Queensland **the Smart State**

Fitzroy Basin Fish Barrier Prioritisation Project

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Department of Primary Industries and Fisheries

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Cover Figure: Photographs of barriers to fish passage (Clockwise: Mackenzie River, Clairview Creek, Waterpark Creek and Stony Creek), photograph of barramundi by Gunther Schmida.

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Glossary of Terms

Diadromous - Diadromous fishes are truly migratory species whose distinctive characteristics include that they (i) migrate between freshwaters and the sea; (ii) the movement is usually obligatory; and (iii) migration takes place at fixed seasons or life stages. There are three distinctions within the diadromous category, catadromous, amphidromous and anadromous.

- Catadromous - Diadromous fishes which spend most of their lives in fresh water, and migrate to sea to breed.
- Amphidromous - Diadromous fishes in which migration between freshwater and the sea is not for the purpose of breeding, but occurs at some other stage of the life cycle.
- Anadromous - Diadromous fishes which spend most of their lives at sea, and migrate to freshwater to breed.

Potamodromous - fish species whose migrations occur wholly within freshwater for breeding and other purposes.

Acronyms

DPI&F - Department of Primary Industries and Fisheries

FBA - Fitzroy Basin Association

GIS – Geographic Information System

FBFBPP - Fitzroy Basin Fish Barrier Prioritisation Project

Introduction

Australia has just over 300 species of freshwater fishes (Allen *et al*. 2002), of which around 49 are found in freshwater streams of the FBA region. Almost half (23) of the species found in the regions streams are diadromous, requiring free access to estuarine or marine waters to successfully complete their life cycles. The remaining species complete their entire life cycle in freshwater, with a large proportion of these (23) undertaking significant migrations. Fish migration between marine and freshwater habitats and within freshwater habitats is therefore a vitally important aspect of the life cycle of freshwater fishes of the FBA region. Barriers preventing fish passage contribute to the loss of species diversity within fish communities, severely impacting the health of the regions aquatic eco-systems and is one of the main impacts that man has had on the fish communities of the region.

FBA Region

The FBA region is located on the central Queensland coast and covers an area of approximately 156,000km², encompassing five sub-regions and over a dozen large river catchments. The FBA region comprises the entire Fitzroy Basin and coastal catchments from the Boyne River in the south to Clairview Creek in the north. The region boasts a sub-tropical climate, typified by variable rainfall, high evaporation rates and prolonged dry periods followed by floods (Cotton Catchment Communities CRC, 2007).

The FBA region encompasses major systems of the Fitzroy, Boyne and Calliope rivers as well as many other short coastal streams along its entire length. The Fitzroy catchment (142 000km²) is the second largest river system draining the east coast of Australia, and the largest running into the world heritage listed Great Barrier Reef (Dougall *et al*. 2007). Six major rivers drain the Fitzroy catchment, the Isaac-Connors, Dawson, Nogoa, Comet, Mackenzie and Fitzroy rivers, entering the sea at Rockhampton. While the Boyne and Calliope rivers drain the southern part of the region entering the sea at Gladstone.

The predominant land use in the FBA region is rangeland grazing, which covers 80.58% of the basin, followed by cropping 6.04%, state forests 5.11%, national parks 3.22%, irrigation 0.48%, mining 0.35%, urban 0.09% and ‘other’ making up 4.12% (Hassall and Associates Pty Ltd, 1997). The region is home to approximately 200,000 people, mainly situated on the coastal fringe around the major urban centres of Rockhampton, Gladstone and Yeppoon. The Fitzroy Basin generally has low population densities, particularly in the northern and western parts of the basin.

Since European settlement, the region has been heavily impacted, with large-scale alterations of natural river systems and the clearing of vegetation for grazing. Landuse impacts include changes in hydrology, landscape water balance, declining water quality, removal of riparian vegetation and the installation of barriers to fish passage. Importantly increased sediment and nutrient loads due to adverse surrounding land use practices have been linked to the degradation of freshwater, estuarine and marine eco-systems, including the Great Barrier Reef Marine Park (Dougall *et al*. 2007, Dougall *et al. 2005).*

The FBA regions water resources include rivers and streams; groundwater resources; and water storages such as barrages, dams and weirs of various sizes. Annual discharge from the major rivers varies immensely, due to the highly variable rainfall and high evaporation rates experienced in the region. Much of the annual discharge from the major river systems comes from runoff during rainfall events, however there are also important spring fed supplies in streams such as the upper Dawson and Nogoa rivers, and Raglan, Carnarvon, Mimosa and Waterpark creeks (Hassall and Associates Pty Ltd, 1997).

The use of water in the FBA region underpins the entire social, environmental, and economic fabric of the area and is intrinsically linked to the day to day life of indigenous and non-indigenous communities. Due to the ever increasing pressure placed on the regions scarce water resources by farmers, and the need to allocate water for the environment, the Fitzroy Water Resource Operation Plan was implemented in 1999. The Fitzroy Basin Resource Operation Plan was designed to act as a key tool in guiding the allocation and management of water in the Fitzroy Basin, and has played an instrumental role in allocating environmental flows to facilitate the requirements of many freshwater fish species in the basin.

The FBA region encompasses a variety of habitats, including the relatively undisturbed Shoalwater Bay area, which contains the largest coastal wilderness area between Nadgee in Southern NSW and Cape Melville on the Cape York Peninsula. The oligotrophic freshwater wetlands of Shoalwater Bay are the northernmost known habitat of the honey-blue eye (*Pseudomugil mellis*), a nationally listed vulnerable fish species under the Commonwealth Endangered Species Protection Act 1993, while the nationally endangered oxleyan pygmy perch (*Nannoperca oxleyana*) may occur in dune swamps in the area (Environment and Heritage, 1995). Freshwater streams and wetlands of Shoalwater Bay are absent of exotic fish species, a characteristic found in no other catchment on the east of Australia (Aust.Gov, 1994a).

The vast expanses of FBA region contain many other unique landscape and habitat types, such as diverse floodplain habitats, pristine estuarine systems, sandstone ranges, coastal heathlands, Brigalow scrub, rainforest ranges and the central part of the Great Barrier Reef Maine Park.

The FBA region contains a wide variety of streams and wetlands that provide fish habitat for numerous fish species, including endemic, vulnerable and threatened species. The Fitzroy Basin is characterised by large slow flowing turbid streams providing habitat for many unique fish species including two endemic species, the southern saratoga (*Scleropages leichardti*) and leathery grunter (*Scortum hillii*). The FBA region also boasts clearwater rainforest streams flowing out of Byfield National Park which contain the northern most distribution of ornate rainbowfish (*Rhadinocentrus ornatus*) and short-headed lamprey (*Mordacia mordax*) (Marsden and Kerslake, 2002). This area also contains the Dismal Swamp which contains a wide range of wetland types with many similarities to the more extensive sandmass wetlands of southeastern Australia (In-stream, 2006). This area is rich in biodiversity because tropical and subtropical species overlap.

Many of the streams in the FBA region have been extensively modified, as this is where most agricultural activity takes place. Some of the small streams are still relatively intact and in fair condition, with good riparian and in-stream habitat (Figure 1), however all of the larger streams show signs of degradation from agricultural activities such as cattle grazing. The lowland region also contains numerous wetlands, floodplains and lagoon systems that are fertile nursery areas for fish species such a barramundi. These too have suffered considerable degradation with few of these systems in good condition.

Figure 1. Small coastal stream with excellent riparian and in-stream vegetation (Stony Creek - Byfield State Forest).

Fish Passage Prioritisation

The Fitzroy Basin Fish Barrier Prioritisation Project (FBFBPP) is a joint project between the Fitzroy Basin Association (FBA) and the Department of Primary Industries and Fisheries (DPI&F). The FBFBPP is the first comprehensive fish barrier prioritisation project undertaken in the FBA region. The purpose of the FBFBPP is to identify all potential barriers to fish passage in the FBA region and prioritise these barriers for remediation. Barriers to fish passage include any structure that impedes the movement of fish, such as culverts, pipes, road crossings, weirs and dams. These structures have been built for a variety of purposes such as irrigation supply, flow gauging and re-regulation, on-farm stock and irrigation supply, urban and industrial supply, flow management and flood control, road crossings or simply for urban beautification and recreation facilities (Marsden *et al.* 2003).

Barriers affect fish community condition by preventing movement of fish species which require free passage along river systems to fulfil a number of key life stage requirements. This movement is essential for:

- Maintaining populations of diadromous species, which require free passage between freshwater and marine habitats for reproduction purposes i.e. barramundi, sea mullet and mangrove jack.
- Maintaining genetic diversity by preventing fragmentation of fish populations, which can leave rare and threatened fish species susceptible to disease and extinction.
- The migration of adults to access habitats for feeding and reproduction purposes.
- The migration of juvenile fish species to reach up stream nursery habitats.

Where barriers exist, catadromous species are most likely to be impacted and are usually the first to become extinct above the barrier. Occasionally the highly variable climatic conditions experienced in the FBA region result in short periods of drown-out during high flow events, allowing fish passage. This however, is no indication of successful migration, as significant delays or complete blockage of fish passage may have occurred as migrations may take place at other stages of the flow event, not just at the highest flow. An example of this is barramundi in the Fitzroy River. Before the Fitzroy River barrage was constructed juvenile barramundi successfully migrated to freshwater habitats in the lower Dawson and Mackenzie river systems (Dunstan 1959). Once the barrage was constructed barramundi numbers declined until they became locally extinct in these river reaches, despite the structure drowning out occasionally. It was not until the installation of a fishway on the barrage that barramundi once again occurred in the reaches upstream. Important commercial and recreational catadromous species such as barramundi, sea mullet and mangrove jack all live in freshwater or upper estuaries for portions of their lives, generally entering freshwater as juveniles and leaving as adults to spawn at sea. It is therefore important that these species have free access to freshwater habitats to maintain viable populations.

Other species that migrate wholly within freshwater are also affected by barriers, though to a lesser degree, as barriers interrupt the continuity of the river and isolate previously continuous fish populations (Harris and Mallen-Cooper, 1994). These species may have spawning migrations delayed or stopped by barriers, preventing successful recruitment. However the likelihood of complete extinction from river reaches is lower than for catadromous species, as although populations may become fragmented they are still generally able to reproduce in the isolated sections, thereby maintaining some population.

The selection criteria process has taken into consideration the importance of various migration patterns and the likelihood of localised extinctions caused by the barrier. As a result the process was designed to favour barriers located close to the estuarine interface in large coastal river systems. Barriers located close to the estuarine interface may prevent diadromous species from migrating to upstream freshwater habitats (Figure 2). This can result in profound long term consequences, as often a whole years recruitment can be lost if juveniles are unable to migrate to up stream habitats. If fish passage is prevented year after year, fish populations can be severely diminished and over time lead to localised species extinction. The impact of barriers on diadromous fish communities is considered to be more critical than the effect on potadromous fish communities as the species that migrate wholly within freshwater can maintain populations despite the presence of barriers.

Figure 2. Juvenile empire gudgeons (left) trapped directly below a barrier to fish passage (right) on Moore’s Creek (Rockhampton, QLD).

