Reef. They are important in the lifecycle of species and also play a role in slowing overland flow and trapping sediments and nutrients (Outlook Report 2014).

Ecosystem health is strongly linked to, and indicated by, the water quality, habitat and species biodiversity (Figure 1.1). Each one of these parameters is influenced by the other and in most instances affected by the economic priorities around the ecological assets.
The systems repair component for the WQIP includes the EHP Wetlands Decision Support System (DSS) tool as a way of prioritising wetlands for the Fitzroy Basin region. We will be able to select priority wetlands for funded activities based on values, threats and capacity to introduce change.

The Great Barrier Reef Marine Park Authority (GBRMPA) 'Blue Maps' and 'Eco Calculator' are to be utilised for determining priority habitat that influences ecosystem service contribution to the surrounding waters including the southern GBR lagoon. Through this process, actions can be determined for consideration in a prioritisation process to target areas where changes made — whether it be protection, repair or maintenance — will have a positive contribution to Reef health.

Across all fisheries risks to the ecosystem remain (Outlook Report 2014). The Outlook Report cites overfishing, incidental catch, fishing of spawning aggregations and illegal fishing as some of the continuing causes. This is outside the scope of a regional NRM group to a certain extent; however, restoring and improving access for fish species to otherwise isolated habitat can only help improve fish stocks, provide prey species, facilitate migration and improve general ecosystem health.

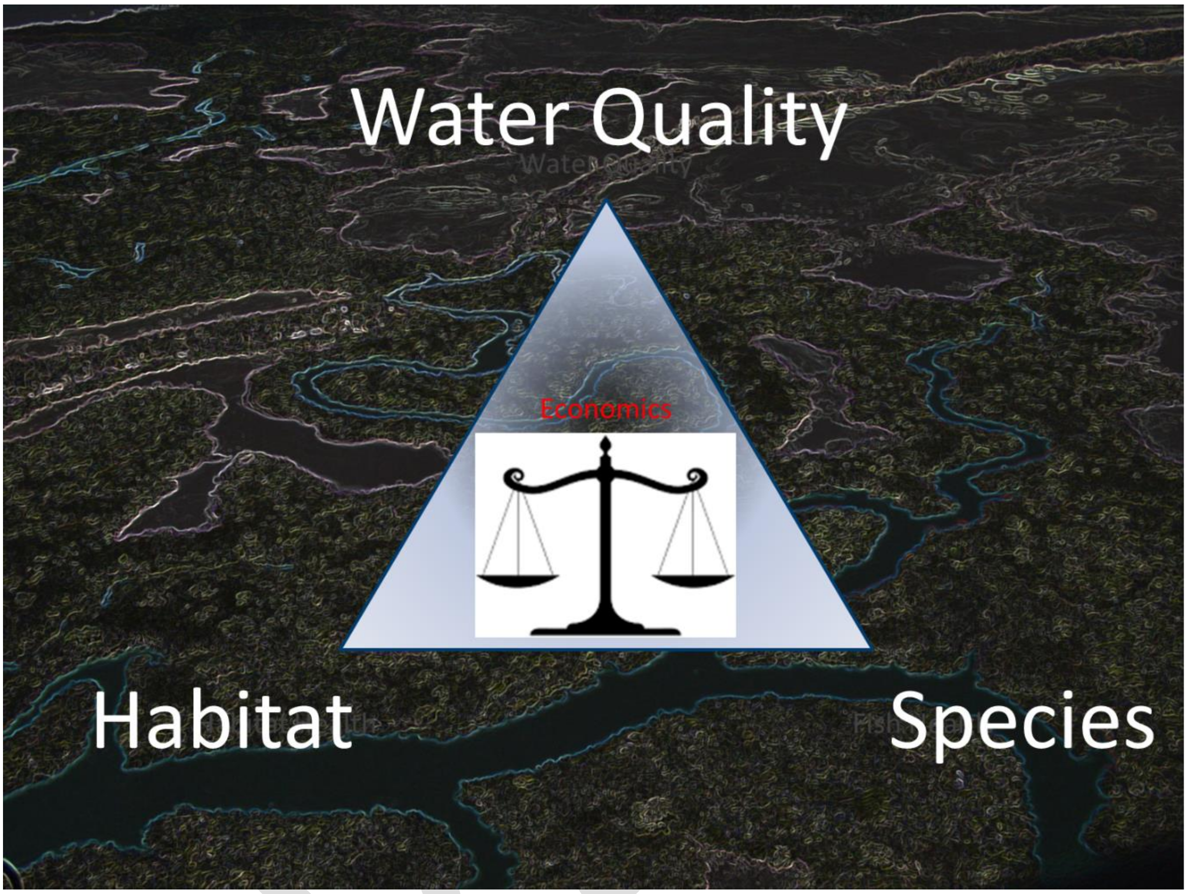


Figure 1.1. Concept for health of ecosystems
(Source: FBA 2015).

A previously commissioned project and resulting report in partnership with the Queensland Government fisheries department (Moore & Marsden 2008) was revisited to determine the top 46 fish barriers that currently form blockage and dislocation of aquatic habitat for fish species in the Fitzroy Basin.

With the above components for this sub-program complete, this report utilises the gathered information and prioritisations and combines them into a matrix process to generate an overall scoring system. The results score individual Neighbourhood Catchments (NCs) within the FBA region (Figure 1.2) based on a combined score from the Fitzroy Basin Fish Barrier Prioritisation Project (FBFBPP), the Wetlands DSS, and BlueMaps to identify the sub-basins where management actions can have the greatest impact for the health and wellbeing of the GBR. The aim is to provide multiple outcomes at the targeted sites, ensuring funding is gaining the best economical outcomes in tandem with the most appropriate system repair actions.

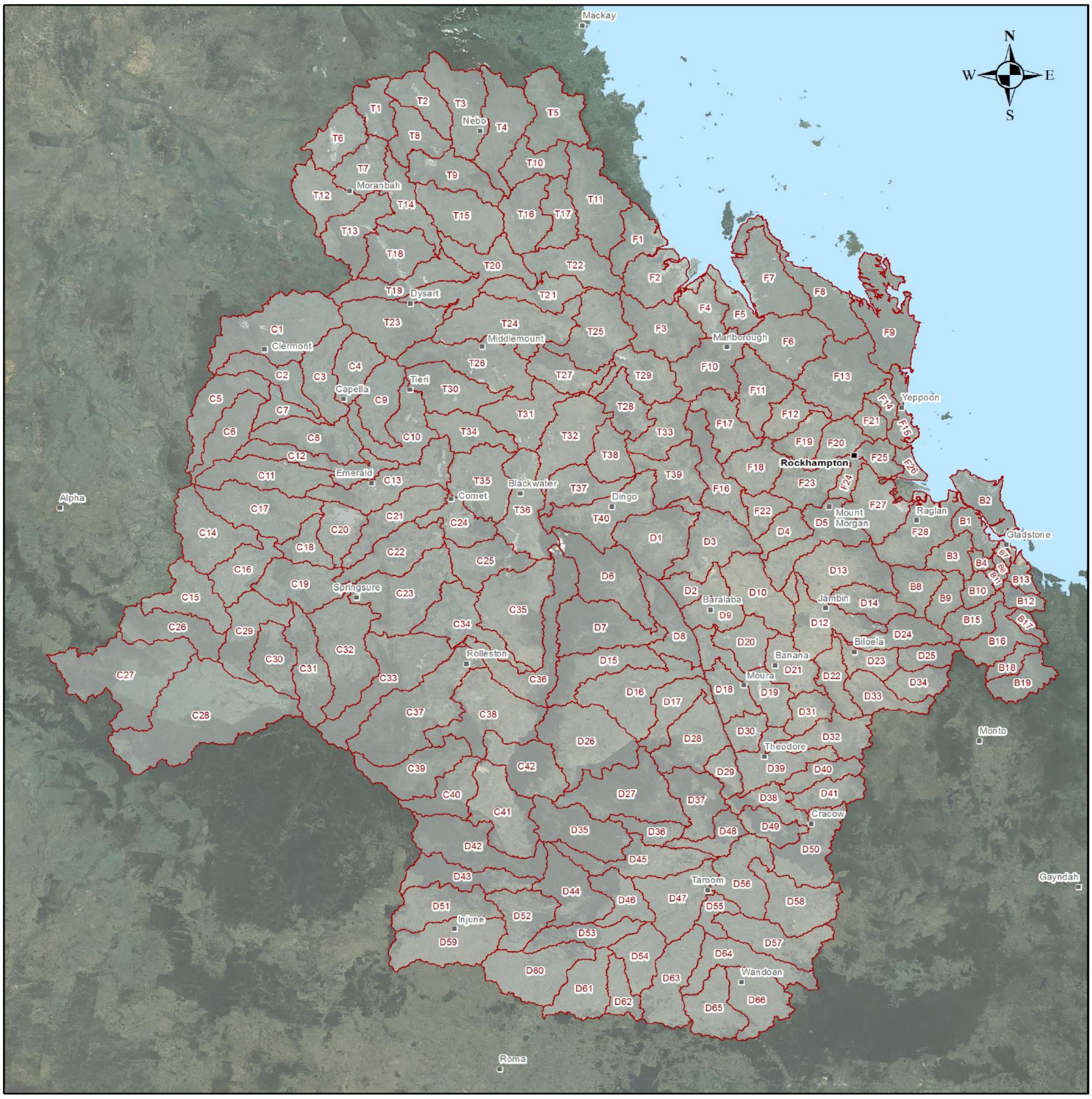


Figure 1.2. The Fitzroy Basin region indicating the Neighbourhood Catchment sub-regions.

The following chapters outline each of the sub-components, their application, their combination into a single tool, and issues relating to the interpretation, application and limitations of the final single scoring system. Users are encouraged to refer to the original reports that underpin each chapter and associated prioritisation tool to gain a full grasp of the aims, functioning, and issues relating to the use of each tool. This will ensure that outcomes from any individual tool or the integrated matrix can be interpreted appropriately, with a clear understanding of the limitations and issues for consideration.

2. Wetland DSS

This chapter provides a summary of the Wetland Decision Support System (Wetland DSS) tool, the rationale behind its development, how it works, and issues relevant to its integration with other decision tools for application in the FBA region. Unless otherwise cited, it draws primarily from the Wetland Decision Support System Workshop Manual 2007, a report by HLA-Envirosciences Pty Ltd (HLA 2007), and Jaensch et al. (2015) *A prioritisation of Fitzroy Basin wetlands for NRM investment,* a report to the Fitzroy Basin Association.

The Australian Government implemented the Great Barrier Reef Coastal Wetlands Protection Programme (GBRCWPP) in response to concerns about the impacts to the GBR from degradation of coastal wetlands. Because there are not enough funds available to complete repair efforts on all wetlands in the GBR catchment, the Wetlands Decision Support System (DSS) was developed to guide the allocation and prioritisation of funds for wetland restoration/protection and remediation in the coastal areas of the GBR. In considering repair efforts it is critical to consider a wide range of complex and interlinked biophysical, social and economic factors that impinge on and will be affected by any works carried out.

The purpose of a DSS is to *support* decision making by assembling and presenting the complex of relevant information in a way that can be understood by decision makers, and communicated to the broader community so that the process is transparent. A DSS is a support system: it is not intended to make decisions. Rather, it provides the rationale behind decisions in a way that people can clearly understand how and why particular wetlands rank highly or poorly in the priority list. It is a flexible system and the outcomes will vary depending on the specific goals and objectives of the user. As such, it is essential that any time the tool is used, a clear set of objectives is defined, and the weighting for each of the scoring criteria are adjusted to meet the stated objectives.

To incorporate this tool into a broader framework for prioritising actions within the FBA region, it will be necessary to apply the tool concurrently with the other tools, and exactly how this is done will depend on the specific goals. The current iteration of the application of the Wetlands DSS to the FBA region provides a good starting point that identifies the highest priority wetlands within the region. Once incorporated into the integrated matrix with the Fish Passage Prioritisation and Blue Maps, it will indicate sub-basins in the FBA that contain high priority wetlands. To guide this process, the remainder of this chapter provides a summary of the mechanics of the tool, and the outcomes of its application to the FBA region.

