Glenore Weir Cone Fishway

Monitoring Report

Tim Marsden

Australasian Fish Passage Services

This report has been prepared by Australasian Fish Passage Services (AFPS).

For further information contact:

Tim Marsden

Principal Consultant

Australasian Fish Passage Services

tim.marsden@ausfishpassage.com

Please cite as: Marsden, T. (2017) Glenore Weir Cone Fishway Monitoring Report. Australasian Fish Passage Services, 29pp.

Contents

Summary

The Glenore Weir Fishway project was initiated to meet the legislative requirements for the continued provision of fish passage in the Norman River as part of the raising of Glenore Weir. The major specific objective of this report was to evaluate the success of the new cone fishway technology constructed on the new weir.

In the 2017 wet season, monitoring of the cone fishway was completed. In total, 27 species of fish were collected from the cone fishway, meeting its original design objectives of providing passage for the migratory fish community of the Norman River. In fact, the innovative cone design passed thousands of fish from a wide range of fish species and size ranges.

The major outcomes were:

- Passage of a wide range of fish species, the most recorded in any tropical fishway.
- Achievement of the objective of efficient passage of the majority of species.
- Extension of the functionality of the weir from passing fish for 15% of flow to 100% of flows.
- Upstream passage of more than 70,000 fish per year.
- Fishways that make a major contribution to restoration of native fish communities in the Norman River Basin.

For Carpentaria Regional Council, the Glenore Weir fishway has been a significant step forward in restoring the environmental values of the lower Norman River and fulfils its obligations under the Fisheries Act to maintaining fish passage in the Norman River.

1. Introduction

The Glenore Weir Fish passage project was initiated to help ameliorate the impacts of the raising of the existing Glenore Weir on fish passage in the Norman River Basin. The old weir has long been recognised as a barrier to fish migrations and would have been detrimental to aquatic habitats and fish communities in the lower reaches of the Norman River and tributaries. The raising of the old weir to a new height, to increase the certainty of supply of water to the township of Normanton, would further impact on fish movements and thus triggered Fisheries legislation. This required the proponents to construct a suitable fish passage system at the site at the same time as the weir was constructed.

To ensure that the fish passage system constructed at the site was successful a monitoring program was to be developed and implemented at the site. This required that monitoring be undertaken during the first wet season of operation. The monitoring would determine the effectiveness of the fish passage system and provide feedback to the Department of Agriculture and Fisheries on the success of the fish passage system at meeting the objectives set out during the design process. This report provides the results of this monitoring program.

1.1. Norman River Basin

The Norman River Basin encompasses a catchment area of 50,423 km^2 (wetlandinfo 2017) and flows into the south-east corner of the Gulf of Carpentaria near Karumba in Queensland. The system drains a large relatively low and flat catchment, that stretches from the western side of the Great Dividing Range in the east, to the gulf savannah plains in the west. The area is largely unpopulated, with little development beyond cattle grazing in the catchment. The major streams of the catchment include the Norman River, Clara River, Yappar River, Belmore Creek and Walker Creek. The Norman River has a low gradient of approximately 0.5m fall per kilometre of length and terminates in a wide alluvial plain near Karumba.

The climate of the Norman River is dry tropical, with most rainfall received between December and March and an extended dry season with little rain throughout the remainder of the year. The catchment area receives on average between 500 mm and 1000 mm of rain per year, but the high evaporation rate (2000 mm per year) ensures mostly dry conditions within the catchment and a highly seasonal stream flow. The catchment has a large range of temperatures with average summer high temperatures over 40^{o}C and winter low temperatures below 10 ^{o}C (Wetlandinfo 2017).