The FBFBPP incorporated a three stage selection criteria process to prioritise barriers from most important through to least important based on the biological, social and economic benefits and the cost of remediation. A total of 10,632 potential barriers to fish passage were identified in the FBA region, with 10,502 potential barriers recorded in-stream (Figure 3) and 131 potential barriers recorded off-stream on wetland habitats. Due to time and funding constraints and the large number of barriers identified in the FBA region, it was important to prioritise barriers so that time and funds could be directed appropriately to fix barriers considered top priority. The first stage of the prioritisation process refined the large number of barriers into a list of 150 potential barriers for detailed investigation. After field inspections it was determined that 59 of the 150 potential barriers were actual barriers to fish migration. Further investigation of the social, economic and technical feasibility of construction of the 59 barriers produced a list suggesting the top 30 barriers requiring remediation in the FBA region.

The three stage prioritisation process consisted of:

- An automated GIS prioritisation process of five biological criteria,
- A manual prioritisation of 10 biological criteria of the refined GIS list,
- A manual prioritisation of refined biological list for six social, economic and technical criteria.

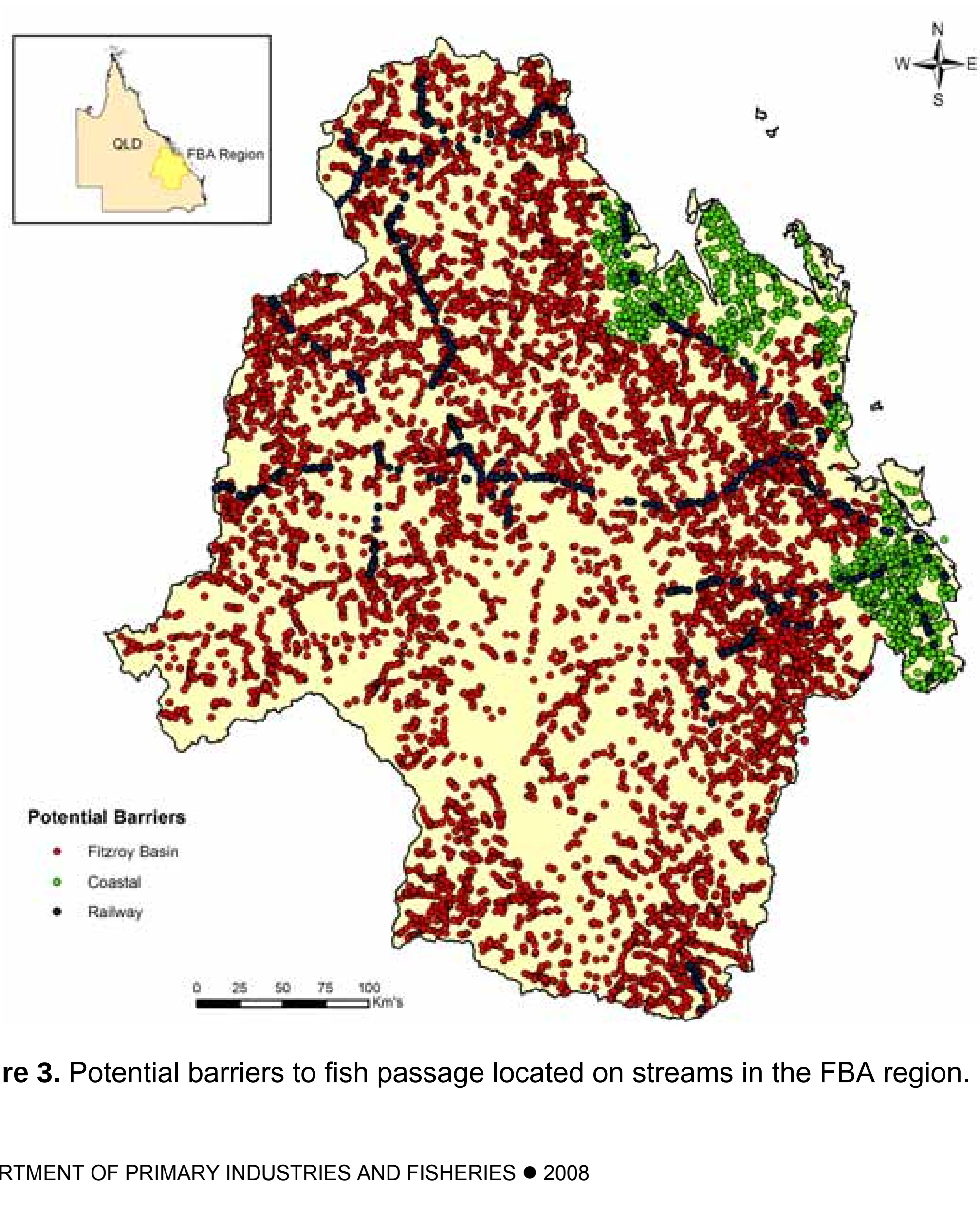

Figure 3. Potential barriers to fish passage located on streams in the FBA region.

Stage one of the selection criteria process initially involved a desktop study of the FBA region to identify potential barriers to fish passage. This was undertaken by identifying and creating a waypoint at all potential barriers intersecting water bodies using OziExplorer mapping software and Geoscience Australia's NATMAP Raster 250K map (2005). After the initial identification process using NATMAP Raster's 250k map, a cross examination process using Spot 5 satellite imagery of the FBA region was undertaken to validate waypoints. GIS software (ArcMap 9.2) was used for this part of the process, which also included replacing cross checked waypoints created in OziExplorer with point shape files in ArcMap. Point shape files were created so that barrier data could be entered into the GIS prioritisation process.

Spot 5 satellite imagery was also used to identify potential barriers such as farm road crossings, small farm weirs and bund walls on ponded pastures, which were impossible to locate using NATMAP Raster's 250K map. Due to the lack of quantitative spatial data representing wetlands in the region and the different habitat characteristics associated with lentic habitats compared with lotic habitats, wetland barrier point shape files were created separately to in-stream barrier point shape files. For quality assurance purposes each potential barrier to fish passage identified during the study was assigned its own unique identification number.

An automated GIS sub program was created specifically to prioritise the 10,502 in-stream barriers in stage one. The GIS program consisted of five selection criteria questions, with each question containing a series of answers each with an individual ranking score i.e.1-5.

The following attributes were fundamental for a potential in-stream barrier to score well in the first stage of the selection criteria process:

- High stream order,
- Barrier located low down in the river system close to the estuary,
- Good catchment condition (minimal adverse surrounding landuse practices),
- Large area of catchment opened up above the barrier to the next barrier or top of catchment (if the barrier is removed).
- Minimal to no barriers located downstream.

The GIS program then analysed all the criteria for each barrier, then ranked the barriers in priority order, with the top 100 ranked barriers requiring field validation in stage 2 of the prioritisation process.

The second stage of the selection criteria process involved field validation of the top 100 potential barriers to confirm there existence and determine barrier parameters. Due to many potential barriers in the top 100 not affecting fish migration, an additional 50 potential barriers were also chosen for field validation in the second stage. Field validation involved using a GPS to locate potential barriers. Once the barrier was located detailed information regarding the barrier type, size, number of culverts/pipes and access to site was noted. This information in conjunction with photos and video of the barrier and its surrounding habitat was used to determine what type of fishway the barrier requires and an approximate cost of remediation. Information regarding access to the site was an important consideration, as fishway construction requires the use of large machinery in close proximity of the barrier.

In addition to the criteria used in the first stage further biological and physical criteria was analysed in the second stage of the prioritisation process. These criteria included:

- Barrier Type – Number of culverts/pipes, length, height, width
- Stream Condition – Percentage condition of riparian vegetation and extent of bank degradation
- Water Supply – Extent of permanency: permanent, seasonally or occasionally dries up with refuge pools
- Water Quality – Extent of pollution: non-polluted, minimal, moderate or heavy
- Habitat for migratory fish species upstream of barriers site – Excellent, reasonable, moderate, poor, very poor.

All this information was collated and used to determine a refined list of the 59 top ranking barriers after stage two.

The third and final stage of the selection criteria process involved investigating the social and economic benefits of constructing a fishway on the existing barrier. This stage is extremely important in determining whether the cost of construction is justified by the social and biological benefits the fishway will generate for both the environment and the community. The third stage involved prioritising the refined barrier list from the second stage of the process to come up with the 30 top ranking barriers in the FBA region.

The social, economic and biological criteria analysed to prioritise barriers in the final stage included:

- The cost of constructing the fishway – lower cost fishways scored higher
- What financial or in kind support is available
- Technical viability – How difficult is it to design and build
- Productivity benefits – Will species benefited improve commercial harvest or recreational fishing opportunities or increase revenue to local business
- Conservation significance – Will improvement have a positive impact on the conservation of species.
- Remediation effectiveness – What species can migrate on particular flows.

Each barrier in the refined list from the second stage was scrutinised and assigned a score based on how well they addressed each of the above criteria. The scores were totalled, and the barrier prioritisation list was finalised, with the top scoring barrier in the third stage becoming the top priority barrier in the FBA region. Remaining barriers were also ranked and prioritised based on how well they addressed the third stage criteria. The end product resulted in a list of the top 30 barriers to fish migration in the FBA region in priority order for rehabilitation.

Barriers on Wetlands

The analysis of GIS data sourced from Environmental Protection Agency, Spot 5 satellite images of the FBA region and information from landholders identified a number of barriers on artificial and natural wetlands throughout the FBA region. These 131 wetland barriers were identified and categorised based on the size of the wetland that they occurred on (Figure 4). Large, permanent coastal wetlands were prioritised into the first group. Large, permanent inland wetlands and small, permanent coastal wetlands were prioritised into the second group. The third group included large, intermittent coastal wetlands and small, permanent inland wetlands. However no wetland barriers have been prioritised as they were considered outside the project objectives as most were not on recognised water courses. Lentic habitat's such as ponded pastures potentially contain significantly high biodiversity values, including excellent nursery habitat for catadromous fish species such as barramundi. However, future investigations into the biodiversity benefits and habitat characteristics (inundation frequency) are required to make informed decisions relating to the fishery potential of these habitats.