Note: The Ramsar wetlands Shoalwater Bay and Corio Bay wetlands were excluded from the process along with Kinka wetlands of national importance and a significant area of the Fitzroy flood plain as these wetlands are currently funded to 2018 and Ramsar wetlands will continue to be considered by FBA as priority in decision processes.

2.1. Methodology

2.1.1. Overview of the DSS

The DSS manual emphasises the critical importance of having clearly identified management objectives before using the DSS to prioritise management actions. This is because decisions about weighting each of the criteria are value judgements, and will vary depending on the specific management objectives. For instance, is the management preference to protect pristine wetlands, or restore degraded ones? Is the goal to improve water quality, or enhance fisheries values? Individual criteria may be given opposite weightings under these different scenarios, and the relative importance of different criteria will also vary widely.

The DSS brings together three types of information to prioritise wetlands for management action.

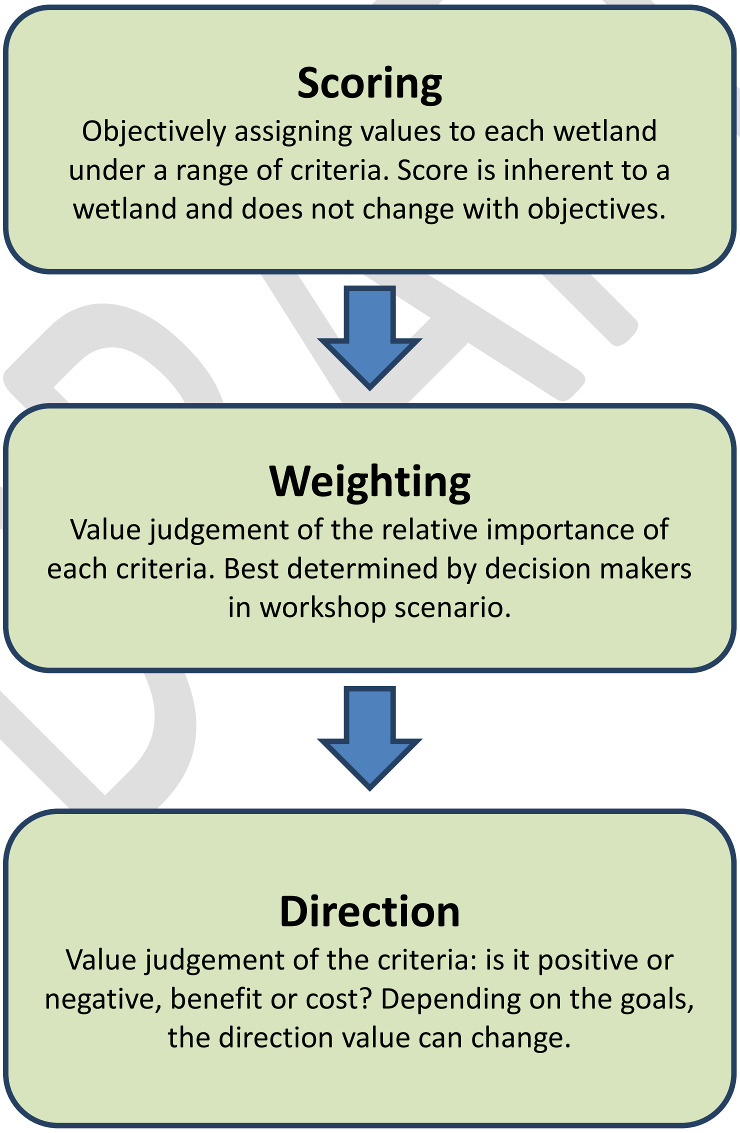


Figure 2.1. The three sources of information combined to prioritise wetlands for management action.

This information is used in the two-step prioritisation process, with Step 1: the **Primary DSS** applied to wetlands across the entire GBR catchment; and Step 2: the **Secondary DSS** applied on a regional scale, in this instance, to the FBA region.

<u>**Scoring**</u> involves applying scores to each wetland across a range of criteria grouped under three broad categories: *Value*, *Threat* and *Capacity*. 'Value' refers to the inherent values that may be attributed to particular wetlands, such as their values as fisheries habitat or for waterbirds. 'Threats' include the various sources of pressures and stressors on the wetland, while 'Capacity' considers community capacity for wetland conservation and the availability of financial assistance for restoration or protection efforts. Scoring is performed to objectively identify the current state of each wetland, and the relevant issues relating to its management. The scores are independent of the goals or management objectives. It is during **Weighting** that the relative importance of each criterion is determined by managers, experts, and other stakeholders.

The criteria definitions and scales are explained in detail in the report commissioned by FBA entitled "*A prioritisation of Fitzroy Basin wetlands for NRM investment*" (Jaensch et al. 2015). Briefly they are:

Values Criteria:

- **Recreational Value** — importance for nature-based recreation
- **Indigenous Value** — site significance to Traditional Owners
- **Fisheries Habitat** — value to commercially or recreationally important fish species
- **Assimilative Capacity** — ability to detain nutrients and sediments to improve water quality
- **Populations of Rare or Threatened Taxa** — significant populations of species listed in State or Commonwealth legislation
- **Vegetation Representativeness** — ratio of pre-European to current representation of Regional Ecosystem types
- **Wetland Representativeness** — identifies unique or remnant wetland types in a region
- **Species Richness** — for major taxa including fish, birds and vascular plants
- **Size** — larger wetlands are considered to have greater potential value
- **Waterbird Habitat Value** — quality of habitat and significance of bird populations supported
- **Wetland Condition** — considers floristic, faunal, hydrological and geomorphological character

Threats Criteria:

- **Fish Passage** — extent of connectivity to downstream estuarine areas relative to pre-European times
- **Land Use Intensity** — proportion of catchment under intensive land uses; dryland and irrigated agriculture and plantations
- **Land Use Intensification** — potential land use zoning for 1 km buffer around wetland
- **Weed Invasion** — threat posed by existing weed infestations
- **Water Quality** — current status of wetland water quality
- **Point Source Pollution** — presence of upstream pollution sources and level of impacts

- **Hydrological Change** — changes to the timing and volume of flows and recharge of surface and groundwaters

Capacity Criteria:

- **Level of Protection** — protection of wetland by statutory or binding management
- **Financial Incentives** — availability of funding to support management efforts
- **Industry Land Use Viability** — profitability of local industry reflects capacity and willingness to support NRM initiatives
- **Engagement Capacity** — extent to which wetland is already recognised as a priority area by local NRM groups and landholders
- **Best Management Practice Feasibility** — feasibility of achieving best management practice given current conditions, capacity and technological constraints

Once candidate wetlands have been scored according to the above criteria, each criterion is weighted according to the specific management objectives.

Weighting is a value-based assessment of the importance of each of the criteria. This is best performed by local decision makers, experts, and other stakeholders in a workshop situation. This provides a transparent mechanism whereby the values of end-users are incorporated into the process. It fosters involvement of various stakeholders, and facilitates consideration of different interests and values each may assign to wetlands and their priorities for remediation action.

Direction indicates if a high score and weighting for a criterion increases or decreases its priority for action. As with Weighting, this is guided by the management objectives and can be determined as part of the weighting process. For instance, if the management preference was to protect pristine wetland areas from degradation, then criteria that scored highly based on healthy, functional ecological values would be positive, thereby increasing the ranking in the priority list, while those scoring highly due to severe impacts would be negative. If the focus was on actions to repair degraded systems, then the reverse directions would be applied.

2.1.2. Application to the FBA region

The Wetlands DSS was applied to the FBA to prioritise wetlands for management action, and this process is detailed in the report by Jaensch et al. (2015). The application of the DSS to the FBA region started with 40 identified candidate wetlands, which were then run through the Secondary DSS process using local managers, experts and stakeholders to prioritise the top 20 wetlands for management action. The 40 wetlands considered did not include Ramsar sites since these are already gaining project support for managing values. The selection was focussed on wetlands that were known or likely to contribute to water quality improvement in the Reef lagoon, wetlands that (otherwise or in addition) had biodiversity values known or likely to be high, and—at this stage to lesser extent—wetlands where some kind of NRM investment seemed feasible.

Sites at which significant previous investments for NRM had occurred, or were ongoing, were omitted. This was because FBA wanted to expand the geographical spread of investments in NRM for wetlands in the Basin and to engage additional landholders. Some sites with previous investment were nevertheless included, because there seemed to be limited prospects for further investment by other organisations in the short-medium term. Several sites that were due to be targeted in upcoming or recently-started projects of FBA—such as on the lower Fitzroy flood plain—were omitted. Some sites where any form of NRM investment seemed highly improbable, or impractical in the short-medium term, were omitted, e.g. sites that were highly remote or subject to severe flooding impacts.

2.2. Results and Discussion

2.2.1. DSS outputs

Consideration of the full range of criteria highlights that many provide potentially conflicting values. This is not a criticism of the process or the tool, but reinforces why the tool must be modified through careful weighting of each criterion according to clearly defined management objectives. For example, under the Fisheries Habitat criterion, a wetland with suitable habitat for fisheries species, but inaccessible due to barriers would score 0 (out of 10), while the same wetland would score 10 out of 10 under the Fish Passage criterion. In this instance, the weighting for these values would depend if existing high value and functional habitat was considered more or less important than restoring access to potentially valuable but currently inaccessible habitat. Without this level of careful consideration during the process, i.e. with equal weighting, these two criteria would effectively cancel each other out. Another way to consider this is that a wetland with valuable fisheries habitat and good functional connectivity would score the same as a wetland with potentially valuable habitat but no connectivity due to barriers. This highlights the need for decision makers to carefully examine the full range of outputs, and to explore how changes to weighting and direction can affect the final results. These recommendations are emphasised in the original DSS Manual and are repeated here.

2.2.2. Secondary DSS: Prioritisation of FBA region wetlands

Application of the Secondary Wetlands DSS to the FBA region resulted in prioritisation of the top 20 wetlands for management action. This process prioritised these 20 wetlands out of an original list of 40 from the region, and did not include Ramsar wetlands that are already the focus of separate management actions. The top ranking wetlands scored highly in each of the three broad categories: *Values, Threats* and *Capacity* (Figure 2.2). Some of the lower ranked wetlands (in the top 20) scored highly in the *Threat* category, but poorly in *Values* and *Capacity* indicating that while these wetlands may benefit considerably from management interventions, the cost and capacity to effectively implement these makes them a less attractive option than the higher ranked wetlands.

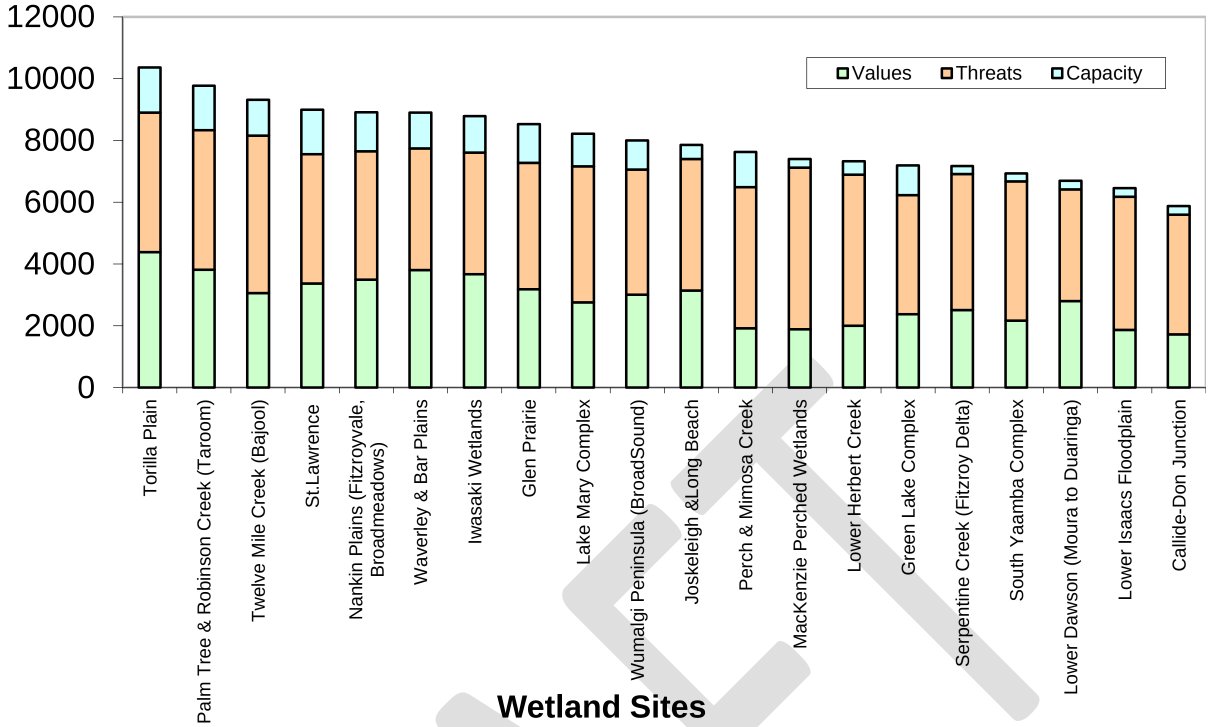


Figure 2.2. Wetland prioritisation results from the application of the Secondary Wetlands DSS to 40 wetlands in the FBA region.
(Source: Jaensch et al. 2015).