1.2. Hydrology

The location of the Norman River in the dry southeast corner of the Gulf of Carpentaria has led to a highly seasonal flow pattern. Flows within the system are restricted to the wetter months, January to April, with little flow outside of these times (Figure 1). During this period, significant flows can occur that lead to extensive flooding. The Norman River has a long and well documented history of flooding, with the town of Normanton regularly cut off by flooding in the Norman River during the wet season. The extensive river floodplains mean that there is regular connectivity of waterways via distributary networks during major flood events (Hydrobiology 2005). However, due to the unpredictable nature of rainfall in this region flows during the wet season may also be very small. For example, the peak flow during the 2008/09 wet season was around 3170m^3/s, whereas peak flows during the 1984/85 wet season only reached 11m^3/s (SMEC 2014).

During the dry season (May-Nov) there are no flows within the system and all streams dry back to a series of waterholes. Only in the larger lowland reaches and in some of the upper rocky gorge streams do waterholes persist throughout the year.

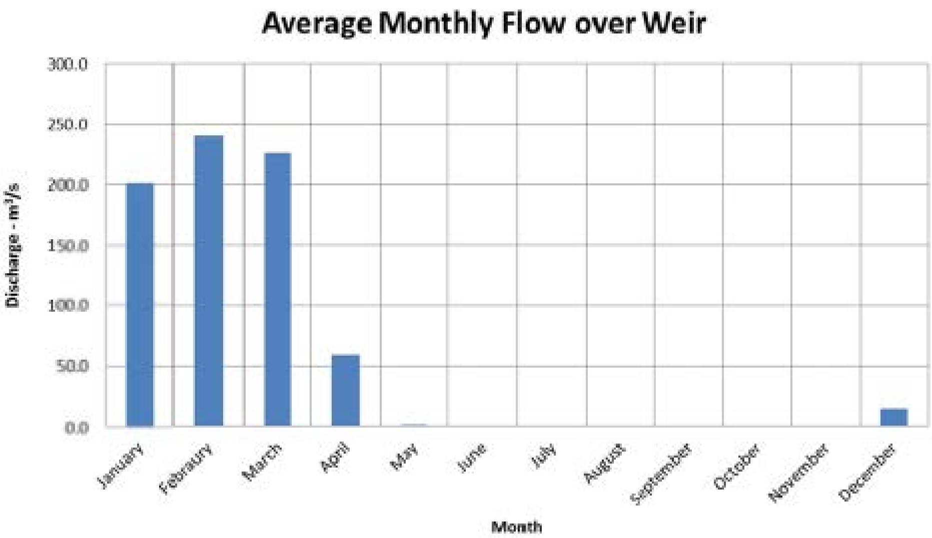

Figure 1. Average monthly flows over Glenore Weir (SMEC 2014)

1.3. Fish Communities

The Norman River contains a biodiverse and important fish assemblage that is relatively unique in tropical Australia with at least 49 species being recorded from the catchment, including a variety of freshwater, estuarine/freshwater and endemic species (Burrows and Perna 2006 and SMEC 2014) (Figure 2).

Almost all of these fish species migrate as part of their life-history with approximately half moving between the estuary and freshwater (Pusey et. al. 2004). Glenore Weir, 112 km from the river mouth, is a major fish passage barrier and has contributed to fragmentation of fish migration pathways between the estuary and freshwater. Several previous studies have been undertaken in the catchment, these have shown between 26 and 30 fish species in the catchment. However due to the remote nature of the catchment and when all studies are combined a total of around 49 species of fish have been identified from the freshwater reaches. Of the 49 freshwater species, there are seven catadromous species, eighteen amphidromous species with the remaining species being considered potamodromous (Table 1), although limited information is available for some species.

Figure 2. Migratory species of the Norman River Basin recorded in this study, a. Hyrtl's tandan, b. giant perchlet, c. barramundi, d. bony bream, e. undescribed tandan (juvenile), f. tarpon, g. undescribed tandan (adult), h. archerfish, i. gulf grunter.

Table 1. Fish species and migration strategies of fish in the Norman River Catchment (Pusey et.al. 2004, Burrows and Perna 2006 and SMEC 2014). Migration Type - A = amphidromous, C = catadromous, P = potamodromous.