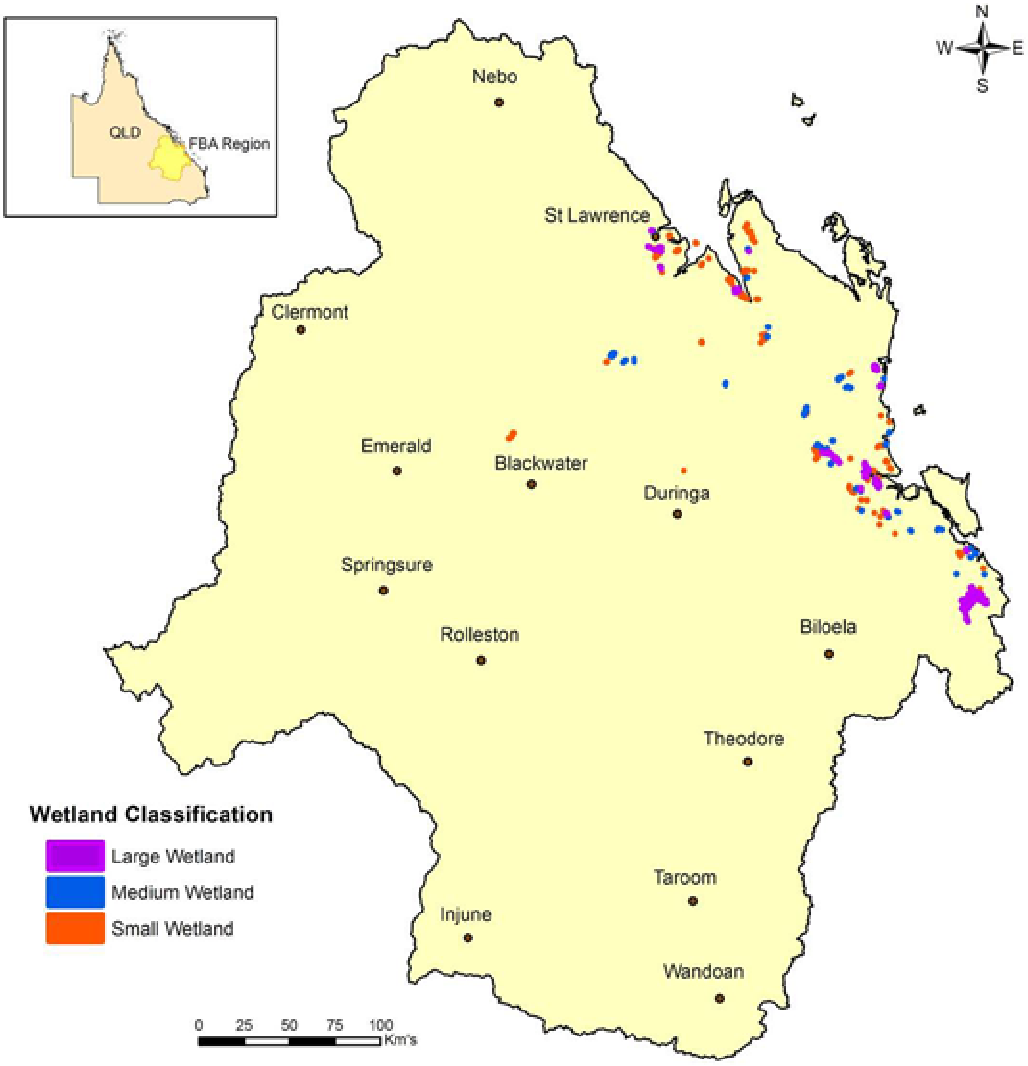

Figure 4. Potential barriers located on wetland habitats in the FBA region.

Methods

Due to the extremely large project area and high number of barriers encountered during the study it was vitally important to prioritise potential barriers so funding and time constraints can be utilised in the most appropriate manner. To achieve this, a three stage selection criteria process was developed to prioritise the large number of potential barriers in the FBA region. The three stages involved evaluating the biological, social and economic benefits of providing free fish passage past the barrier for both the environment and the community. The final result of the prioritisation process after taking these considerations into account is a list of the top 30 barriers to fish migration in the FBA region.

Stage 1 – GIS Prioritisation of Biological Criteria

A desktop examination was undertaken to initially identify potential barriers to fish passage in the FBA region. This was achieved by identifying and creating waypoints at road crossings and roads intersecting water bodies using OziExplorer software and Geoscience Australia's NATMAP Raster 250K map (2005).

After the initial barrier identification process using NATMAP Raster 250K map, GIS software (ArcMap 9.2) was employed to validate identified barriers using Spot 5 satellite imagery. Spot 5 satellite imagery was also used to locate potential barriers such as farm road crossings, small farm weirs and bund walls on ponded pastures which are impossible to locate using the NATMAP Raster 250K map. Waypoints created for each potential barrier using OziExplorer were replaced with point shape files in ArcMap so GIS analysis could be performed. To maintain quality assurance, each potential barrier was assigned its own unique identification number.

Furthermore, as the project evolved during the desktop study a decision was made to create a further three additional groups of potential barriers. These three groups would cover all potential barriers on wetlands (lacustrine, palustrine and estuarine systems) i.e. lagoons, ponded pastures and lakes. The lack of quantitative spatial data representing wetlands in the region and the different habitat characteristics associated with lentic habitats compared with lotic habitats, meant wetland (off-stream) barrier point shape files were created separately to in-stream barrier point shape files. Separating in-stream barrier point shape files from the off-stream barrier point shape files would also assist during the GIS analysis stage.

Once all potential in-stream barriers had been cross checked using Spot 5 satellite imagery, and assigned a shape file point, they were analysed using an automated GIS program. The GIS program was created specifically to prioritise the large quantity of potential in-stream barriers identified during the study. To achieve this, five biological questions were incorporated into the GIS program. For each question a score was assigned (i.e. 1-5) relating to how the barrier fulfilled the biological criteria. Barriers were then prioritised based on their total score, with the top scoring barrier becoming the highest priority barrier during the first stage of the prioritisation process.

The five biological questions and associated scoring system incorporated into the automated GIS program for the first round of the prioritisation process are as follows:

Question 1.

Stream Type

The first GIS question set out to determine what stream order the barrier was located on and whether the stream was direct to sea. High stream order, direct to sea streams gained the highest score, while minor stream order, inland streams gained lower scores.

a. Stream orders 1, 2 and 3 inland (does not go direct to sea) and stream orders 1 direct to sea are removed from the barrier prioritisation process.

b. Stream order ≥ 6 direct to sea. *(10 points)*

c. Stream order ≥ 7 or stream order ≥ 5 direct to sea. *(7 points)*

d. Stream order ≥ 6 or stream order ≥ 4 direct to sea. *(5 points)*

c. Stream order ≥ 5 or stream order ≥ 3 direct to sea. *(3 points)*

d. Stream order ≥ 4 or stream order ≥ 2 direct to sea. *(1 point)*

Question 2.

<u>What is the stream length (km) cut off by the proposed barrier as a proportion (%) of the total stream length (km) within the catchment?</u> (This should take into account all tributaries of the catchment downstream to the declared downstream limit, not just the tributary in which the barrier is located in).

a. 80+% of total catchment. *(5 points)*

b. 60-79% of total catchment. *(4 points)*

c. 40-59% of total catchment. *(3 points)*

d. 21-39% of total catchment. *(2 points)*

e. ≤20% of total catchment. *(1 point)*

Question 3.

<u>Catchment Condition</u> (This should take into account the whole catchment downstream to the declared downstream limit (freshwater/estuarine interface), not just the sub-catchment the barrier is located in i.e. if a barrier is located on the Dawson River, then its catchment condition would include the entire Fitzroy Basin, if a barrier is located on the Comet River, then its catchment condition would also include the entire Fitzroy Basin).

a. No intensive cropping/urban. *(7 points)*

b. 1%-4% intensive cropping/urban. *(4 points)*

c. 5%-14% intensive cropping/urban *(3 points)*

d. 15-29% intensive cropping/urban. *(2 points)*

e. 30%-39% intensive cropping/urban. *(1 point)*

f. ≥40% intensive cropping/urban. *(0 points)*

Questions 4

<u>What stream length (km) is opened up, upstream of the barrier to the next barrier or barriers or top of stream</u> (if there are no more barriers upstream), including all

tributaries. If it is the uppermost barrier (there must be barriers below) then take 3 points off the score (lowest score possible is 0).

a. 500+ km's. *(5 points)*

b. 100 - 499 km's. *(4 points)*

c. 50 - 99km's. *(3 points)*

d. 10 - 49 km's. *(2 Points)*

e. 0.6 – 9 km's. *(1 Point)*

f. 0 – 0.5 km's. *(0 Points)*

Questions 5

Number of barriers downstream in a direct path to sea.

a. No barriers downstream. *(7 points)*

b. One barrier downstream. *(5 points)*

c. Two to four barriers downstream. *(3 points)*

d. Five to Nine barriers downstream. *(2 points)*

e. Ten or more barriers downstream. *(0 points)*

Software Used:

ESRI ArcGIS 9.2

ArcGIS Extension tools include:

- Network Analyst
- Spatial Analyst
- EtGeowizards
- X-Tools

Data Supplied and Used:

Spatial layers supplied by FBA:

- Fitzroy basin boundary (polygon)
- Fitzroy sub-basin boundary (polygon)
- Landuse boundary (polygon)
- Stream network with stream order (polyline)
- Various satellite images covering the Fitzroy basin (raster)

Spatial layers supplied by Fisheries Mackay:

- 239 Estuarine interface locations (points)
- 10,502 Barriers locations (points)
    - o 1709 Coastal barriers
    - o 8353 Inland barriers
    - o 440 Railway barriers

Stage 2 – Full Biological Criteria Prioritisation

Stage two of the barrier prioritisation process involved field validation of the top 100 ranked barriers from stage one of the process. To achieve this a GPS (Garmin GPSmap76) tracking system was set up in conjunction with a laptop computer using OziExplorer mapping software. This was used to systematically locate the geographic position of each barrier in relation to uniquely identifiable locations (towns, roads, streams), allowing for efficient validation of potential barriers.

Once a potential barrier had been located and confirmed to be a barrier to fish passage, vital information about the barriers physical parameters and surrounding habitat were recorded. Important barrier parameters included: the type of barrier, number of culverts/pipes, head loss, length, height and width of the structure. Additionally, photos and video of the barrier were taken and access to the site noted.

Furthermore, detailed biological information on stream condition, water supply, habitat for migratory fish upstream of the barrier, available fish passage downstream and distance from tidal interface was recorded. Barriers were assigned a score of 1-5, for each of the biological criteria. Scores were collated with the stage one scores, with the top combined scoring barrier becoming the top ranked barrier after the second stage of the prioritisation process.

Physical and biological questions and associated scoring system for the second stage of the prioritisation process are as follows:

Question 1.

Barrier type

a). Tidal barrage. *(5 points)*

b). Dam or weir ≥3m. *(4 Points)*

c). Dam or weir 1.5 – 3m high or culvert or pipes ≤60% of stream width. *(3 Points)*

d). Dam or weir ≤1.5m high or culvert or pipes ≥60% of stream width. *(2 Points)*

e). No barrier – *DO NOT SCORE REMAINING CRITERIA.*

Question 2.

Stream condition

a). Pristine-undisturbed (no apparent clearing of rip veg, bank degradation, etc). *(5 Points)*

b). Low disturbance (≤ 25% of upstream areas degraded as above). *(4 Points)*

c). Moderate disturbance (25-50% of upstream areas degraded as above).*(3 Points)*

d). High disturbance (51-75% of upstream degraded). *(2 Points)*

e). Very high disturbance (≥ 75% of upstream degraded). *(1 Point)*

Question 3.

Water Supply/Quantity

a). Natural, permanent, non-polluted. *(5 Points)*

b). Natural, permanent via supplemented flow and/or minimal pollution. *(4 Points)*

c). Stream occasionally dries up with refuge pools with some pollution. *(3 Points)*

d). Stream occasionally dries up with refuge pools with moderate pollution.*(2 Points)*

e). Stream dries seasonally with no refuge pools, or heavy pollution. *(1 Point)*

Question 4.