The prioritisation process found the Wetlands DSS to be a useful tool for the FBA region, but noted that the bias toward coastal wetlands in several important criteria resulted in few inland wetlands scoring highly. This is despite several inland wetlands having apparent high value and good potential for investment to provide improvements. As a result, Jaensch et al. (2015) recommend future assessments consider inland wetlands separately using a modified scoring system not biased towards coastal connectivity.

The weighting of each criterion was based on the detailed understanding by FBA staff who know the region, the priorities, and feasibility of implementing works. This process identified some important gaps in available data. For instance, water quality and point-source pollution were considered the most important of the *Threats* criteria, and were assigned a weighting of 10. However, little data was available for either of these criteria, and hence scores were set to average by default.

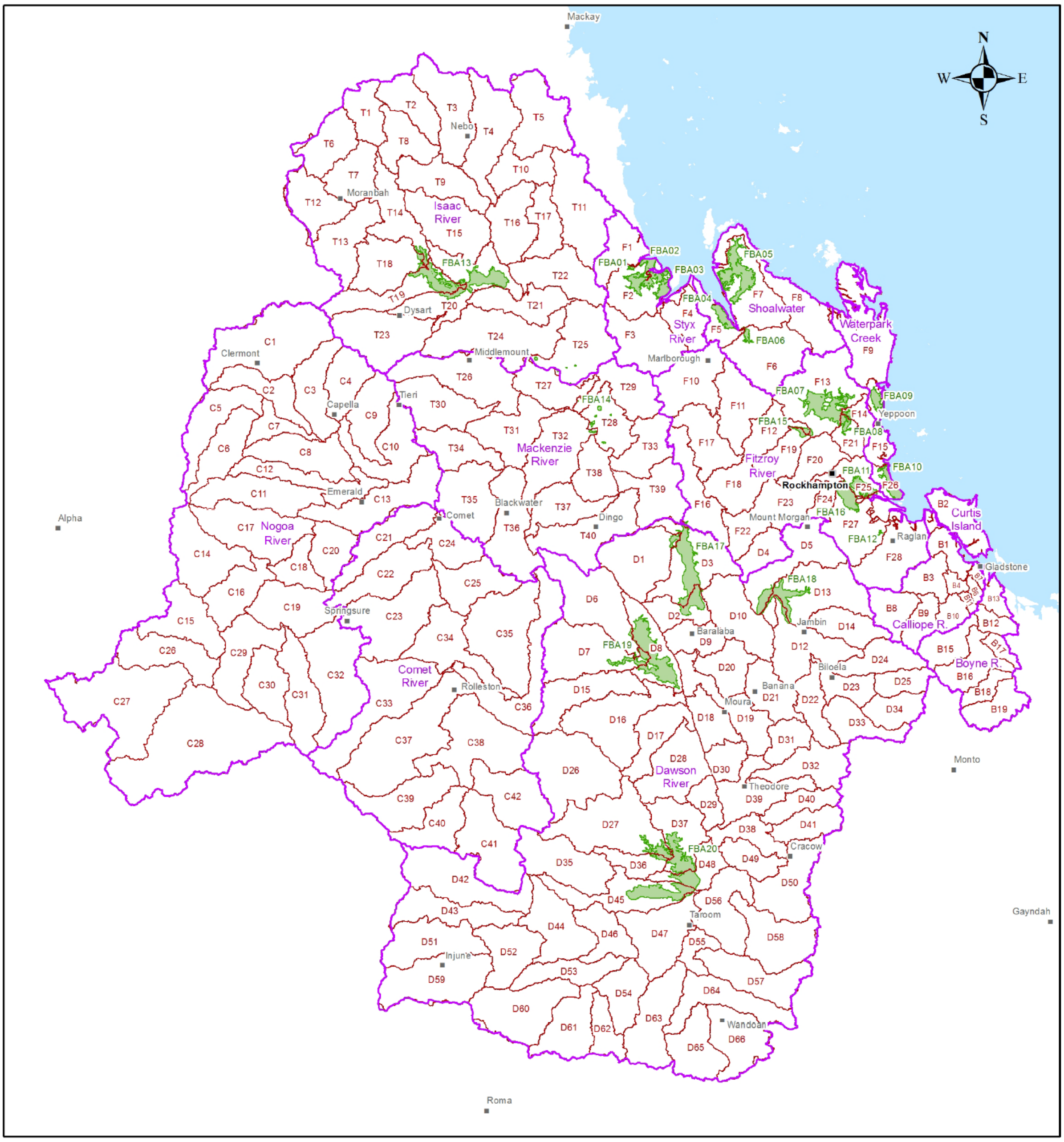


Figure 2.3. Wetland prioritisation results from the application of the Secondary Wetlands DSS to 20 wetlands in the FBA region

(Source: FBA 2015).

3. Ecological Process Calculator (Eco Calculator)

Figure 3.1. The Eco Calculator scores the current status of the provision of ecosystem services by GBR catchment ecosystems relative to their pre-European condition
(Source: GBRMPA 2015).

This chapter describes the development and application of the Eco Calculator and Blue Maps for guiding management efforts in the FBA region, and unless otherwise cited is drawn in whole or in part from a draft report to the FBA from the Great Barrier Reef Marine Park Authority (GBRMPA 2015).

In 2009, the *Outlook for the Great Barrier Reef* identified water quality and coastal development as two of the three main threats to the Great Barrier Reef. The publication *Informing the Outlook for Great Barrier Reef Coastal Ecosystems* (published in 2012) showed that widespread modifications have occurred in much of the Great Barrier Reef catchment. What is not known is what, if any, impact these changes are having on the Reef and what are the levels of acceptable change?

Ecological processes provided by catchment coastal ecosystems are critical for the long-term health and resilience of the Great Barrier Reef. Ecological processes include biological, biogeochemical and physical processes. For example, coastal ecosystems such as wetlands trap water allowing biofilms and aquatic algae to grow and assimilate heavy metals, they allow sediments to settle and nutrients to be cycled. Wetlands also slow overland flows allowing greater groundwater recharge and more residual time for ecological processes to occur. They are also important habitats and refugia for species connected to the Reef.

The Ecological Processes Calculator is a general tool for assessing the changes to ecological processes provided by catchment ecosystems that support the health and resilience of the Great Barrier Reef. The calculator compares the capacity of pre-European (pre-clear) coastal ecosystem ecological processes to those of a present day (2009) catchment made up of natural and modified ecosystems. The calculator can also be used to determine the impacts of improved practices (current best practice) on the ecological processes provided at a general scale and, when used with Blue Maps, as a tool for functional restoration planning.

Scores are provided at a basin-scale, with basins subdivided using the Blue Map to distinguish levels of connectivity to GBR. Final scores range from poor to very good. However, the relevance of this will depend on the question and objective. If protecting intact habitat is important, then a score of 'very good' will be weighted highly. If restoring degraded habitat is top priority, then the reverse is true, and scores of 'poor' should have higher weighting.

The combined Eco Calculator and Blue Maps can guide management prioritisation in the FBA region in two general ways: using Blue Maps to identify the parts of the region with greatest connectivity and thus impact on the GBR, and then focussing on actions that will best address the issues identified by the Eco Calculator as most important. Conversely, once a number of sites are identified for potential action, they could be prioritised according to the values identified by the Blue Map and Eco Calculator.

3.1. Methodology

3.1.1. Development of the Ecological Process Calculator

In 2010, GBRMPA held a workshop with a panel of experts from a wide range of disciplines to identify and understand the ecological processes that are provided by coastal ecosystems for the health and resilience of the Great Barrier Reef. This workshop identified and refined a list of coastal ecosystems, grouped according to similarities in the ecological processes that they deliver for the Great Barrier Reef. These functional groups were: ***estuaries*** (includes mangroves and saltmarsh), ***freshwater wetlands***, ***forested flood plains***, ***grass and sedgelands***, ***heath and shrublands***, ***rainforests***, ***forests and woodlands***. It was also recognised that modified coastal ecosystems impact on, and can provide some ecosystem services for the GBR, and hence additional ecosystem types were included for further assessment: ***grazing natural areas***, ***forestry***, ***intensive animal production***, ***intensive commercial and residential***, ***dryland production***, ***irrigated production***, ***ponded pastures***, ***water storage***, ***transport and mining***. The extent of coastal ecosystems was then determined by grouping Queensland Government Regional Ecosystems into the assigned coastal ecosystems classifications. This grouping allowed spatial analysis of changes to vegetation from pre-European times to current times. The workshop also identified that the capacity for each coastal ecosystem to deliver ecosystem services will vary across the GBR catchment, due to changes in climate, rainfall, connectivity, landform, and size.

The ecological services provided by coastal ecosystems are grouped into four main categories: recharge-discharge processes, physical processes (sediments), biogeochemical processes, and biological processes. A detailed description of each of the individual processes/services and how each was quantified and scored is provided in GBRMPA (2015), while a summary of the processes is provided below.

Recharge-discharge processes:

- Detains water; flood mitigation; potentially connects aquatic ecosystems; regulates water flow — groundwater; regulates water flow — overland flows.

Physical processes (sediments):

- *Sedimentation—fine:* trap fine sediments; retain fine sediments; release fine sediments slowly.
- *Sedimentation— coarse:* trap coarse sediments; retain coarse sediments; release coarse sediment slowly.
- *Material transport:* transports material for coastal processes; particulate deposition and transport (sediments, nutrients, chemicals); material deposition and transport (debris, dissolved organic matter [DOM], rock).

Biogeochemical processes:

- *Production:* Primary production; secondary production.
- *Nutrient:* source of nitrogen and phosphorous; uptakes nutrients; regulates nutrients.
- *Carbon:* carbon source; sequesters carbon; regulates carbon.
- *Decomposition:* source of DOM.
- *Regulation:* salinity regulation; regulates temperature.

Biological processes:

- *Survival:* habitat refugia for aquatic species with reef connections; habitat for terrestrial species; connected to reef; food source; habitat for ecologically important animals.
- *Dispersal:* replenishment/ecosystem colonisation; pathway for migratory fish.
- *Pollinate:* Pollination.
- *Recruitment:* habitat contributes significant recruitment.

For each river basin, these processes are scored as a percentage change from pre-European times, and the results are presented for each basin divided into regions of connectivity to the GBR based on Blue Maps (see section 3.1.3. below). Percent change from pre-European times of ± 10 % were classified as ‘Very Good’, ± >10-25% as Good’, ± >25-50% as ‘Moderate’, ± >50-75% as ’Poor’, and ± >75% and ‘Very Poor’. Each system was then given a final scorecard that averaged the percentage change values for the processes in each category. Within each Blue Maps sub-region, the dominant modified ecosystem was identified since action in these areas is likely to yield the greatest range of ecosystem service benefits.

3.1.2. Application to the FBA region

Following the workshop, a literature review allowed for further assessment of the capacity of these natural and modified ecosystems to provide services, and their vulnerabilities. From this, an ecological process matrix was developed and applied in a further workshop to focus on individual basin case studies to allow for variability in ecosystem capacity to be examined. This led to the development of the *Coastal Ecosystem Assessment Framework* (GBRMPA 2012), which was then applied to a further seven basins in the GBR catchment. The analysis identified many of the key assets, drivers and pressures impacting on the capacity of coastal ecosystems to deliver ecological processes. The basin assessments also identified that drivers occurring at a basin-scale can significantly impact upon the capacity of ecological process delivery and therefore needed to be considered.

The next step was to quantify the extent of changes to ecological processes in each basin. As a result, the Ecological Processes Calculator for the Great Barrier Reef (also referred to as the Eco Calculator) was developed for use in collaboration with local experts to capture the inherent variability in ecological processes delivered at finer scales. It is designed to capture coastal ecosystem and modified ecosystem processes at local scales (basin to sub-basin scale) and calculate the approximate changes in capacity of ecological processes delivered between pre-clear coastal ecosystems and the current landscape (post-clear). It is not intended to be a precise tool and should only be considered a guide in its current form. Note that the use of other groupings of Regional Ecosystems (RE) (based on Queensland's Regional Ecosystem mapping program) can be used for finer scale analysis. A full list of identified ecological processes is available in Appendix 1 of the draft report (GBRMPA 2015).

The Ecological Process Calculator uses the workshop-assigned capacity scores, pre-clear and post-clear coastal ecosystem extents and Australian Land Use Mapping Project (ALUMP) land use data (hectares) to calculate a percentage change score for each ecological process. By merging the ALUMP data and Coastal Ecosystem data into an Excel spreadsheet, data can be combined using the pivot table function. Percentage change scores can also be calculated for other spatially defined areas such as the coastal zone or flood plain. GBRMPA has used the areas of connectivity boundaries from the Blue Maps tool.

This process was recently applied specifically to the FBA Region through workshops involving local experts, managers and stakeholders. The resulting assessment provided capacity scores across the range of ecosystem services for the Styx, Water Park, Fitzroy, Shoalwater, Calliope, and Boyne basins, and identified the dominant modified land use likely to drive changes in capacity to deliver ecosystem services in each basin.

3.1.3. Blue Maps

The importance of ecological processes and the capacity of coastal and modified ecosystems to deliver these processes with benefits to the Great Barrier Reef are often dependant on the proximity of the service area to the Reef. The Blue Maps developed by the Great Barrier Reef Marine Park Authority show the areas of strongest connectivity through the mapping of wetter areas of the catchment (Figures 3.2 and 3.3). Although the whole catchment is connected to the Great Barrier Reef, and some processes such as sediment transport can originate from the top of the catchment, many more processes occur where connectivity is greatest. The Blue Maps identify those areas with the greatest value for the delivery of ecological processes that benefit the Great Barrier Reef (Figure 3.3).

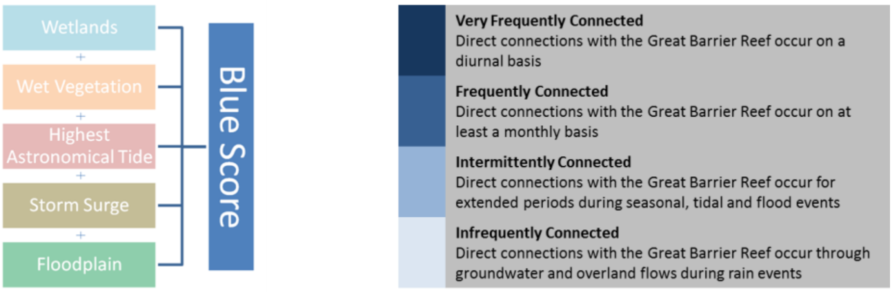


Figure 3.2. Data layers and connectivity frequencies used to define the regions in Blue Maps
(GBRMPA 2015).

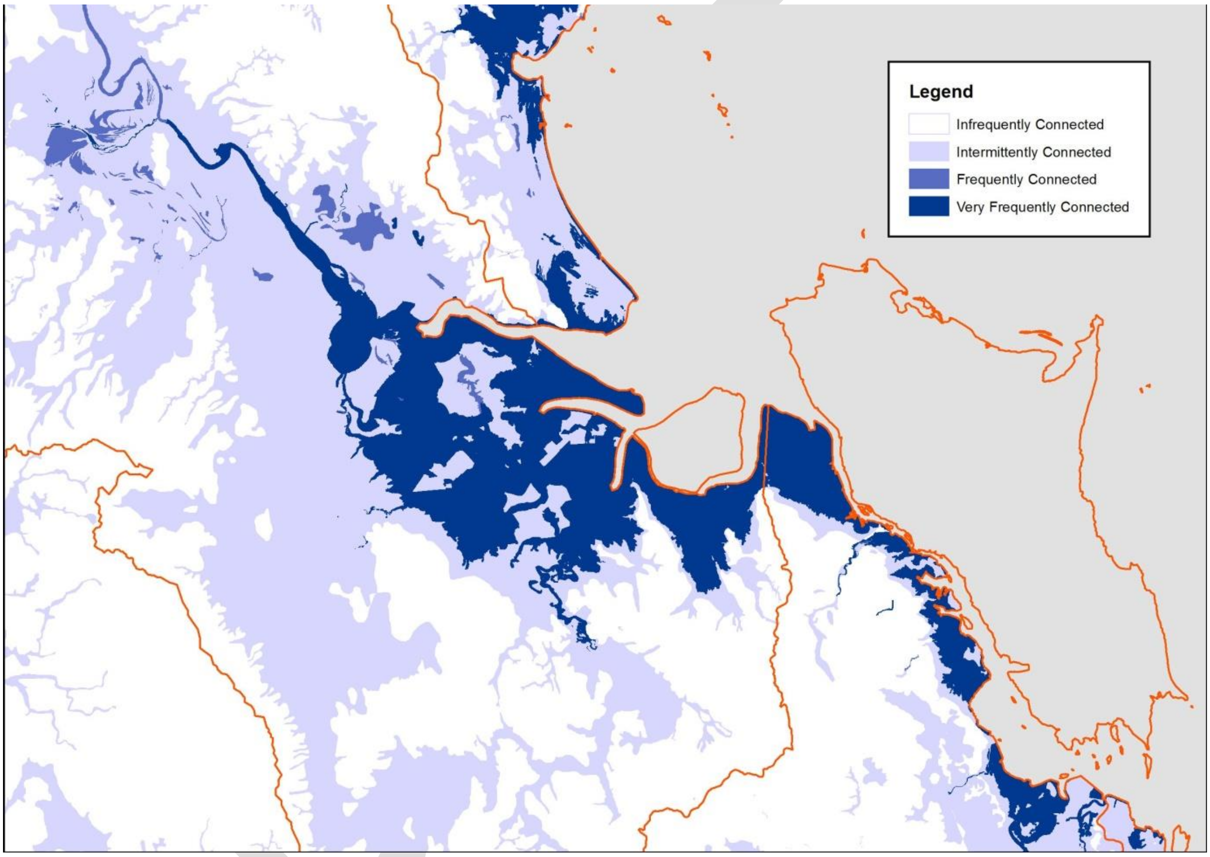


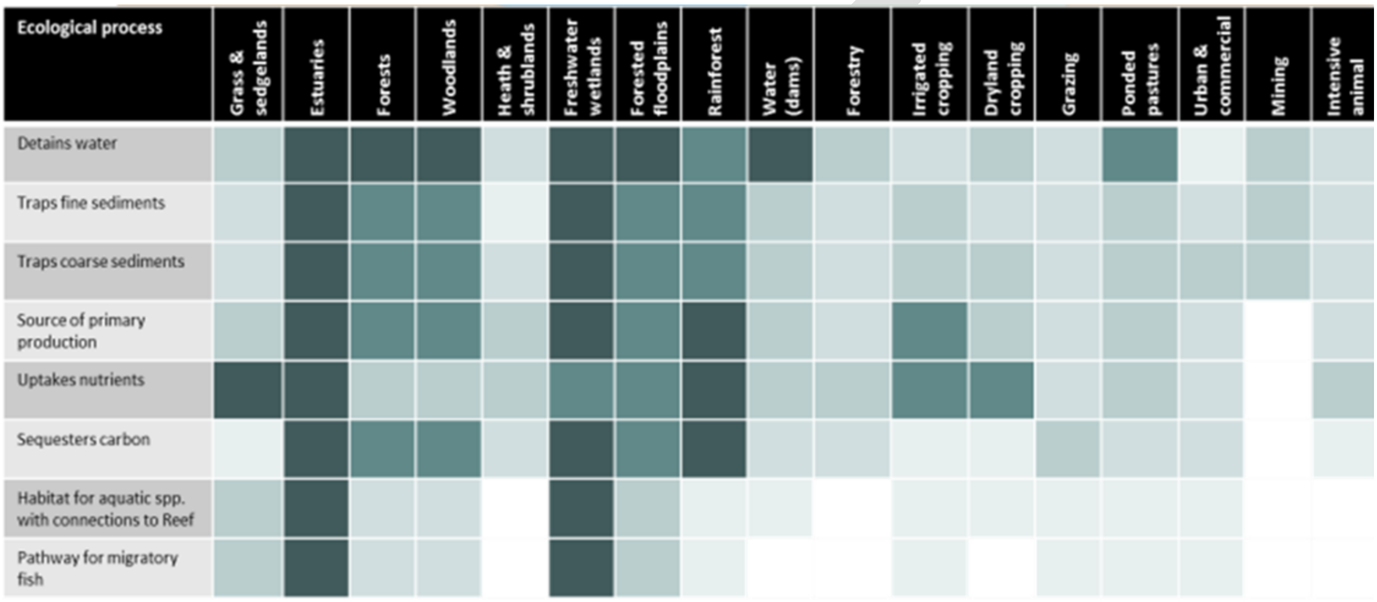
Figure 3.3. Blue Maps classifications of the lower Fitzroy basin defining levels of connectivity to the waters of the GBR
(GBRMPA 2015).

The resulting Blue Maps represent a measure of areas based upon their frequency of connection with the GBR, either directly or through the subterranean movement.

3.2. Results

The development of the Eco Calculator identified the capacity of a range of natural and modified coastal ecosystems to provide ecological services that potentially benefit the GBR (Table 3.1). While it is recognised that the capacity of specific ecosystem types to deliver particular ecological services will vary throughout the GBR catchment, the outputs in Table 3.1 provide a representative indication of the types and extent of services provided by each ecosystem.

Table 3.1: Ecological processes for natural and modified ecosystems in the GBR catchment.



Note: The darker the cell, the higher the capacity for the ecosystem to deliver the ecological process. Source: GBRMPA 2015.

The Eco Calculator can be used to help refine prioritisations derived from the integrated tool, and also to identify the type of ecosystem services an area may provide, and the type of actions that will provide the best improvements for the GBR.

Blue Maps was applied to each of the Neighbourhood Catchments within the FBA region (Figure 1.2). This allowed the calculation of the area within each NC that lies in each of the Blue Maps connectivity categories. Twenty-nine of the 193 NCs contained at least some land classified as ’Very Frequently Connected (VFC)’ by Blue Maps (Figure 3.2). Of these, only two had >25% in the VFC category: F2 (35%) and F27 (26%). Very little area within the FBA region was classified as ‘Frequently Connected (FC)’. Only 22 NCs had land within the FC category, and the proportion of each NC classified as frequently connected ranged from <0.01 to 6%. Parts of every NC within the basin are classified as ’Intermittently Connected’ and ‘Infrequently Connected’ with these categories covering a large proportion of the whole basin.