Habitat for migratory fish species upstream of barrier site

a). Excellent. Diverse and abundant fish habitat. *(5 Points)*

b). Good. Reasonable amount of suitable fish habitat. *(4 Points)*

c). Moderate amount of suitable fish habitat. *(3 Points)*

d). Poor. Little suitable fish habitat. *(2 Points)*

e). Very poor. Little or no suitable fish habitat. *(1 Point)*

Stage 3 – Social, Economic and Technical Feasibility Prioritisation

The third stage of the prioritisation process involved investigating the social, economic and environmental benefits of barrier remediation. A very important aspect of this stage of the process was considering the net benefits of fixing the barrier against the economic cost of remediation. This process was achieved through analysing the top 59 barriers with a range of social, economic and biological criteria. Like stage one and two of the prioritisation process, each criterion contained a question with a range of answers. A separate score was assigned for each answer. Once all the barriers had been analysed, scores were collated, with the highest scoring barrier becoming the top ranked barrier in the FBA region. The end result of the third stage is a list of the top 30 ranked barriers to fish migration in the FBA region in priority order.

The social, economic and biological questions and associated scoring system used to prioritise barriers in the third stage included:

Question 1.

Estimated cost

a). Low cost (small/low nature like fishway or short culvert baffles). *(5 Points)*

b). Low-moderate cost (small/high nature like fishway or high culvert baffles or small size/low height technical fishway). *(4 Points)*

c). Moderate cost (high nature like fishway or medium size/low height technical fishway). *(3 Points)*

d). Moderate - high cost (large size/low height technical fishway). *(2 Points)*

e). High cost (large size/high height technical fishway). *(1 Point)*

Question 2.

What support by way of financial, access or inkind support is available?

a). Easy access, good financial and inkind support available. *(5 Points)*

b). Reluctant access, some financial or inkind support available. *(3 Points)*

c). Reluctant access, no financial or inkind support available. *(1 Point)*

d). No access, no financial or inkind support available. *(0 Points)*

Question 3.

Technical viability - How difficult is it to design and build

a). Simple installation of current design with limited engineering required. *(5 Points)*

b). Modest installation of current design with some engineering (includes combo fishways). *(3 Points)*

c). Complex installation and engineering or a new design. *(1 Point)*

Question 4.

Productivity benefits - Will species benefited improve commercial harvest or recreational fishing opportunities or increase revenue to local businesses (consider the % improvement on current fish passage as well)

a). A high benefit to a large number of commercial and or recreational species. *(5 Points)*

b). A moderate benefit to a moderate number of commercial and or recreational species. *(3 Points)*

c). A small benefit to a small number of commercial and or recreational species. *(1 Point)*

d). No benefit to commercial and or recreational species. *(0 Point)*

Question 5.

Conservation significance - Will the improvement have a positive impact on the conservation of species?

a). Listed species present. *(5 Points)*

b). Species present that are rare or restricted within the region (but not rare or restricted outside the region). *(3 Points)*

c). Only common or abundant species within the region present. *(1 Point)*

Question 6.

How effective will the remediation be?

a). All species at all migration flows are able to pass. *(5 Points)*

b). All species at some migration flows or some species at all migration flows are able to pass. *(3 Points)*

c). Some species at some migration flows are able to pass. *(1 Point)*

Results

Stage 1

A total of 10,502 potential in-stream barriers were analysed by the automated GIS program during the first stage of the prioritisation process. The highest score for this section was 31 out of a possible 34 points which was attained by the Fitzroy river barrage (Table 2). A further 70 barriers scored between 20 and 30 points, while the remaining 10,431 potential barriers scored less than 20 points (Table 1).

Table 1. The number of potential barriers identified at each score from the highest score to the lowest score

Score	Number Potential barriers	Score	Number Potential barriers
31	1	24	11
30	1	23	5
29	0	22	19
28	2	21	12
27	3	20	8
26	7	19	28
25	2	18 or less	10,403

Table 2. The list of the top 20 barriers identified after GIS prioritisation of barriers during stage 1.

Priority	Barrier Reference Number	Stream Name	Total Score
1	6474	Fitzroy R	31
2	8785	Styx R	30
3	1	Fitzroy R	28
4	524	Fitzroy R	28
5	523	Fitzroy R	27
6	6169	Serpentine Lagoon	27
7	9348	Amity Ck	27
8	3122	Fitzroy R	26
9	3952	Fitzroy R	26
10	6168	Serpentine Lagoon	26
11	9095	Herbert Ck	26
12	9393	St Lawrence Ck	26
13	9529	Halfway Ck (Black)	26
14	9722	Boyne R	26
15	4455	Swan Ck	25
16	8906	Shoalwater Ck	25
17	78	Raglan Ck	24
18	535	Amity Ck	24
19	1000	Boyne R	24
20	3951	Fitzroy R	24

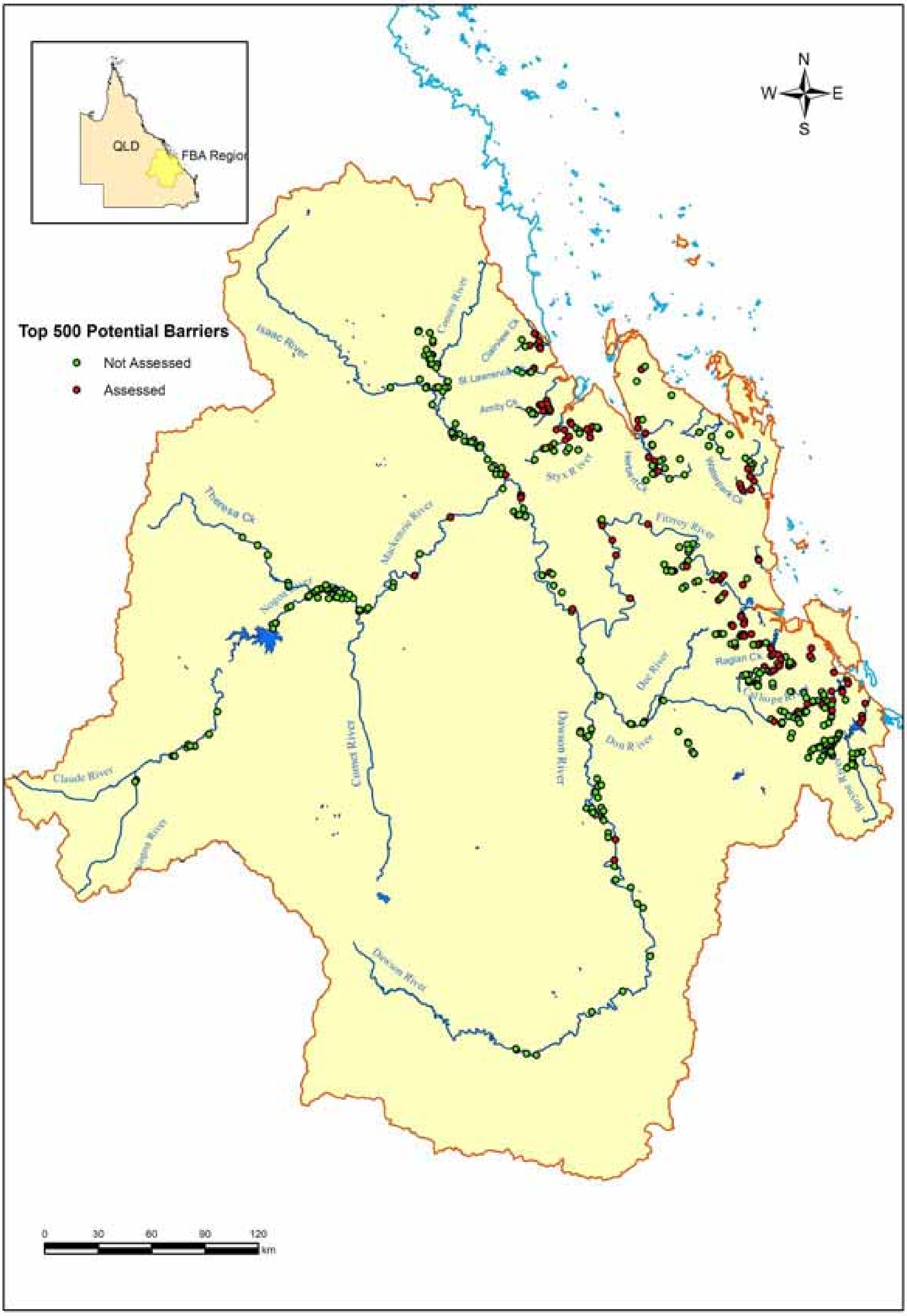

Figure 5. Location of the top 500 potential barriers after stage 1. Red dots indicating barrier has been assessed (136), green dots indicating no assessment.

Stage 2

A total of 136 potential barriers were validated in the field (Figure 5) during the second stage of the prioritisation, 59 were found to be barriers to fish migration. The 59 barriers (Figure 6) were then priority ranked (Table 3) in accordance with the biological criteria set out for stage two, before advancing to the third stage of the prioritisation process.

Table 3. Top 59 ranked barriers to fish migration after stage 2.