Because scaling of the Blue Maps proportional areas was weighted to favour areas with greater connectivity to the GBR, the 10 NCs with the greatest area of VFC land comprised eight of the top 10 final scores from Blue Maps scoring. The current weighting system should be carefully evaluated to determine if it provides appropriate focus on areas most closely connected to the GBR. As it stands, the weighted Blue Maps scores applying a weighting of 4 for areas 'very frequently connected' through to 1 for areas 'Infrequently Connected' assumes, for example, that a unit area of land that is very frequently connected has double the value of the same area of land that is only intermittently connected. So while the current Blue Maps weighting procedure highlights NCs most connected to the GBR, the details of the weighting system need further consideration.

4. Fish Barriers

Figure 4.1. St Lawrence Weir (Barrier ID 9393) on St Lawrence Creek is a high priority barrier to fish passage within the FBA region.
(Source: Marsden 2015).

Healthy functional ecosystems that support fish and fisheries do not act in isolation, but rather form part of an ecosystem mosaic that provides all the needs of fish species throughout their lives. The Fitzroy Basin contains a diversity of aquatic habitats from freshwater lagoons and swamps, small rivers and streams, through some of the largest rivers on the continent, to mangrove swamps and estuaries, all of which ultimately connect into coastal waters and the lagoon of the Great Barrier Reef. Many fish in the basin make extensive movements during their lives, and 23 of the 49 fish species recorded in the FBA region's freshwaters are diadromous, meaning they require access to estuarine and marine waters to complete their lifecycle (Moore & Marsden 2008). These include many of our most prized and iconic species such as barramundi. Therefore, maintaining functional connectivity between these systems is critical for effectively managing the Fitzroy Basin's valuable fishery resources and biodiversity.

All barriers to fish migration within the FBA region were identified, assessed and prioritised in the 2008 Fitzroy Basin Fish Barrier Prioritisation Project (FBFBPP) (Moore & Marsden 2008). That project identified 10,502 potential in-stream barriers to fish migration, and used a three-stage process to prioritise the top 30 barriers for future remediation. Since then a number of barriers have been remediated within the basin, and in 2015 the fish barrier prioritisation was updated to identify the remaining barriers and catchments with the greatest need of remediation (Marsden 2015). This chapter provides an overview of the process by summarising these reports, including the key methods and findings of the update. The aim is to provide managers with an understanding of the issues and considerations surrounding remediation of fish passage in the FBA region, so that the tool can be used to support prioritise management actions to achieve broader environmental outcomes. For full details, please refer to the original 2008 and updated 2015 reports (Moore & Marsden 2008; Marsden 2015).

4.1. Prioritisation Methodology

The FBFBPP involved a three-stage process to prioritise barriers based on a range of biological, social and economic costs and benefits of remediation (Figure 4.2).

- **Stage 1:** automated GIS process to identify potential barriers and prioritise top 150 based on five broad attributes (stream order; position along stream gradient; catchment condition; area of habitat opened by remediation; downstream barriers).
- **Stage 2:** field validation confirming actual barriers and data collection on physical, biological and logistical parameters relevant to remediation efforts; manual refining of prioritisation based on scores for: barrier type; stream condition; water supply; water quality; upstream habitat quality.
- **Stage 3:** refined final prioritisation based on scores for: cost; available financial support; technical viability/difficulty; productivity benefits; conservation significance; remediation effectiveness.

A detailed description of the methodology, including listing of the specific criteria and scoring used at each stage of the process is provided in Moore and Marsden (2008).

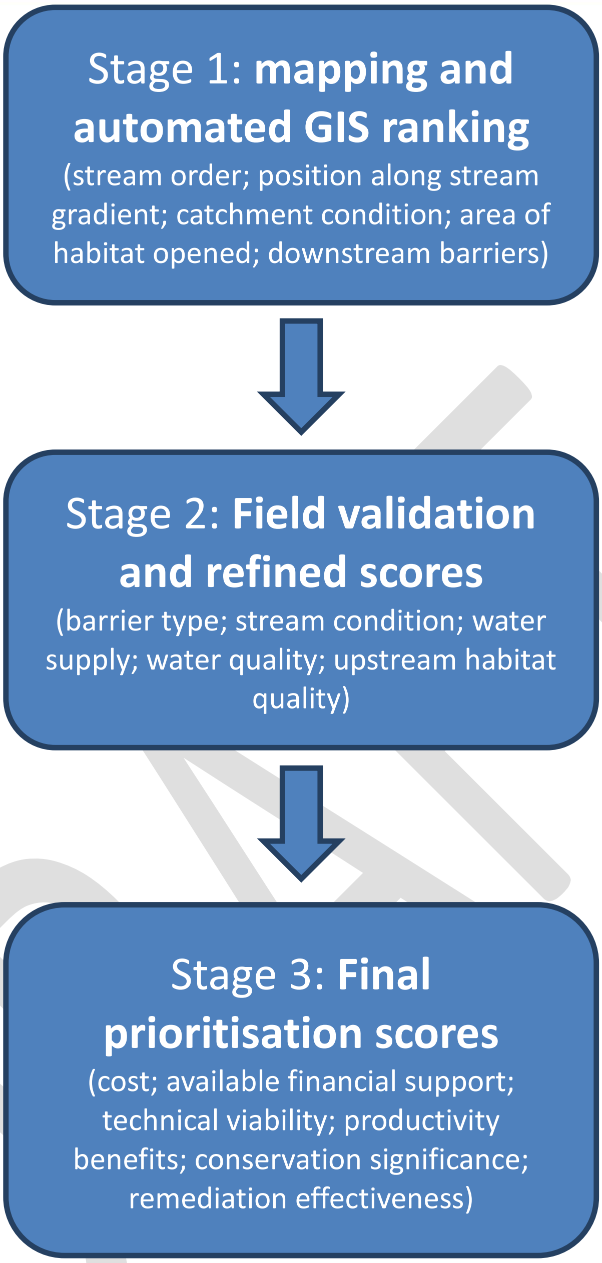


Figure 4.2. The three stage process used to prioritise fish barriers for remediation in the Fitzroy Region.

4.2. Results

Stage 1 of the original FBFPP identified a total of 10,632 potential barriers to fish passage: 10,502 in-stream (Figure 5.1) and 131 off-stream in wetlands. After applying the five initial criteria, this was refined down to the top 150 potential in-stream barriers for further investigation.

Field validation in Stage 2 identified that 59 of the 150 potential barriers identified in Stage 1 represented actual barriers to fish migration (Figure 5.2). Data collection during the field visits allowed ranking of these 59 actual barriers. The application of the criteria in Stage 3 produced the final priority list of the top 30 barriers for remediation efforts.

The 2015 re-assessment considered the 59 barriers identified at Stage 2 of the original process (Figure 5.2). It used these 59 rather than the final 30 from Stage 3 in order to start the re-assessment process with a focus on fish community impacts rather than broader social, economic and logistical considerations. Although these other considerations are important, the purpose of the re-assessment was to allow the significant fish barriers to be considered in a broader integrated process including the Wetlands DSS, Blue Maps and Eco Calculator, and as such it was important to focus the re-assessment directly on impacts to fish passage.

The re-assessment primarily accounted for 13 priority structures that had been remediated to varying degrees since the 2008 assessment (Table 5.1 and Figure 5.3). The remediation efforts resulted in the remediated barriers being removed from the priority list, and the scores for remaining barriers being adjusted due to changes in the number of downstream barriers due to the restoration efforts. As a result, the top 46 fish barriers to target remediation in the Fitzroy Region have been identified (Table 5.2 and Figure 5.3).

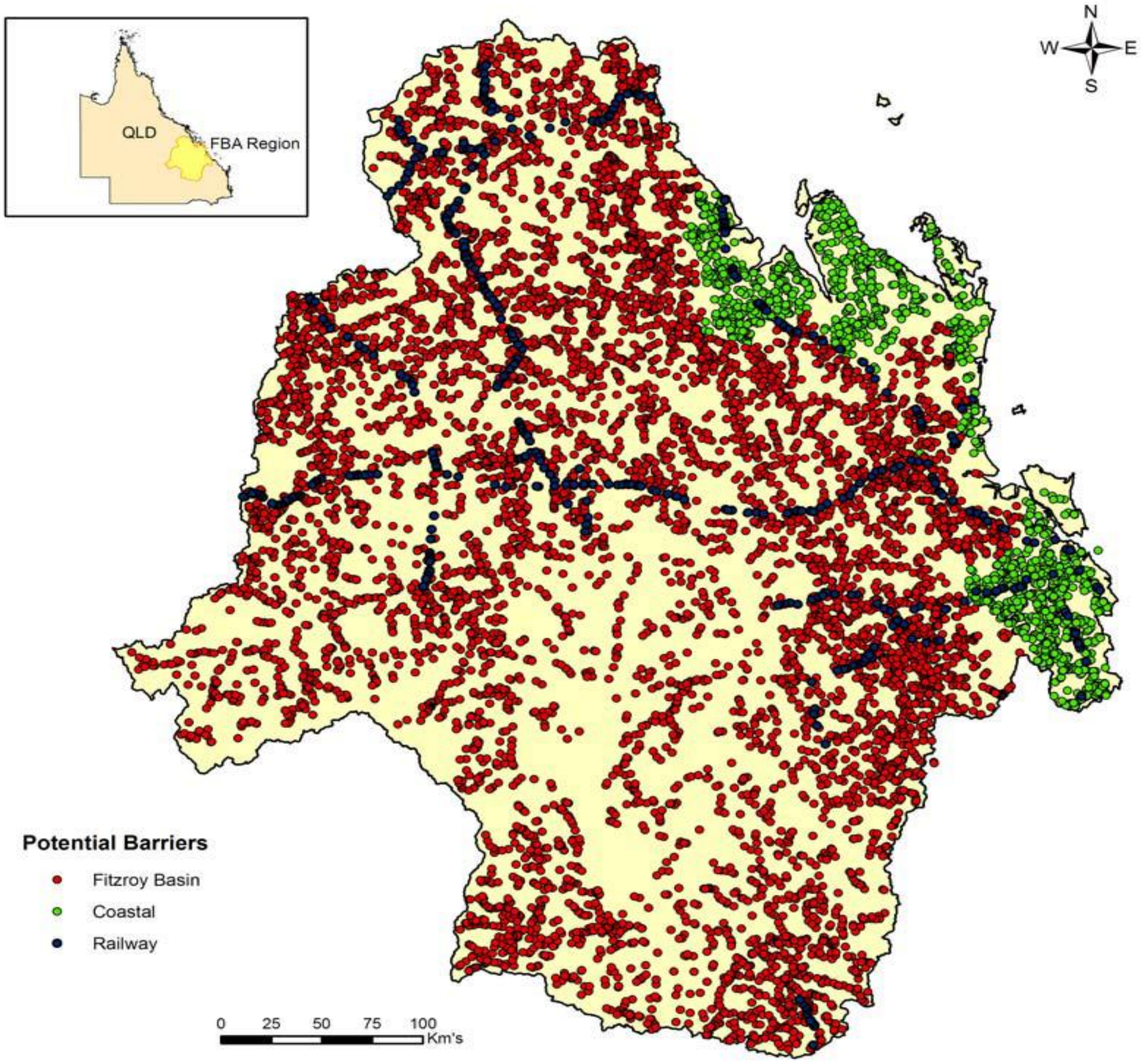


Figure 5.1. The 10,502 potential in-stream barriers within the Fitzroy Basin Association Region identified during Stage 1 of the 2008 prioritisation process.

(Source: Moore & Marsden 2008.)