Priority	Barrier ID	Stream Name	Barrier Name/Type	Stage 2 Score
1	6474	Fitzroy R	Fitzroy Barrage	49
2	1	Fitzroy R	Eden Bann Weir	45
3	9348	Amity Ck	Tidal Barrage/Bund Wall	45
4	524	Fitzroy R	Redbank Crossing	43
5	1000	Boyne R	Mann's Weir/Tidal Barrage	42
6	523	Fitzroy R	Hanrahan's Crossing	42
7	3952	Fitzroy R	Craiglee Crossing	41
8	3951	Fitzroy R	Glenroy Crossing	40
9	9001	Boyne R	Awonga Dam	40
10	6169	Serpentine Lagoon	Tidal Barrage/ Bund wall	40
11	9393	St Lawrence Ck	St.Lawrence Weir	40
12	535	Amity Ck	Wumalgi Rd/Pipes	39
13	8652	Calliope R	Blackgate Road Crossing	39
14	8945	Waterpark Ck	Waterpark Ck Weir	39
15	2	Mackenzie R	Tartrus Weir	38
16	525	Mackenzie R	Duaringa Apis Ck Rd Crossing	38
17	8618	Calliope R	Mt Alma Rd Crossing/Culverts	38
18	8677	Clairview Ck	Clairview Weir	38
19	3	Mackenzie R	Bingegang Weir	37
20	9002	Cattle Ck	Old Hwy/Pipes	37
21	8354	Boyne R	Pikes Crossing	36
22	25	Raglan Ck	Langmom Rd/Pipes	35
23	9718	Lake Callemondah	Barrage/Weir	35
24	4	Mackenzie R	Bedford Weir	34
25	22	Raglan Ck	Upper Raglan/Pipes	34
26	527	Stony Ck	Creek Crossing-Byfield S.Forest	34
27	534	Montrose Ck	Weir/Town water supply	34
28	8716	Amity Ck	Old HWY/Pipes	34
29	9441	Clairview Ck	Creek Crossing	34
30	9392	Wran Ck	Weir/Pipes	34
31	5	Dawson R	Neville Hewitt Weir	33
32	1042	Bridge Ck	Wumalgi/Pipes	33
33	85	8 Mile Ck	Bajool Weir	33
34	3015	Mackenzie R	Tartrus Road Crossing	33
35	9165	Unnamed Ck	Rundle Ranges	33
36	82	12 Mile Ck	12 Mile Ck Rd/ Pipes	32
37	4152	Dawson R	Boolburra/Pipes	32
38	8731	Stoodleigh Ck	Barretts Rd/Pipes	32
39	528	Stony Ck	Creek Crossing-Byfield S.Forest	31
40	9629	Sandy Ck	Next to railline/Pipes	31
41	526	Lake Callemondah	Creek Crossing	30
42	1032	Oakey Ck	Archer Station/Pipe	30
43	8784	Tooloombah Ck (Styx)	Rocky Crossing	30
44	9000	Ewen Ck	Stanage Bay Rd/Pipes	30
45	529	Stony Ck	Daddy's Crossing/Byfield S.Forest	29
46	9192	Unnamed Ck	Wydham Rd-Gladstone/Pipes	29
47	9550	Block Ck	Stanage Bay Rd/Pipes	29
48	6	Dawson R	Moura Weir	28
49	69	12 Mile Ck	2nd Barrier u/stream hwy-Langmom Rd/Pipes	28
50	531	Moores Ck	Botanical Gardens/Pipes	28
51	6348	Dawson R	Nun's Crossing	28
52	9041	Coorooman Ck	Coorooman Ck Rd/Culverts	28
53	6144	12 Mile Ck	3rd Barrier u/stream hwy-Langmom Rd/Pipes	27
54	6198	Nankin Ck	Thompsons Pt Rd/ Culverts	27
55	8642	Unnamed Ck	Harvey St - Gladstone/Pipes	27
56	530	Stony Ck	Freeman's Crossing/Byfield S.Forest	26
57	532	Moores Ck	Simpson St/Pipes	25
58	8606	Calliope R	Pipes	25
59	2664	Dawson R	Kianga River Rd/Pipes	24

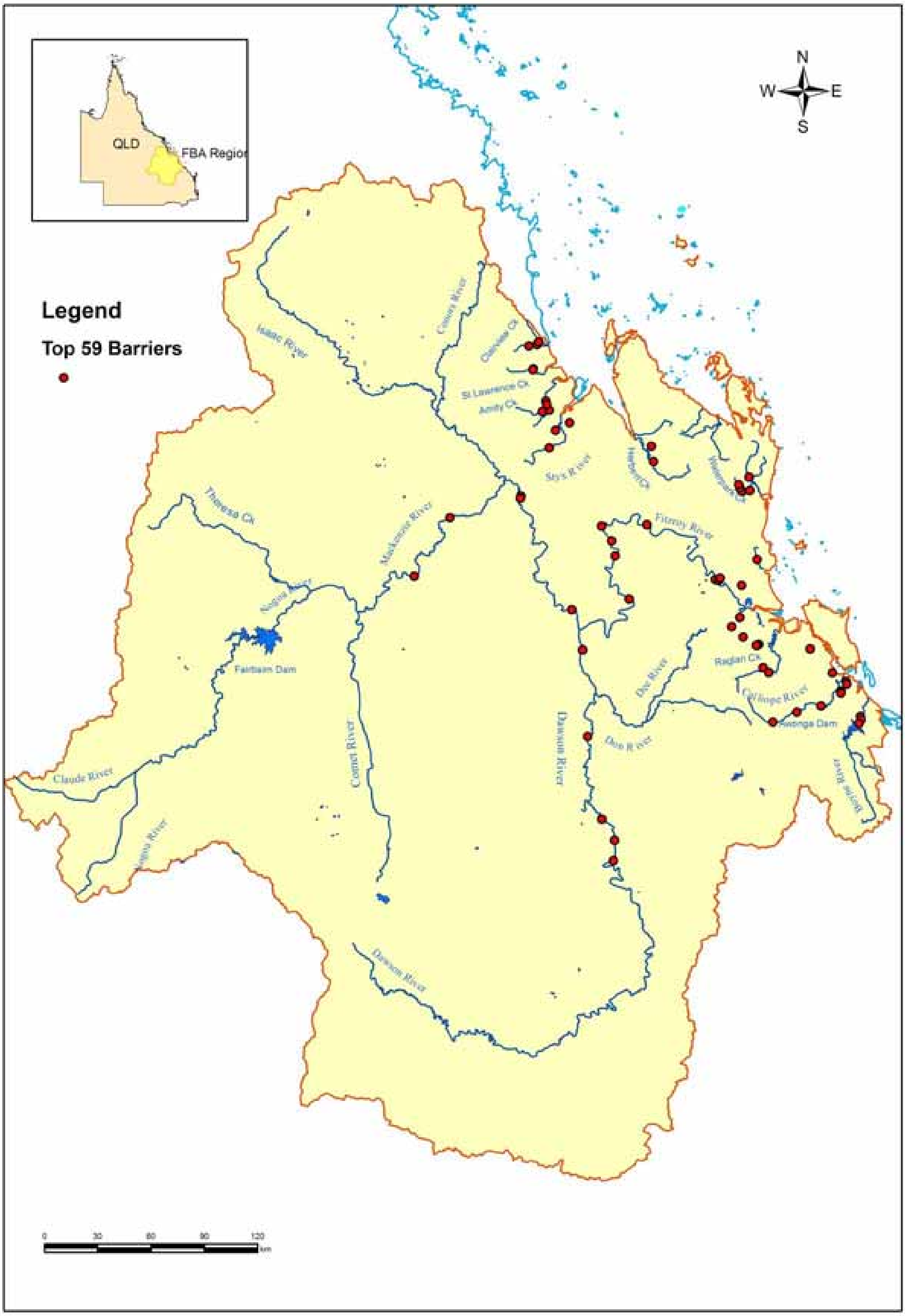

Figure 6. Location of the top 59 barriers to fish migration from stage two of the prioritisation process.

Stage 3

The third and final stage of the barrier prioritisation process involved analysing the top 59 barriers after stage two of the process with a number of economic, social and technical criteria. Each of the 59 barriers were prioritised in accordance with the scoring system set out for stage three of the process. The end product of the prioritisation process is a priority list of the top 30 ranked barriers to fish passage in the FBA region requiring future remediation (Table 3 and Figure 7).

Table 3. Top 30 ranked barriers to fish migration in the FBA region in priority order for future remediation.

Priority	Barrier ID	Stream Name	Barrier Name/Type	Total Adjusted Score
1	524	Fitzroy R	Redbank Crossing	159.3
2	1000	Boyne R	Mann's Weir/Tidal Barrage	157.4
3	9348	Amity Ck	Tidal Barrage/Bund wall	149.9
4	3952	Fitzroy R	Craiglee Crossing	148.8
5	523	Fitzroy R	Hanrahan's Crossing	147.4
6	3951	Fitzroy R	Glenroy Crossing	146.9
7	9393	St Lawrence Ck	St.Lawrence Weir	146.9
8	535	Amity Ck	Wumalgi Rd/Pipes	145
9	9002	Cattle Ck	Old Hwy/Pipes	144.5
10	8652	Calliope R	Blackgate Rd/Pipes	141.7
11	6474	Fitzroy R	Fitzroy Barrage	140.9
12	82	8 Mile Ck	Bajool Weir	138.2
13	85	12 Mile Ck	12 Mile Ck Rd/ Pipes	136.8
14	22	Raglan Ck	Upper Raglan/Pipes	135.4
15	8716	Amity Ck	Old HWY/Pipes	135.4
16	8945	Waterpark Ck	Waterpark Ck Weir	135
17	5	Dawson R	Neville Hewitt Weir	133.5
18	1	Fitzroy R	Eden Bann Weir	133.2
19	8618	Calliope R	Mt Alma Rd Crossing/Pipes	133.1
20	25	Raglan Ck	Langmom Rd/Pipes	127.3
21	6169	Serpentine Lagoon	Tidal Barrage	126.9
22	525	Mackenzie R	Duaringa Apis Ck Rd Crossing	126.4
23	8677	Clairview Ck	Weir	126.4
24	526	Lake Callemondah	Barrage	124.4
25	1042	Bridge Ck	Wumalgi/Pipes	123.5
26	9441	Clairview Ck	Road Crossing	122
27	3015	Mackenzie R	Tartrus Road Crossing	120.1
28	9165	Unnamed Ck	Rundle Ranges	120.1
29	2	Mackenzie R	Tartrus Weir	119.7
30	4	Mackenzie R	Bedford Weir	118.7

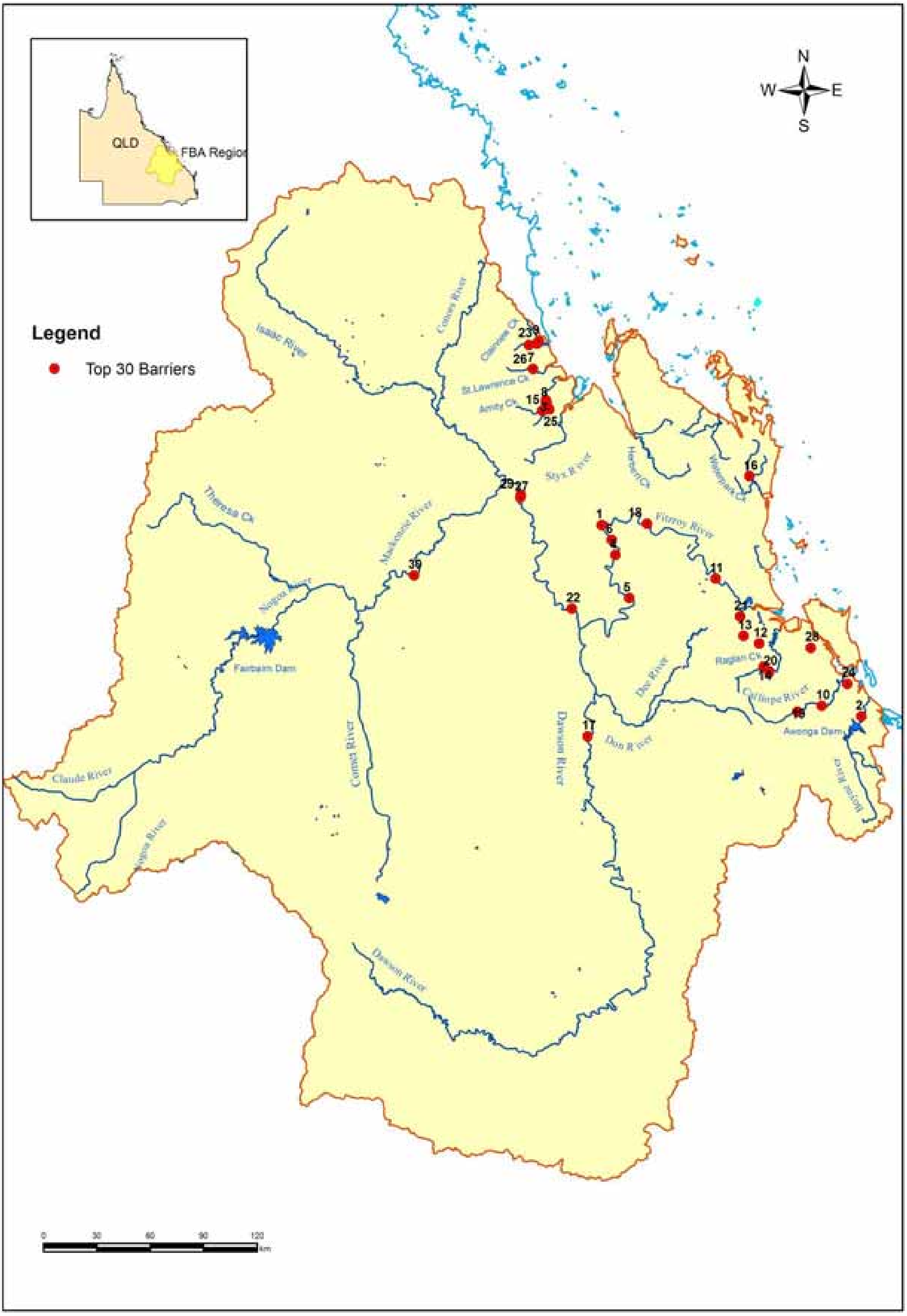

Figure 7. Location and priority rank of the top 30 barriers to fish migration in the FBA region.