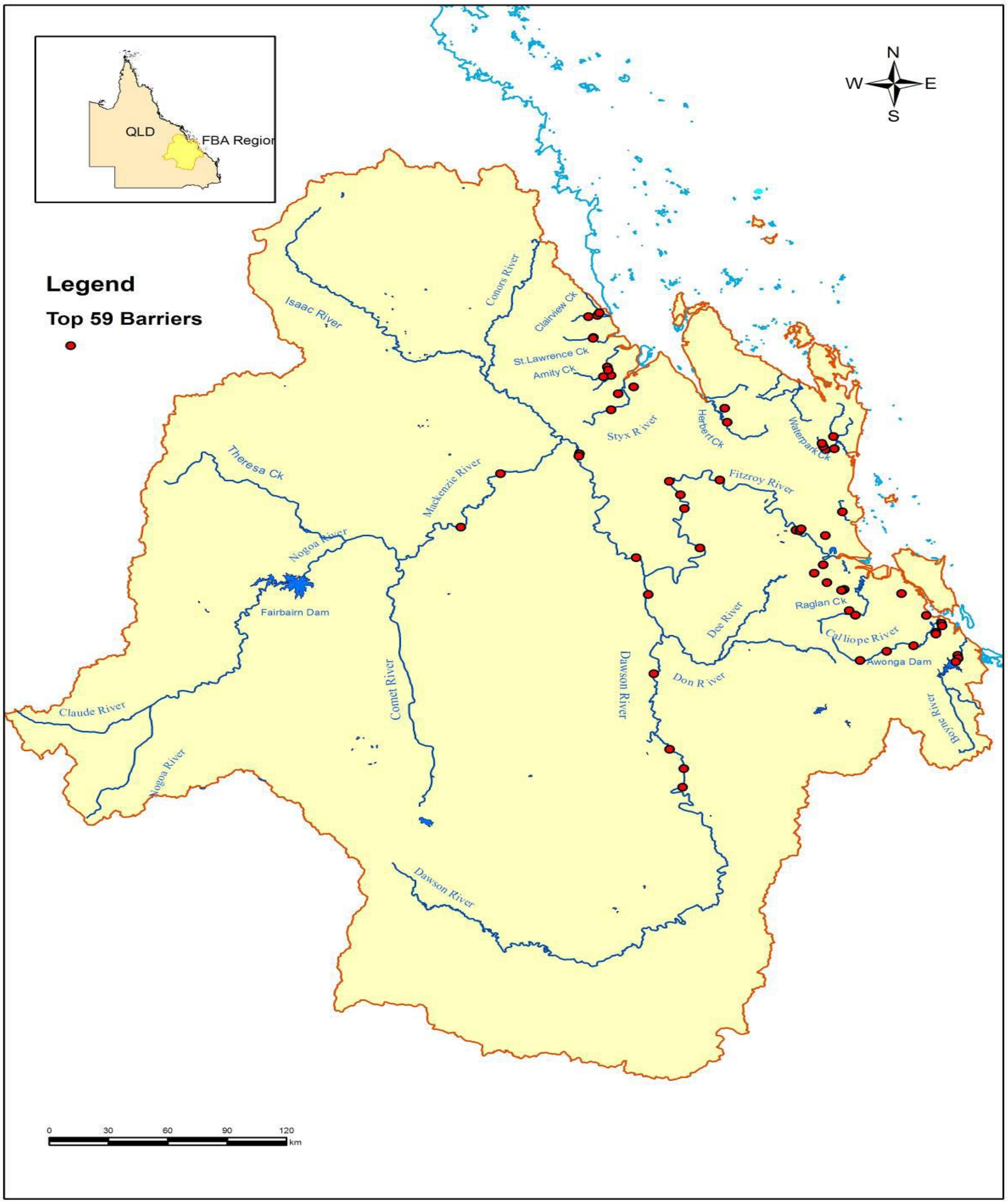


Figure 5.2. The top 59 priority fish barriers in the FBA region as identified during Stage 2 of the 2008 prioritisation project

(Source: Moore & Marsden 2008)

Table 5.1. Fish passage barriers within the FAB region that have been remediated since the 2008 prioritisation project, and were therefore removed from the re-assessment in 2015.

Barrier ID	Stream Name	Barrier Name/Type	Remediation action	Transparency
6474	Fitzroy R	Fitzroy Barrage	Fishway installation	Low
1	Fitzroy R	Eden Bann Weir	Fishway installation	Moderate
5	Dawson R	Neville Hewitt Weir	Fishway installation	High
6	Dawson R	Moura Weir	Fishway installation	Moderate
9348	Amity Ck	Tidal interface crossing/Bund	Fishway installation	Very High
1042	Bridge Ck	Wumalgi/Pipes	Fishway installation	Very High
9002	Cattle Ck	Old Hwy/Pipes	Removal	Very High
9441	Clairview Ck	Creek Crossing	Removal	Very High
531	Moore's Ck	Botanical Gardens/Pipes	Fishway installation	High
527	Stony Ck	Creek Crossing-Byfield S.Forest	Fishway installation	Very High
529	Stony Ck	Daddy's Crossing/Byfield S.Forest	Fishway installation	Very High
8945	Water Park Ck	Water Park Ck Weir	Fishway installation	Moderate
9392	Wran Ck	Weir/Pipes	Fishway installation	Moderate

(Source: Marsden 2015).

Table 5.2. Prioritisation of the 46 fish passage barriers in the FBA region, re-assessed in the 2015 project.

Priority	Barrier ID	Stream Name	Barrier Name/Type
1	524	Fitzroy R	Redbank Crossing
2	1000	Boyne R	Mann's Weir
3	523	Fitzroy R	Hanrahan's Crossing
4	3951	Fitzroy R	Glenroy Crossing
5	3952	Fitzroy R	Craiglee Crossing
6	535	Amity Ck	Wumalgi Rd/Pipes
7	9001	Boyne R	Awonga Dam
8	6169	Serpentine Lagoon	Tidal interface bund wall
9	9393	St Lawrence Ck	St Lawrence Weir
10	8652	Calliope R	Blackgate Rd/Pipes
11	8618	Calliope R	Mt Alma Rd Crossing/Pipes
12	8677	Clairview Ck	Clairview Weir
13	2	Mackenzie R	Tartrus Weir
14	525	Mackenzie R	Duaringa Apis Ck Rd
15	3	Mackenzie R	Bingegang Weir
16	8354	Boyne R	Pikes Crossing
17	8716	Amity Ck	Old Hwy/Pipes
18	9718	Lake Callemondah	Barrage
19	25	Raglan Ck	Langmom Rd/Pipes
20	4	Mackenzie R	Bedford Weir
21	534	Montrose Ck	Weir/Town water supply
22	22	Raglan Ck	Upper Raglan/Pipes
23	85	8 Mile Ck	Bajool Weir
24	9165	Black Swan Ck	Flinders Rd-Rundle Ranges
25	3015	Mackenzie R	Tartrus Road Crossing
26	4152	Dawson R	Boolburra/Pipes
27	528	Stony Ck	Byfield State Forest
28	82	12 Mile Ck	12 Mile CK Rd/ Pipes
29	8731	Stoodleigh Ck	Barretts Rd/Pipes
30	9629	Sandy Ck	Next to railline/Pipes
31	530	Stony Ck	Freeman's Crossing
32	9000	Ewen Ck	Stanage Bay Rd/Pipes
33	526	Lake Callemondah (Police Ck)	Creek Crossing
34	1032	Oakey Ck	Archer Station/Pipe
35	8784	Tooloombah Ck (Styx)	Rocky Crossing
36	6348	Dawson R	Nuns Crossing
37	9550	Block Ck	Stanage Bay Rd/Pipes
38	9192	Unnamed	Wydham Rd-Gladstone/Pipes
39	69	12 Mile Ck	2nd Barrier u/stream Pipes
40	9041	Coorooman Ck	Coorooman Ck Rd/Culverts
41	6144	12 Mile Ck	3rd Barrier u/stream Pipes
42	6198	Nankin Ck	Thompsons Pt Rd/ Culverts
43	8642	Unnamed	Harvey St - Gladstone/Pipes
44	532	Moore's Ck	Musgrave St weir
45	2664	Dawson R	Kianga River Rd/Pipes
46	8606	Calliope R	Pipes

(Source: Marsden 2015).

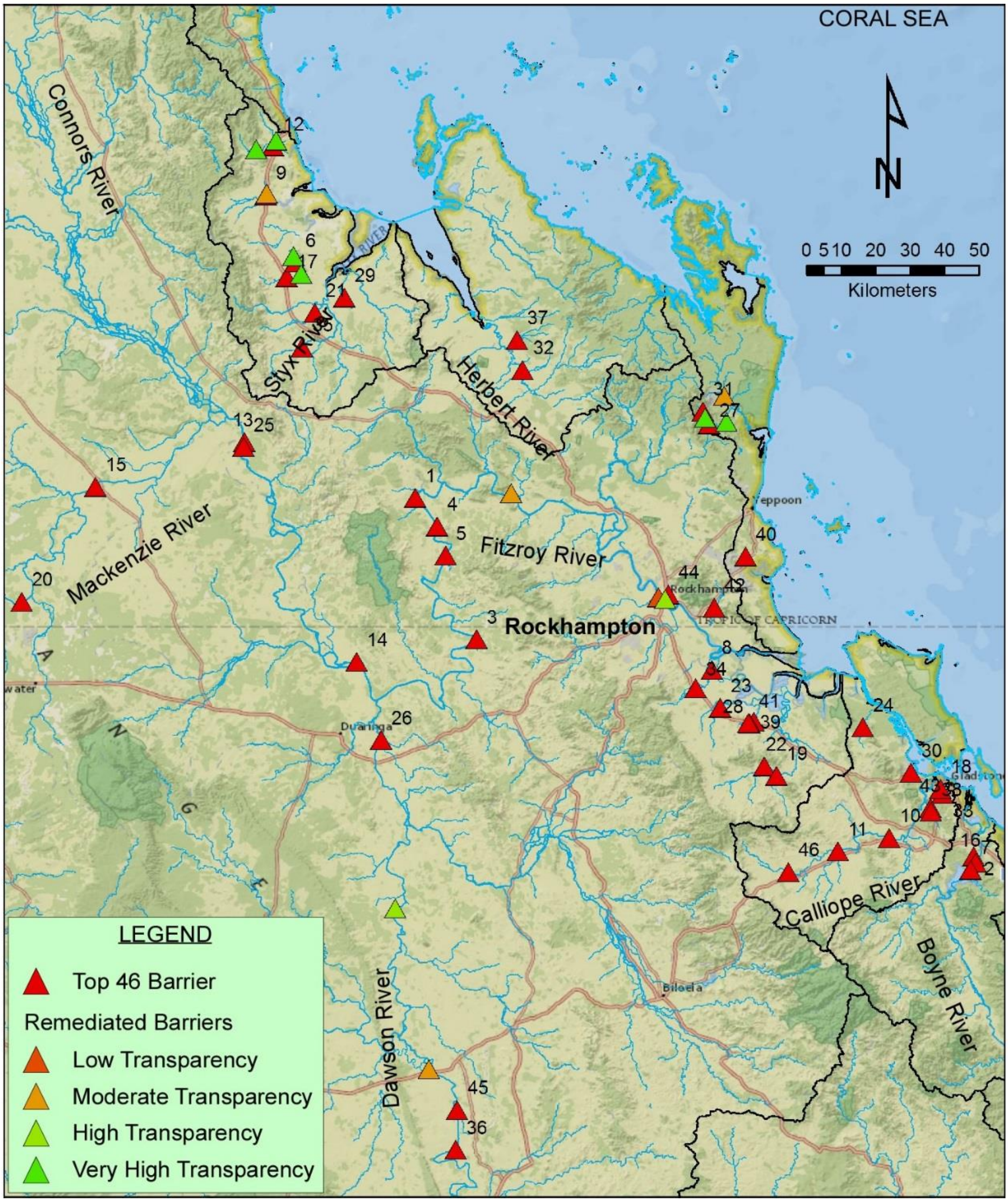


Figure 5.3. Location of the 46 barriers re-prioritised in the 2015 assessment, and the 13 barriers remediated to varying degrees since the 2008 assessment

(Source: Marsden 2015).

4.3. Outcomes and Issues

The original FBFBPP guided the remediation of 13 barriers to fish passage. This has improved connectivity within the basin, re-connected previously isolated populations, and opened more habitat for migratory fish species to utilise. The revised priority list from the 2015 re-assessment provides an update to guide further works on in-stream barriers (Table 5.2 and Figure 5.3). As it was intended, this process is focussed on prioritising in-stream barriers for remediation that provide the greatest benefit for the basin as a whole. The 2015 report (Marsden 2015) identified a number of gaps and issues that need addressing in order to realise the best outcomes from fish passage remediation efforts within the FBA region.