Discussion

Instream Barriers

The desktop study of the FBA region identified a total of 10,502 potential barriers to fish passage. The majority of these potential barriers were located on low stream order ephemeral streams which provide very little fish habitat. As a result of this, all barriers located on stream orders 1, 2 and 3 in low rainfall inland areas were eliminated during the first step of the automated GIS prioritisation process. In addition to this, all potential barriers located on coastal stream order 1's were also eliminated during the GIS stage of the prioritisation process. Potential barriers located on stream orders ≥2 in higher rainfall coastal areas remained in the process.

The automated GIS program then prioritised the remaining potential barriers to fish migration in accordance with the biological criteria set out for the GIS stage of the process. Due to time and funding constraints the top 100 ranked barriers were initially chosen for field validation. Of the top 100 ranked potential barriers chosen for field validation, 86 were assessed, with 35 of these being actual barriers to fish migration, while 51 not affecting fish passage as they were structures such as bridges and natural rock crossings (Figure 8). Due a number of potential barriers not affecting fish migration in the initial top 100, a further 50 additional potential barriers were also chosen for field validation. Of the additional 50 potential barriers assessed, 24 of these were barriers to fish migration while 26 were not barriers.

Figure 8. Natural rock crossing on Montrose Creek, Broadsound, QLD.

In total, of the 136 field validated potential barriers, 59 were actual barriers to fish migration, 77 were not barriers, while 14 potential barriers were unable to be assessed as a result of access difficulties, whereby the barrier was located on private property and the landholder was un-contactable or the potential barrier was located in the restricted Shoalwater Bay army training area. It would be useful in the future that these 14 potential barriers be assessed. However, personal communication with Bill Sawnok from Infofish Services who has visited many of the streams in the restricted Shoalwater Bay training area has indicted that he has not seen any barriers to fish passage in the area, which includes 9 potential barriers. Of the remaining 5 un-assessed barriers, 3 look like natural creek crossings, and 2 like bund walls.

Through the prioritisation process the barriers were ranked according to the impact that they are having on the fish communities of the FBA regions streams and the cost and technical feasibility of rehabilitation of fish passage at the site. From this prioritisation process a list of top priority barriers according to the 3 stage process has been developed. This list (See Appendix 1) provides a guide to the most likely places that targeted rehabilitation of fish passage will have the greatest benefit to the fish communities of the region. The list contains many significant barriers in the region such as the Fitzroy Barrage and Eden Bann Weir, as well as a number of smaller barriers that while having less impact are cheaper and simpler to fix. The list also contains a number of structures that have functioning fishways installed on them, however it should be recognised that some of these are older fishways that may not be passing the whole fish community and as such the barrier is still partially there.

With the prioritisation now completed and a list of potential sites for rehabilitation of fish passage recommended the FBA can now move forward with an investment program that looks to gain funds for the various options outlined for each structure in the priority list (Appendix 1). It should be recognised that the list is a guide only and some real-world realities may make some sites more or less “doable”. For example some of the structures will be inundated if the proposed raising of Eden Bann Weir or the Fitzroy Barrage go ahead or Rookwood Weir is constructed, making the need to rehabilitate these sites uncertain. While further information collected on the habitats and structures in inaccessible areas may bring them into contention for rehabilitation. In all cases rehabilitation of a site should be investigated thoroughly prior to any investment being undertaken to ensure that the investment expenditure is being spent in the right place.

Wetland barriers

Although off-stream barriers to fish migration were not part of the project objectives, they were considered to be very important fish habitats, therefore, potential barriers on these lentic habitats were identified during the initial desktop study. Once the potential off-stream barriers had been identified they were placed through one stage of selection criteria, which investigated the size, inundation frequency and location of these habitats. Several potential off-stream barriers (Figure 9), were assessed during the validation stage of the project, but were not ranked and prioritised with the in-stream barriers, due to the completely different habitat characteristics associated with these aquatic environments. However, it is critically important that off-stream barriers are considered for future investigations as many of these habitats are located on coastal wetlands which are important nursery areas for catadromous species such as barramundi and tarpon.

Figure 9. Left. Tidal interface ponded pasture (Nankin) at the mouth of the Fitzroy River. Right. Barrier to fish migration (pipe), on a tidal interface ponded pasture at the mouth of Waterpark Creek.

Conclusion

The 10,502 potential barriers within the FBA region were successfully identified and distilled down to a list of the highest priority sites within the region. These sites represent the areas where the greatest “bang-for-buck” can be achieved with minimal expenditure on the behalf of the FBA. By remediating fish passage at these sites extensive areas of fish habitat will be opened up to migratory fish species. This will ensure the successful maintenance of fish populations in many of the regions waterways, while investing rehabilitation funds in a responsible manner.

Recommendations

- Development of an investment strategy for a fish migration barrier remediation program targeting barriers in the top 30 barriers to fish passage identified in this report. This program would include:

    - Preparation of an investment strategy for the highest priority sites based on information in this report

    - Negotiation with structure owners to permit rehabilitation of highest priority sites

    - Detailed survey of the sites and production of design documents for suitable fishways

    - Construction of agreed fishway designs

    - Establishment of ongoing maintenance agreements with local structure owners

    - Monitoring of the rehabilitated sites to ensure proper operation of the fishway

    - Pre and post barrier remediation fish community sampling to determine the effectiveness of providing fish passage past the barrier.

- Instigation of an off-stream barrier prioritisation project aimed at the regions wetland habitats. In particular the numerous coastal and tidal interface pondage pastures. This is particularly important because of the potential fisheries and biodiversity benefits these wetland habitats can provide for the environment if free passage is provided.

- Negotiation for access to the restricted Shoalwater Bay army training area to assess potential barriers to fish migration that could not be looked at within the timeframes of this project.

- Further fish community monitoring of the regions waterways to better understand fish communities and their migration requirements. This is particularly important in the unique aquatic habitat types of the Shoalwater Bay area, to determine the population status of the honey-blue eye (*Pseudomugil mellis*), a nationally listed vulnerable fish species, and potentially detect the presence of the nationally endangered oxleyan pygmy perch (*Nannoperca oxleyana*) which may also occur in the area.

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References

Allen, G. R., Midgley, S. H. & Allen, M. (2002). *Freshwater Fishers of Australia*. Western Australian Museum, Perth

Australian Government. (1994a). Commonwealth *Commission of Inquiry, Shoalwater Bay. Capricornia Coast, Queensland* - Final report, Australian Government Publishing Service, Canberra.

Cotton Catchment Communities. (2007). *Fitzroy Basin*. Site accessed on the 02 June 2008.URL:Address: http://www.cotton.pi.csiro.au/content/Catchments/MyCatchments/Fitzroy_Basin.aspx

Dougall, C., Carroll, C., Herring, M. & Trevithick. (2007). *Sednet Modelling in the Fitzroy Basin (2007); Spatially Variable Ground Cover and Revised Gully Layers Can Potentially Generate Significant Changes in Erosion Sources and Patterns*. In Oxley, L. and Kulasiri, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2007, pp. 881-887. ISBN: 978-0-9758400-4-7. http://www.mssanz.org.au/modsim07/papers/15_s37/SednetModelingInThe_s37_Dougall_.pdf

Dougall, C., Packett, R. & Carroll, C. (2005). *Application of the Sednet Model in Partnership with the Fitzroy Basin Community*. In Zerger, A. and Argent, R.M. (eds) MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, November 2005, pp. 1119-1125. ISBN: 0-9758400-2-9. http://mssanz.org.au/modsim05/papers/dougall.pdf

Dunstan, D.J. (1959). *The barramundi (lates calcarifer) (bloch) in Queensland Waters*. CSIRO Division of Fisheries and Oceanography Technical Paper No. 5.

Environment and Heritage Section, Department of Defence. (1995). *Shoalwater and Corio Bays Area - Queensland*. Site accessed on the 02 June 2008. URL Address: http://www.wetlands.org/reports/ris/5AU044en.pdf

Harris, J.H. and Mallen-Cooper, M.C. (1994). *Fish passage development in the rehabilitation of fisheries in mainland South-eastern Australia*. In 'Proceedings of the International Symposium and Workshop on Rehabilitation of Inland Fisheries', Hull, 6-10, April, 1992 (Ed. I. Cowx) pp. 185-193.

Harris,.J.H. (1984). *Impoundment of coastal drainage's of south-eastern Australia, and a review of its relevance to fish migration*. *Aust. Zool*. **21**(3), 235-250.

Hassall & Associates Pty Ltd. Situation Analysis – Fitzroy Basin Association. Site accessed on the 02 June 2008. URL Address: http://www.hassall.com.au/_lib/doc/FBASituationAnalysis_001.pdf).

Katopodis, C. 1992. *Fish screening guide for water intakes.* Working Document, Freshwater Institute, Winnipeg, Manitoba, USA.

Marsden, T.J., Thorncraft, G.A. & McGill, D.A. (2003). *Gooseponds Creek Fish Passage Project*, NHT Project No. 2002108, Final Project Report. Queensland Department of Primary Industries and Fisheries, Mackay.

Marsden, T.J. & Kerslake, M. (2002). *Sandy Creek Weir Assessment Fisheries Survey*. Queensland Department of Primary Industries and Fisheries, Mackay.

In-Stream. (2006). *Shoalwater Bay*. In Tappin, A. (eds) Australian and New Guinea Fishes Association Queensland Inc. Volume 15 (number 1), February 2006, pp. 16-20.