The FBFBPP specifically ***excluded barriers in wetlands***, ponded pastures and other off-stream habitats in Stage 1 of the process. Because the focus of the FBFBPP was on connectivity for migratory fish throughout the region, and particularly for diadromous species of fisheries significance, it prioritised only in-stream barriers with more weight given to those in the coastal reaches of rivers. With such a focus, off-stream wetlands represent individual potential end-points of migrations by such species, while upland rivers may be beyond their natural range, and therefore these systems receive low weighting in the prioritisation process. Marsden (2015) noted that these upland and off-stream habitats are particularly important for a range of species, including local diadromous fishery species such as barramundi, and recommended that future prioritisations could be stratified to ensure these areas are represented in future priority lists.

In the original 2008 report, Moore and Marsden (2008) point out that while off-stream wetlands have a range of values for biodiversity, we currently lack the understanding of their functional values to allow their inclusion within the prioritisation framework. For example, while many ponded or bunded wetlands potentially provide valuable habitat for fish such as barramundi, without a clear understanding of the dynamics of flooding and physical connectivity, and of immigration, occupation and emigration by fishes, it is impossible to understand the actual functional values of individual wetlands, or their responses to remediation actions. For example, a potential barrier to fish passage on a wetland may in fact be the only thing that causes retention of enough water to allow the successful occupation by fish; while conversely, the barrier may create a temporary wetland that attracts large numbers of recruiting fishes, but subsequently dries out before successful emigration, thereby forming a death trap for fish. Without a clear understanding of these issues, it is not currently possible to include bunded or ponded pastures into the assessment. The 2015 re-assessment made a clear recommendation that further work is undertaken to understand how flood plain wetlands function for fish so that they can be included into future assessments.

The previously high priority barriers that had undergone some level of remediation were removed from the 2015 re-assessment. This occurred even where the remediated barrier was still considered to provide low transparency for fish (i.e. poor passage, or still remains a significant barrier — e.g. Fitzroy Barrage, Figure 5.3). There is a need (identified in the report) to assess the effectiveness of remediation efforts to ensure positive outcomes from investments. This is particularly important in relation to considering further fish passage works in the basin. For instance, the Fitzroy Barrage lies at the head of the Fitzroy River estuary, and despite the addition of a fishway between the 2008 and 2015 assessments, it is considered to have low transparency, i.e. it remains a significant barrier to fish passage under many conditions. As such, works to improve fish passage in any areas upstream of the barrage may be ineffective if the downstream barrier remains.

The report also notes the importance of assessing the effectiveness of remediation works in improving fish passage, the appropriate management of any fish passage structures (e.g. fishway), and the need for regular re-assessment of the functionality of existing fishways. It is recommended that this become part of the integrated decision support tool so that managers can make informed choices among options based on the performance and practical effectiveness of previous remediation efforts.

5. An Integrated System Repair Prioritisation Tool

The outputs of the individual prioritisation tools were combined to generate an overall scoring system for each Neighbourhood Catchment within the FBA region (Figure 2.2) based on a combined score from the FBFBPP, the Wetlands DSS, and Blue Maps. This integrated tool identifies the sub-basins where management actions can have the greatest impact for the health and wellbeing of the GBR. The aim is to provide multiple outcomes at the targeted sites ensuring funding is gaining the best economical outcomes in tandem with the most appropriate system repair actions.

5.1. Methods

The outputs of the Wetlands DSS (Figure 3.2), Blue Maps (Figure 3.3) and the Fish Barrier Prioritisation 2015 (Table 5.2 and Figure 5.3), were combined to provide an overall score for each Neighbourhood Catchment within the FBA region (Figure 2.2). The aim was to identify areas where remediation works or management actions could potentially provide multiple benefits across a range of values, thereby providing the best returns on investment. ***The outputs of the integrated prioritisation should not be considered as a final ranking for action, but rather as identifying areas to be considered more closely for the potential for synergistic benefits from any particular management action.***

To combine the outputs from each tool, scores from the Wetlands DSS and Fish Barrier Prioritisation were first standardised to range from 1–10, with the highest scoring barrier or wetland rescaled to 10, and the lowest scoring of those considered rescaled to a score of 1. The 46 fish barriers ranked during the 2015 re-assessment (Table 5.2 and Figure 5.3) were rescaled based on the Stage 2 scores from that re-assessment. This means the scores reflect impacts on fish passage without regard to capacity or cost of remediation. The result is that fish barriers having the greatest impact on fish passage in the basin are scored most highly. The 20 wetlands prioritised in the 2015 Wetlands DSS for the FBA region (Figure 3.1) were rescaled in the same way, based on the overall score, which combines the scores for ’Values’, ’Threats’ and ’Capacity’.

Scores were then summed for each Neighbourhood Catchment (NC) within the FBA. Individual fish barriers were always within a single NC, and an individual NC may contain more than one ranked fish barrier. Wetlands may span across NC boundaries, and so scores for an individual wetland may apply to more than one NC. As for fish barriers, an individual NC may contain more than one ranked wetland. All NCs were then sorted based on the pooled Fish Barrier and Wetlands DSS scores, and only the 61 NCs containing at least one ranked barrier or wetland were considered further.

Each of the NCs containing at least one ranked barrier or wetland was then given a score based on the Blue Maps measure of connectivity to the GBR. The proportion of the total area of each NC within each of the four Blue Maps connectivity frequency categories was calculated. These proportions were weighted (multiplied) as follows: 'Very Frequently Connected' = 4; 'Frequently Connected' = 3; 'Intermittently Connected' = 2; and 'Infrequently Connected' = 1. The resulting scores could theoretically range between 400 (for an NC that was 100% VFC) to 100 (an NC 100% Infrequently Connected). As for the other outputs, these scores were rescaled to range from 1–10 with the highest scoring NC rescaled to 10, and the lowest scoring to 1. The final integrated scoring system then simply summed together the standardised scores from the Fish Barrier, Wetlands DSS, and Blue Maps tools to give an overall score for each of the 61 NCs considered.

5.2. Results

The two highest scoring NC sub-regions, F27 and F2 (Figure 6.1 and Table 6.1) scored highly across all three components, each contained multiple highly ranked fish barriers and wetlands, and are highly connected to the GBR. F27 includes the Fitzroy estuary while F2 spans from the Styx River to St Lawrence Creek (Figure 2.2).

The next 10 highest scoring NCs (F17-T29) tended to score highly in only one or two of the three sub-tools, indicating while these regions may contain multiple barriers or wetlands, they tend not to contain both (Table 6.1). Only three of the remaining 49 NCs contained both fish barriers and wetlands ranked by the individual tools. Some of these 49 NCs contain highly ranked barriers or wetlands despite scoring poorly in the integrated assessment. For example, F18 contains a single ranked feature, Hanrahans Crossing, which received the equal second-highest score of any fish barrier in the entire FBA region (Marsden 2015). Similarly, F21 contains part of the Lake Mary Complex, which was the 9th highest scoring wetland in the Wetlands DSS, yet as the only ranked feature in F21, this NC scores poorly in the integrated assessment.

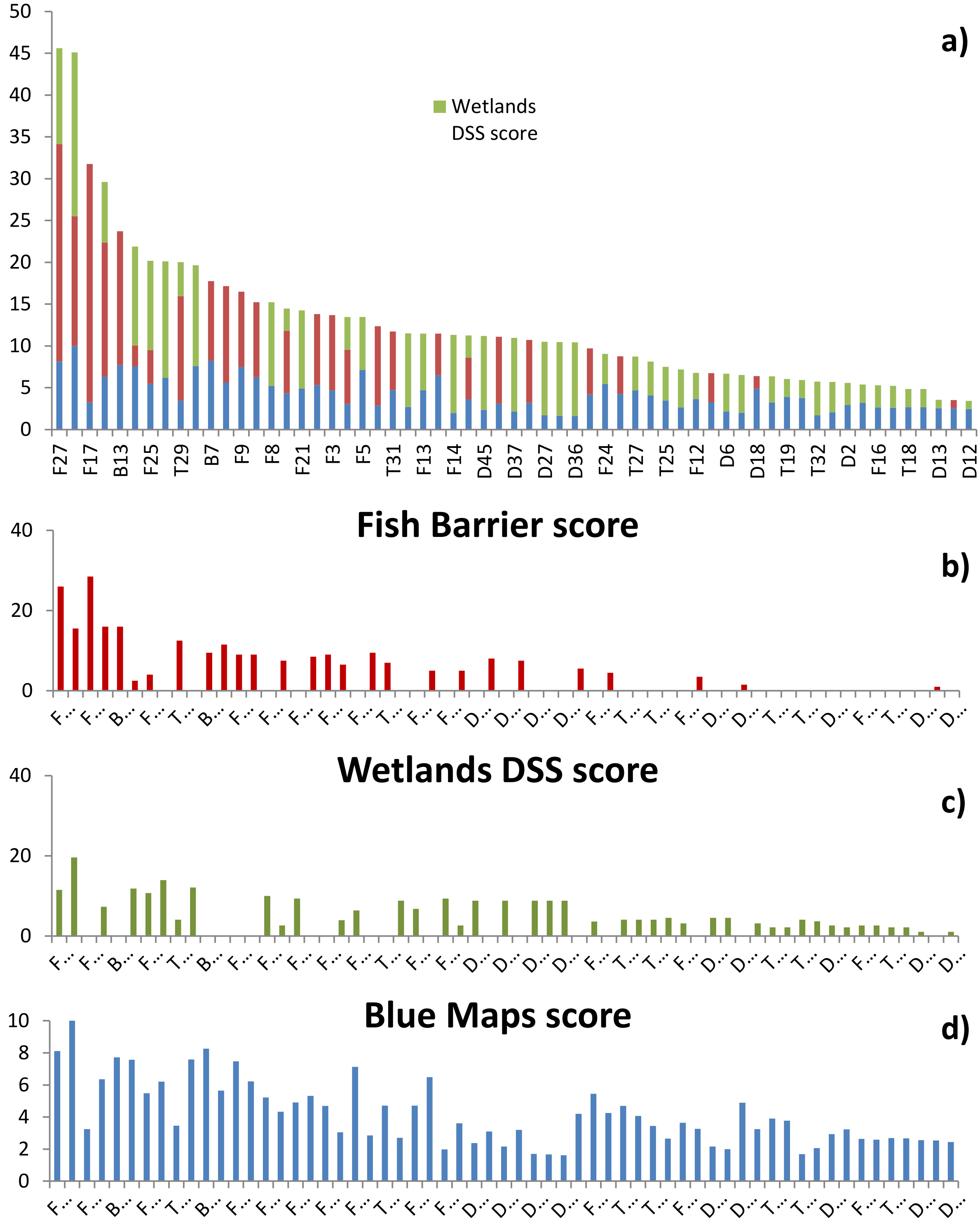


Figure 6.1. a) Integrated prioritisation of FBA Neighbourhood Catchments based on the sum of the re-scaled scores for: b) Fish Barriers, c) Wetlands DSS, and d) Blue Maps. The location of each NC within the FBA region is indicated in Figure 2.2.

Table 6.1. Integrated scores for FBA region Neighbourhood Catchments.