Appendix 1

Top 30 Barriers to fish migration in the FBA region

Priority	1	
Stage 1 and 2 Priority	Stage 1	Stage 2
	3	4
Barrier ID	524	
Stream Name	Fitzroy River	
Location	23°6.236, 149°52.554	
Barrier Type	River crossing	
Barrier Name	Redbank Crossing	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$30,000	

Priority	2	
Stage 1 and 2 Priority	Stage 1	Stage 2
	17	5
Barrier ID	1000	
Stream Name	Boyne River	
Location	24°2.563, 151°19.969	
Barrier Type	Tidal Bund	
Barrier Name	Manns Weir	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$40,000	

Barrier No 1000

Overall Priority	3	
Stage 1 & 2 Priority	Stage 1	Stage 2
	5	3
Barrier ID	9348	
Stream Name	Amity Creek	
Location	22°28.432, 149°32.223	
Barrier Type	Tidal Bund	
Barrier Name		
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$25,000	

Barrier No. 9348

Overall Priority	4	
Stage 1 & 2 Priority	Stage 1	Stage 2
	8	7
Barrier ID	3952	
Stream Name	Fitzroy River	
Location	23°15.73, 149°56.194	
Barrier Type	River Crossing	
Barrier Name	Craiglee Crossing	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$30,000	

Barrier No. 3952

Overall Priority	5	
Stage 1 & 2 Priority	Stage 1	Stage 2
	5	5
Barrier ID	523	
Stream Name	Fitzroy River	
Location	23°28.178, 150°01.669	
Barrier Type	River Crossing	
Barrier Name	Hanrahan's Crossing	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$30,000	

Barrier No.523

Overall Priority	6	
Stage 1 & 2 Priority	Stage 1	Stage 2
	17	7
Barrier ID	3951	
Stream Name	Fitzroy River	
Location	23°10.585, 149°55.364	
Barrier Type	River Crossing	
Barrier Name	Glenroy Crossing	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$30,000	

Barrier No. 3951

Overall Priority	7	
Stage 1 & 2 Priority	Stage 1	Stage 2
	8	7
Barrier ID	9393	
Stream Name	St Lawrence Creek	
Location	22°18.503, 149°28.468	
Barrier Type	Tidal Bund/Weir	
Barrier Name	St.Lawrence Weir	
Fishway Type Needed	Vertical Slot/Rock Ramp	
Approx. Cost of Fishway	≈$100,000	

Barrier No. 9393

Overall Priority	8	
Stage 1 & 2 Priority	Stage 1	Stage 2
	17	12
Barrier ID	535	
Stream Name	Amity Creek	
Location	22°29.768, 149°33.184	
Barrier Type	Pipes	
Barrier Name	Wumalgi Rd	
Fishway Type Needed	Culverts	
Approx. Cost of Fishway	$20,000	

Barrier No. 535

Overall Priority	**9**	
Stage 1 & 2 Priority	Stage 1	Stage 2
	33	19
Barrier ID	9002	
Stream Name	Cattle Creek	
Location	22°10.115, 149°30.253	
Barrier Type	Pipes	
Barrier Name	Old Hwy	
Fishway Type Needed	Remove Pipes	
Approx. Cost of Fishway	$9,000	

Barrier No. 9002

Overall Priority	**10**	
Stage 1 & 2 Priority	Stage 1	Stage 2
	33	12
Barrier ID	8652	
Stream Name	Calliope River	
Location	23°59.232, 151°06.007	
Barrier Type	River Crossing	
Barrier Name	Blackgate Rd Crossing	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$13,000	

Barrier No. 8652

Overall Priority	**11**	
Stage 1 & 2 Priority	Stage 1	Stage 2
	1	1
Barrier ID	6474	
Stream Name	Fitzroy River	
Location	23°21.858, 150°29.419	
Barrier Type	Tidal Barrage	
Barrier Name	Fitzroy Barrage	
Fishway Type Needed	Vertical slot fishway on opposite bank	
Approx. Cost of Fishway	≈ $2M	

Barrier No. 6474

Overall Priority	12	
Stage 1 & 2 Priority	Stage 1	Stage 2
	64	31
Barrier ID	82	
Stream Name	8 Mile Creek	
Location	23°40.612, 150°44.909	
Barrier Type	Weir	
Barrier Name	Bajool Weir	
Fishway Type Needed	Bypass channel/rock ramp	
Approx. Cost of Fishway	$70,000	

Barrier No.82

Overall Priority	13	
Stage 1 & 2 Priority	Stage 1	Stage 2
	72	31
Barrier ID	85	
Stream Name	12 Mile Creek	
Location	23°38.438, 150°39.997	
Barrier Type	Pipes	
Barrier Name	12 Mile Creek Rd	
Fishway Type Needed	Culverts	
Approx. Cost of Fishway	$20,000	

Barrier No. 85

Overall Priority	14	
Stage 1 & 2 Priority	Stage 1	Stage 2
	201	24
Barrier ID	22	
Stream Name	Raglan Creek	
Location	23°48.026, 150°46.460	
Barrier Type	Pipes	
Barrier Name	Upper Raglan	
Fishway Type Needed	Culverts	
Approx. Cost of Fishway	$20,000	

Barrier No. 22

Overall Priority	15	
Stage 1 & 2 Priority	Stage 1	Stage 2
	100	24
Barrier ID	8716	
Stream Name	Amity Creek	
Location	22°31.597, 149°31.894	
Barrier Type	Pipes	
Barrier Name	Old HWY	
Fishway Type Needed	Culverts	
Approx. Cost of Fishway	$30,000	

Barrier No. 8716

Overall Priority	16	
Stage 1 & 2 Priority	Stage 1	Stage 2
	33	12
Barrier ID	8945	
Stream Name	Waterpark Creek	
Location	22°50.979, 150°40.419	
Barrier Type	Weir	
Barrier Name	Waterpark Weir	
Fishway Type Needed	Vertical Slot Fishway	
Approx. Cost of Fishway	$55,000	

Barrier No. 8945

Overall Priority	17	
Stage 1 & 2 Priority	Stage 1	Stage 2
	100	31
Barrier ID	5	
Stream Name	Dawson River	
Location	24°10.026, 149°48.717	
Barrier Type	Weir	
Barrier Name	Neville Hewitt Weir	
Fishway Type Needed	As recommended in Fish Passage Report	
Approx. Cost of Fishway	$50,000	

Barrier No. 5

Overall Priority	**18**
Stage 1 & 2 Priority	Stage 1: 3, Stage 2: 2
Barrier ID	1
Stream Name	Fitzroy River
Location	23°05.419, 150°06.597
Barrier Type	Weir
Barrier Name	Eden Bann Weir
Fishway Type Needed	Vertical Slot on opposite bank to lock
Approx. Cost of Fishway	≈$3M

Barrier No.1

Overall Priority	**19**
Stage 1 & 2 Priority	Stage 1: 64, Stage 2: 15
Barrier ID	8618
Stream Name	Calliope River
Location	24°01.313, 150°58.0
Barrier Type	Culverts
Barrier Name	Mount Alma Rd
Fishway Type Needed	Baffles
Approx. Cost of Fishway	$10,000

Barrier No. 8618

Overall Priority	**20**
Stage 1 & 2 Priority	Stage 1: 201, Stage 2: 22
Barrier ID	25
Stream Name	Raglan Creek
Location	23°49.502, 150°48.400
Barrier Type	Culverts
Barrier Name	Langmom Rd
Fishway Type Needed	Baffles
Approx. Cost of Fishway	$10,000

Barrier No. 25

Overall Priority	21	
Stage 1 & 2 Priority	Stage 1	Stage 2
	5	8
Barrier ID	6169	
Stream Name	Serpentine Lagoon	
Location	23°32.965, 150°38.982	
Barrier Type	Tidal Bund	
Barrier Name		
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$20,000	

Barrier No. 6169

Overall Priority	22	
Stage 1 & 2 Priority	Stage 1	Stage 2
	28	15
Barrier ID	525	
Stream Name	Mackenzie River	
Location	23°20.102, 149°42.815	
Barrier Type	Road Crossing	
Barrier Name	Duaringa Apis Rd Crossing	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$50,000	

Barrier No.525

Overall Priority	23	
Stage 1 & 2 Priority	Stage 1	Stage 2
	17	15
Barrier ID	8677	
Stream Name	Clairview Creek	
Location	22°11.207, 149°29.752	
Barrier Type	Weir/Pipes	
Barrier Name	Clairview Weir	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$50,000	

Barrier No. 8677

Overall Priority	24	
Stage 1 & 2 Priority	Stage 1	Stage 2
	64	22
Barrier ID	9718	
Stream Name	Lake Callemondah	
Location	23°51.544, 151°13.998	
Barrier Type	Tidal Barrage	
Barrier Name		
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$40,000	

Barrier No. 9718

Overall Priority	25	
Stage 1 & 2 Priority	Stage 1	Stage 2
	137	31
Barrier ID	1042	
Stream Name	Bridge Creek	
Location	22°31.083, 149°34.044	
Barrier Type	Pipes	
Barrier Name		
Fishway Type Needed	Culverts	
Approx. Cost of Fishway	$25,000	

Barrier No. 1042

Overall Priority	26	
Stage 1 & 2 Priority	Stage 1	Stage 2
	52	24
Barrier ID	9441	
Stream Name	Clairview Creek	
Location	22°11271, 149°27.709	
Barrier Type	Raod crossing	
Barrier Name		
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$20,000	

Barrier No. 9441

Overall Priority	27	
Stage 1 & 2 Priority	Stage 1	Stage 2
	100	31
Barrier ID	3015	
Stream Name	Mackenzie River	
Location	22°58.170, 149°25.157	
Barrier Type	Road Crossing	
Barrier Name	Tartrus Road Crossing	
Fishway Type Needed	Rock Ramp	
Approx. Cost of Fishway	$20,000	

Barrier No. 3015

Overall Priority	28	
Stage 1 & 2 Priority	Stage 1	Stage 2
	100	31
Barrier ID	9165	
Stream Name	Unnamed Creek	
Location	23°31.884, 149°42.344	
Barrier Type	Pipes	
Barrier Name	Rundle Ranges	
Fishway Type Needed	Culverts	
Approx. Cost of Fishway	$15,000	

Barrier No. 9165

Overall Priority	29	
Stage 1 & 2 Priority	Stage 1	Stage 2
	52	15
Barrier ID	2	
Stream Name	Mackenzie River	
Location	22°27.692, 149°25.346	
Barrier Type	Weir	
Barrier Name	Tartrus Weir	
Fishway Type Needed	Fish Lock	
Approx. Cost of Fishway	≈ $4M	

Barrier No. 2

Overall Priority	**30**	
Stage 1 & 2 Priority	Stage 1	Stage 2
	173	24
Barrier ID	4	
Stream Name	Mackenzie River	
Location	23°22.648, 148°50.268	
Barrier Type	Weir	
Barrier Name	Bedford Weir	
Fishway Type Needed	Fish Lock	
Approx. Cost of Fishway	≈ $4M	

Barrier No. 4

Appendix 2.