NC ID	Blue Maps score	Fish Barrier score	Wetlands score	ITEGRATED RANKING SCORE	Blue Maps Ranking	Barrier Ranking	Wetlands Ranking
F27	8.12	26	11.51	**45.62**	3	2	5
F2	10.00	15.5	19.60	**45.10**	1	4	1
F17	3.25	28.5		**31.75**	65	1	nr
F1	6.35	16	7.27	**29.62**	12	3	10
B13	7.72	16		**23.72**	4	3	nr
F15	7.57	2.5	11.81	**21.88**	6	19	4
F25	5.48	4	10.69	**20.17**	17	17	6
F7	6.21		13.91	**20.12**	14	nr	2
T29	3.47	12.5	4.05	**20.02**	58	5	14
F26	7.59		12.06	**19.66**	5	nr	3
B7	8.27	9.5		**17.77**	2	7	nr
F28	5.64	11.5		**17.14**	16	6	nr
F9	7.48	9		**16.48**	7	8	nr
B1	6.23	9		**15.23**	13	8	nr
F8	5.22		10	**15.22**	20	nr	7
T39	4.33	7.5	2.64	**14.47**	34	11	19
F21	4.91		9.35	**14.26**	23	nr	8
B12	5.33	8.5		**13.83**	19	9	nr
F3	4.69	9		**13.69**	29	8	nr
F6	3.05	6.5	3.91	**13.46**	78	13	15
F5	7.13		6.33	**13.46**	8	nr	12
F18	2.85	9.5		**12.35**	86	7	nr
T31	4.72	7		**11.72**	28	12	nr
D47	2.71		8.81	**11.52**	89	nr	9
F13	4.72		6.77	**11.49**	27	nr	11
B6	6.48	5		**11.48**	11	15	nr
F14	1.98		9.35	**11.32**	153	nr	8
D3	3.62	5	2.64	**11.26**	52	15	19
D45	2.37		8.81	**11.18**	121	nr	9
B10	3.09	8		**11.09**	75	10	nr
D37	2.16		8.81	**10.97**	133	nr	9
B9	3.20	7.5		**10.70**	69	11	nr
D27	1.70		8.81	**10.51**	168	nr	9
D48	1.67		8.81	**10.48**	171	nr	9
D36	1.62		8.81	**10.43**	174	nr	9
T35	4.19	5.5		**9.69**	37	14	nr
F24	5.45		3.60	**9.05**	18	nr	17
F4	4.25	4.5		**8.75**	36	16	nr

NC ID	Blue Maps score	Fish Barrier score	Wetlands score	ITEGRATED RANKING SCORE	Blue Maps Ranking	Barrier Ranking	Wetlands Ranking
T27	4.69		4.05	**8.74**	30	nr	14
T28	4.07		4.05	**8.12**	43	nr	14
T25	3.45		4.05	**7.50**	59	nr	14
D8	2.66		4.52	**7.18**	98	nr	13
F12	3.64		3.13	**6.77**	51	nr	18
D30	3.26	3.5		**6.76**	64	18	nr
D6	2.15		4.52	**6.67**	135	nr	13
D7	2.00		4.52	**6.52**	151	nr	13
D18	4.88	1.5		**6.38**	25	20	nr
F19	3.25		3.13	**6.38**	66	nr	18
T19	3.90		2.16	**6.06**	44	nr	20
T20	3.77		2.16	**5.93**	48	nr	20
T32	1.69		4.05	**5.74**	169	nr	14
D10	2.07		3.64	**5.71**	146	nr	16
D2	2.93		2.64	**5.57**	83	nr	19
T21	3.22		2.16	**5.39**	67	nr	20
F16	2.64		2.64	**5.28**	100	nr	19
D1	2.59		2.64	**5.24**	103	nr	19
T18	2.68		2.16	**4.85**	94	nr	20
T14	2.67		2.16	**4.84**	96	nr	20
D13	2.55		1	**3.55**	108	nr	21
B8	2.54	1		**3.54**	110	21	nr
D12	2.44		1	**3.44**	118	nr	21
D5	2.32		1	**3.32**	123	nr	21

Note: The individual re-scaled scores for each NC are provided from Blue Maps, Fish Barrier Prioritisation, and the Wetlands DSS, as well as the final integrated scores. Note that individual barriers and wetlands were scored between 1 and 10, so an NC with a score >10 indicates it contains more than one ranked barrier or wetland. For 'Barrier Ranking' and 'DSS Ranking', "nr" indicates *not ranked*, i.e. did not contain a ranking barrier or wetland. Blue Maps rankings reflect rank for all NCs within the FBA region.

5.3. Considerations and Limitations

The integrated prioritisation tool combining outputs from prioritisations of fish barriers, wetlands, and connectivity to the GBR provides an indication of areas within the FBA region that contain multiple ranking wetlands or barriers, with high connectivity to the GBR. As such, these areas should be examined more closely when considering particular management actions. These areas provide the greatest potential for achieving synergistic benefits across multiple values when management actions are undertaken, thereby maximising outcomes for investment. However, any particular action within the highest ranking Neighbourhood Catchments (NCs) from the integrated assessment will not necessarily produce the desired outcome for a variety of reasons (explained below). To achieve the overall goal of most efficiently improving ecosystem health, it is absolutely critical to ***understand the functioning of each individual tool, and the limitations of the process of combining these into a single score***.

The current integrated tool gives equal weighting to outputs from each of the three sub-tools, and to the highest and lowest ranked features in each. The highest ranked fish barrier is given equal weight to the highest ranked wetland, and the re-scaled scores for wetlands, fish barriers, and Blue Maps are given equal weighting in the summed score for each NC. It is unlikely that remediating the highest ranked fish barrier and highest ranked wetland would provide equivalent benefits for the basin and the GBR, yet if considered as a ranked priority list, the current prioritisation assumes they would. As was clearly stressed by the developers of each of the sub-tools, it is critical to ***have clear management objectives that guide the prioritisation process, since outcomes depend greatly on value judgements of the end-users.***

Final scores in the integrated ranking are the sum of re-scaled scores for individual features within the NC. As such, while high-scoring NCs tend to contain multiple ranked features, high-ranking barriers or wetlands may be the only ranking feature within an NC, and so may gain a poor score in the integrated assessment. Based on the detailed process for each individual prioritisation, remediation of these high-ranking features may produce wide-reaching benefits for the basin and the GBR even though they lie isolated in low-scoring NCs. Therefore it is important to ***consider the outcomes of the individual prioritisations together with that of the integrated tool***.

Many factors are considered across multiple sub-tools. Where they are assigned equivalent value and weighting, the result is an inflation of the final score based on scoring multiple times for a given factor. Conversely, where the different sub-tools assign conflicting values to a single factor, the effect is for the scores to cancel out. For example, each of the three sub-tools has a clearly acknowledged downstream bias, whereby features or areas closer to the coast receive greater weighting. When the outputs of the individual tools are combined, the importance of downstream areas is greatly inflated over those upstream. While the overall objective of the program is to improve the resilience of the GBR, it is not clear that the final inflated scores with a strong downstream bias accurately reflects the impacts or benefits of remediation actions in different parts of the basin. Another example is the treatment of fish passage barriers, which are considered in both the Fish Barrier and Wetlands DSS tools (more than once in each). A large area of potentially valuable wetland habitat above an impassable fish barrier would score highly in the barrier prioritisation because remediation of the barrier would open access to a significant area of valuable habitat, while the same area would score poorly in the Wetlands DSS, because action in the wetland would have limited benefit if fish cannot access it. The significance of these factors in the final prioritisation clearly depends on value judgements and the aims of the end-users. Having a system that simply cancels such scores out or over-inflates them is not satisfactory. Therefore it is important to ***re-evaluate the individual tools in a comprehensive way to ensure that factors or processes are treated equivalently in each, and that redundant scoring is removed to avoid 'double dipping' or over-inflating final scores based on repeated score for a single factor.***

The final rankings are based on scores that consider only features that lie within the boundaries of each NC. Fish barriers downstream, or connectivity to wetlands or other valuable habitat upstream are not currently included in the final scores. Clearly when the underlying aim is to make improvements that have the widest-reaching outcomes, it is important to ***further develop the integrated prioritisation to include upstream and downstream connectivity with other ranked wetlands or barriers beyond the boundaries of each individual NC***. While the current prioritisations are heavily weighted towards downstream areas with greater connectivity to the GBR, it is still possible that individual sites for management action may be influenced by downstream impacts.

High scoring NCs may not necessarily indicate opportunities for actions that have broader impacts. This is because even though they may occur within the same catchment, individual barriers or wetlands within the NC may have little or no interaction with each other. While high scoring NCs do indicate higher potential for such synergies, it is critical to carefully ***evaluate actual synergies within candidate NCs before actions are planned***.

The integrated prioritisation only considers fish barriers or wetlands that were ranked by the individual prioritisation tools. The fish barrier prioritisation initially identified some 10,500 potential barriers within the FBA region, with the final prioritisation ranking the top 46 for action. Similarly, the Wetlands DSS 2 applied to the FBA region considered only 40 wetlands from the region and prioritised the top 20. The individual tools were developed and implemented by experts in their respective fields, and the outputs clearly identify the fish barriers and wetlands of highest priority for action. However, unranked barriers or wetlands must be considered when aiming to obtain the greatest basin-wide outcomes for any management actions. For example, high priority wetlands may be completely inaccessible to migratory fish due to unranked fish passage barriers that have not been considered. Likewise, small management actions may provide access to or improvement of large areas of low- or non-ranked wetlands. So while it is clear that individual high-ranked fish barriers and wetlands should be prioritised for management actions, it is critical to ***fully consider the potential for un-ranked features to seriously impact on the success of any management action at priority sites.***

There is a clear need to monitor and evaluate the success of previous remediation works in order to guide the most efficient effort on future works. For example, as pointed out by Marsden (2015), the 2015 re-assessment of fish barriers excluded those on which some remediation works had been completed since the previous assessment, regardless if the remediation works were entirely effective. As a consequence, it is possible that ineffective prior works may reduce the benefit of future works on other connected features. For example, remediation of wetlands above the Fitzroy Barrage is based on the assumption that the fishway on the barrage provides effective passage. Efforts to improve fish habitat above the barrage may be ineffective if the barrage itself remains a significant barrier to fish. Therefore, ***robust evaluation of the success of remediation or repair works is an essential component of any process aimed at gaining the greatest benefit from limited funds***.

No single score can effectively reflect the full range of values or considerations when prioritising these systems for remediation works. So while the integrated prioritisation tool presented here identifies areas within the FBA region that contain multiple ranked features of interest, careful consideration of the individual components and factors that underpin each sub-tool is critical if the maximum benefits from remediation or repair actions are to be realised.

6. Recommendations

The documented prioritisation processes throughout this publication are meant to guide the end user and therefore it would be disadvantageous to rely on a single final score to prioritise management actions based on complex and detailed individual processes. Doing so assumes that the final scores accurately reflect the goals and values of the end-user. It is essential to fully understand each of the sub-components so that the final prioritisation does reflect the aims, and achieves the goal of maximising benefit from investments.

Decision support tools such as this integrated prioritisation tool aim to *support* decision making by assembling and presenting the complex of relevant information in a way that can be understood by decision makers, and communicated to the broader community so that the process is transparent. They are not intended to make decisions in themselves. Rather, they provide the rationale behind decisions in a way that people can clearly understand how and why particular features rank highly or poorly in the priority list. Each of the sub-components is a flexible system (except Blue Maps), and the outcomes will vary depending on the specific goals, objectives and value judgements of the user. As such, it is essential that any time the tool is used, that a clear set of objectives is defined, and the weighting for each of the scoring criteria are adjusted to meet the stated objectives.

The key recommendations arising from this report are:

- **Understand the functions of each individual tool, and the limitations of the process of combining these into a single score.**
- **Have clear management objectives that guide the prioritisation process, since outcomes depend greatly on value judgements of the end-users.**
- **Consider the outcomes of the individual prioritisations together with that of the integrated tool**.
- **Re-evaluate the individual tools in a comprehensive way to ensure that factors or processes are treated equivalently in each, and that redundant scoring is removed to avoid 'double dipping' or over-inflating final scores based on repeated score for a single factor.**
- **Further develop the user-interface of the integrated prioritisation tool to include upstream and downstream connectivities with other ranked wetlands or barriers beyond the boundaries of each individual NC**.

- **Evaluate actual synergies within candidate NCs before actions are planned**.

- **Consider the potential for un-ranked features to seriously impact on the success of any management action at priority sites.**

- **Robust evaluation of the success of remediation or repair works is an essential component of any process aimed at gaining the greatest benefit from limited funds**.

The ideal final tool for prioritising work in the FBA region will provide not only a single final score for each NC, but will allow the user to drill down through layers that represent and capture the complexities of each individual sub-tool, thereby allowing management decisions to be based on a full appreciation of the complexity and connectivity among different parts of the basin.

7. Closure

This document was prepared for FBA in collaboration with our Program partners. If you have any questions or require additional details, please contact the Fitzroy Basin Association Inc. Rockhampton QLD.

8. References

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