GIS Methods Used During Stage One of Barrier Prioritisation - Tu Nguyen

Introduction

GIS tools were used to filter, identify and rank all the barriers in the Fitzroy basin. The GIS processes were divided into 3 steps:

1. Data cleaning, filtering and validating for all the spatial layers.
2. Specific and customised GIS tools were used to answer each of the five questions based on the spatial criterias.
3. Values obtained from each question were summarised to give a total value and rank for each barrier.

There were many challenges and difficulties encountered during the GIS analysis process. The main issues were:

1. Using a stream network that had no linear referencing intelligence. For example, the polyline construction did not behave in a systematic way (end points and start points to the stream network did not match; and there were gaps between the line segments).
2. Working with a very large stream network that had many stream flow scenarios, for instance multiple loops and stream crossovers.

Efforts to reach the best available solutions and alternatives to resolve these issues were achieved successfully. Where possible, the GIS analysis was automated, with many other processes manually done. As a result, the GIS project took longer than expected to complete (two months instead of two weeks).

To fully understand the GIS methods explained in this document, the reader requires knowledge of spatial programs, in particular the ESRI software product.

Software Used:

ESRI ArcGIS 9.2

ArcGIS Extension tools include:

- Network Analyst
- Spatial Analyst
- ETGeowizards
- X-Tools

Microsoft Excel

Map datum: GDA94

Projection: UTM Zone 55.

Data Supplied and Used

Spatial layers supplied by Fitzroy Basin Association FBA:

- Fitzroy basin boundary (polygon)
- Fitzroy sub-basin boundary (polygon)

- Landuse boundary (polygon)
- Stream network with stream order (polyline)
- Various satellite images covering the Fitzroy basin (raster)

Spatial layers supplied by DPI&F Mackay:

- 239 Estuarine interface locations (points)
- 11436 Barrier locations (points)
    - 1709 Coastal barriers
    - 8353 Inland barriers
    - 440 Railway barriers
    - 934 additional barriers identified after checking

Other topographic data such as contours, spot heights and Digital Elevation Model (DEM) layers were all considered for assisting with the GIS analysis. However, the resolution and accuracy of these additional layers were not appropriate, and thus were not utilised in the final GIS analysis process.

Step One: Data processing

1. Initially all spatial vector layers were converted to UTM Zone 55 (the coordinate system is read in metres and not in degrees).
2. All barrier location files were merged together. Each barrier was given a unique barrier number in the attributes table.
    a. DPI&F Mackay collected and supplied four separate barrier files (inland barriers, coastal barriers, railway barriers, other barriers). The geoprocessing "Merge" tool was used to merge all spatial layers.
3. All the interface points and barriers were buffered by 250m. All point locations not within 250m of the stream network were eliminated. All points within 300m of the stream network were retained and their position relocated to the closet stream location by using the "Select by Location" tool and then applying the snapping tool.
4. All "stream order ones" from the stream network layer and "stream order twos" from the inland stream network layer were removed. This reduced the stream network from 32717 polylines down to 11468 polylines. This process also eliminated the number of barriers from 11436 down to 3548. This filtering process significantly reduced the GIS cleaning time from approximately six weeks down to two weeks.
    a. Inland streams were selected using the sub-catchment boundary areas. The "Select by Attributes" tool was used.
5. Further cleaning and preparation of each stream network was required to support the network analysis process. The stream order layer was edited in preparation to create Routes.
    a. A "Clean" function was used to improve the integrity of the polyline topology. The tool removed overshoots and repaired gaps in the stream network.
    b. A buffer was created for the stream network. The buffer tool was used to create a ten metre buffer on all streams. Next, the "Dissolve" tool was used group the individual stream networks.
    c. A network number field was added to give each network a unique network ID. A "Spatial Join" was used to link to the original attributes from the original streams layer with the new networks created. Splitting the stream network into smaller parts made the analysis process more manageable.
    d. Each polyline stream network was edited and clipped to start from the interface point.
6. ArcCatalog was used to create a network dataset
    a. The network dataset produced junctions and endpoints on the stream network.
    b. The network analyst tools used were:
        i. Service area function
        ii. Closest facility function
        iii. Route function

c. Various routes (polylines) were created from the interface and barrier points to all the barriers, junctions and endpoints on the stream network.
d. Each of the routes contained a distance (stream segment length) value, which was critical in determining the answers to some of the spatial questions.
e. The remaining barriers were given a new barrier address code, which represented the location of the barrier in relation to all other barriers on the same network. Allocating the barrier address code was done manually. The process enabled GIS to understand the order and relationship of each barrier with other barriers on the same network.

Step Two: Using GIS to answer questions one through to five

Question One. Stream Type

The values for the stream type were calculated using a simple mathematical formula. A new field was created in the stream network attributes table and the values were populated using the "Field Calculator" function. There were two formulas, one for coastal streams going direct to sea and the other for inland streams. The functions were separately applied to the two groups of streams (coastal or inland), which was determined by the sub-catchment boundary it was contained in. Each barrier was then assigned a value based on what the value of the stream order it intersected. The values of the stream orders were transferred to the barriers table by using a "Select by location" tool and then performing a "Spatial Join" function.

Formula used for Coastal streams

```
Static Value As Integer

If ([StrmOrder] > 5) Then

  Value = 7

ElseIf ([StrmOrder] = 5) Then

  Value = 5

ElseIf ([StrmOrder] = 4) Then

  Value = 3

ElseIf ([StrmOrder] = 3) Then

  Value = 2

ElseIf ([StrmOrder] = 2) Then

  Value = 1

Else

Value = 0

End If
```

Formula used for Inland streams

```
Static Value As Integer

If ([StrmOrder] > 6) Then

  Value = 5

ElseIf ([StrmOrder] = 6) Then

  Value = 3

ElseIf ([StrmOrder] = 5) Then

  Value = 2

ElseIf ([StrmOrder] = 4) Then

  Value = 1

Else

Value = 0

End If
```

Question Two. Percentage of stream length cut off by barrier

For each barrier, an intersect query was used to identify all routes belonging to the stream flow. From the selected streams, a total stream distance (TSD) was derived and summarised in a table. The distance from the barrier to the interface point (DBIP) was subtracted from the total stream distance (TSD) to give the total stream length (TSLC) cut off by the barrier. The TSLC was then divided by the total network length (TNL) and multiplied by 100 to give a percentage.

TSLC = TSD – DBIP

Percentage cut of total catchment (PCTC) = (TSLC / TNL) * 100

Formula used for assigning values to each barrier

```
Static Value As Integer

If ([PCTC] ≥ 80) Then

  Value = 5

ElseIf ([PCTC] ≥ 60 and [PCTC] < 80) Then

  Value = 4

ElseIf ([PCTC] ≥ 40 and [PCTC] < 60) Then

  Value = 3

ElseIf ([PCTC] ≥ 21 and [PCTC] < 40) Then
```

Value = 2

Else

Value = 1

End If

Question Three. Catchment Condition

The Fitzroy basin catchment (polygon) layer supplied had a classification field describing various land use types. The land use features were selected using an attributes query to group all the land use types into two categories, intensive cropping or no intensive cropping.

Category for Intensive Cropping include:

- Cropping
- Perennial horticulture
- Irrigated cropping
- Irrigated perennial horticulture
- Irrigated modified pasture
- Intensive animal production
- Manufacturing and industry
- Residential
- Mining

Category for No Intensive Cropping include:

- Nature conservation
- Managed resource protection
- Other minimal use
- Grazing natural vegetation
- Production forestry
- Plantation forestry
- Grazing modified pasture
- Services
- Utilities
- Transport and communication
- Waste treatment and disposal
- Lake

- Reservoir/dam
- River
- Marsh/wetland

A new field was created in the land use feature table to identify the two categories. The percentage of intensive land use for each sub catchment area was calculated using the spatial "Intersect" tool. The intensive land use percentage values were distributed to the other adjoining catchments downstream and the new percentage values were averaged and summarised for each of the sub-catchment areas. Each barrier would inherit the percentage value of each catchment using a "Spatial Join" function (if the barrier belongs to a particular catchment, then the barrier will take on the values of that catchment).

Formula used for assigning catchment values to each barrier

Static Value As Integer

If ([IC] = 0) Then

  Value = 7

ElseIf ([IC] ≥ 1 and [IC] ≤ 4) Then

  Value = 4

ElseIf ([IC] ≥ 5 and [IC] ≤ 14) Then

  Value = 3

ElseIf ([IC] ≥ 15 and [IC] ≤ 29) Then

  Value = 2

ElseIf ([IC] ≥ 30 and [IC] ≤ 39) Then

  Value = 1

Else ([IC] ≥ 40) Then

  Value = 0

End If

Question Four. Stream length opened upstream

Using the closest facility function of the network analyst extension, the closest barrier to the endpoints on all tributaries were determined and assigned a minus three (-3) value. This value was entered into a field called the last barrier on tributary (LBT). Also using the closest facility function, for each barrier in question, the closest barriers and endpoints were identified and the distances between the barriers and endpoints (segment lengths) were returned and stored into the barriers' attributes table as distance opened (DO), recorded in kilometres.

Formula used for assigning values to distance between barriers

Static Value As Integer

If ([DO] ≥ 500) Then

Value = 5

ElseIf ([DO] ≥ 100 and [DO] ≤ 499) Then

Value = 4

ElseIf ([DO] ≥ 50 and [DO] ≤ 99) Then

Value = 3

ElseIf ([DO] ≥ 10 and [DO] ≤ 49) Then

Value = 2

ElseIf ([DO] ≥ 0.6 and [DO] ≤ 9) Then

Value = 1

Else ([DO] ≥ 0 and [DO] ≤ 0.5) Then

Value = 0

End If

A new field was created to total the distance between barriers (DBB), which involved the sum of the DO + LBT. A "Minimum" function was used to ensure that DBB would have a minimum value of zero if the total was in negative.

DBB = DO + LBT

Question Five. Number of barriers downstream

Using the service area function of the network analyst extension, the route between the interface point and the barrier was created. The route was used to perform an intersect by location query. The query returned all the barriers located on the route. The number of barriers that were selected also included the current barrier in question. The number of barriers returned needed to be one less (subtract 1) to give the final count of the number of barriers downstream in a direct path to the interface point. A new field is created to store the value for the number of barriers downstream (NBD) between the current barrier and the interface point.

Formula used for assigning values to number of barriers downstream

Static Value As Integer

If ([NBD] = 0) Then

Value = 10

ElseIf ([NBD] = 1) Then

Value = 5

ElseIf ([NBD] ≥ 2 and [NBD] ≤ 4) Then

Value = 3

ElseIf ([NBD] ≥ 5 and [NBD] ≤ 9) Then

  Value = 2

ElseIf ([NBD] ≥ 10) Then

  Value = 0

End If

Step Three: Summarising the values for each question

Once the barrier's table is populated with the appropriate values, the sum and rank for each barrier was calculated. The table was exported to an Excel spreadsheet and using the Excel mathematical functions, the sum and rank of each barrier were calculated. The Excel table was imported back to GIS to perform further mapping and analysis.

An example of the final attributes table for the barriers layer:

Bnum	Q1	Q2	Q3	Q4	Q5	Sum	Rank
555	5	3	2	5	10	25	12