Common name	Species	Migration
Ophisternon gutturale	One-gilled eel	C
Ambassis macleaya	Macleay's glassfish	P
Ambassis elongatus	Elongate perch	A
Ambassis nalua	Scalloped glassfish	A
Ambassis sp.	Northwest glassfish	P
Parambassis gulliveri	Giant glassfish	P
Anodontoglanis dahli	Toothless catfish	P
Ariopsis berneyi	Berney's catfish	P
Ariopsis graeffei	Lesser salmon catfish	A
Ariopsis leptaspis	Triangular shield catfish	A
Ariopsis paucus	Carpentaria catfish	P
Ariopsis sp.	Fork-tailed catfish	A
Neosilurus hyrtlii	Hyrtl's tandan	P
Neosilurus sp. nov.	undescribed catfish	P
Porochilus rendahli	Rendahl's tandan	P
Brachirus salinarum	Saltpan sole	A

Common name	Species	Migration
Brachirus selheimi	Freshwater sole	P
Carcharhinus leucas	Bull shark	A
Himantura chaophrya	Freshwater stingray	A
Pristis microdon	Freshwater sawfish	A
Chanos chanos	Milkfish	C
Lates calcarifer	Barramundi	C
Megalops cyprinoides	Tarpon	C
Notesthes robusta	Bullrout	C
Thryssa scratchleyi	Freshwater anchovy	P
Hypseleotris compressa	Empire gudgeon	A
Oxyeleotris lineolatus	Sleepy cod	P
Oxyeleotris selheimi	Giant gudgeon	P
Chlamydogobius ranunculus	Tadpole goby	??
Glossamia aprion	Mouth almighty	P
Glossogobius aureus	Golden goby	A
Glossogobius giuris	Flathead goby	A
Glossogobius sp. 2 (munroi)	Munro's goby	??
Amniataba percoides	Barred grunter	P
Hephaestus fuliginosus	Sooty grunter	P
Leiopotherapon unicolor	Spangled perch	P
Pingalla gilberti	Gilbert's grunter	P
Scortum ogilbyi	Gulf grunter	P
Craterocephalus stercusmuscarum	Fly-specked hardyhead	P
Melanotaenia splendida inornata	Chequered rainbowfish	P
Nematalosa come	Bony bream	A
Nematalosa erebi	Bony bream	P
Liza alata	Diamond mullet	A
Liza subviridis	Greenback mullet	A
Scatophagus argus	Spotted scat	C
Selenotoca multifasciata	Banded scat	C
Kurtus gulliveri	Nursery fish	A
Strongylura krefftii	Longtom	A
Toxotes chatareus	Seven-spot archer fish	A

The species listed in Table 1, provides a comprehensive record of the fish community of the Norman River Catchment. Within this list there are several rare, threatened and endemic species. Species such as freshwater sawfish and the freshwater stingray are listed species that have undergone population declines in many areas (Peverell 2009). Both species freely move between freshwater and estuarine habitats and maintaining free migration pathways is a critically important aspect of their conservation. (Peverell

2009). Other species such as the undescribed neosiluris catfish are only found in the Norman River catchment. While little is known of this species, its movement through the fishway as both adults and juveniles indicates the species is migratory.

1.4. Migratory Patterns

As the Norman River basin sits in the dry tropical zone of the Gulf of Carpentaria, the fish species within the system undertake migrations associated with the short flows that occur within the basin during the wet season. In tropical systems, a wide diversity of species migrate upstream all year-round, whenever flow is available. However, the largest movements are recorded associated with the elevated flows of the wet season. As there are generally no flows occurring outside of the wet season in the Norman River catchment, all migrations are restricted to this time. In adjacent catchments, such as the Flinders River, where flows occur over a longer period of the year, fish migrations occur also on low flows in the dry season.

In the Norman River catchment, the short wet season forces a condensed migration pattern for the local fish species. The first river flows at the beginning of the wet season are thought to be a major movement cue for many species such as the forked and eeltail catfishes, grunters, perchlets and bony bream. During the season, high and low flows attract various different fish species and sizes. Low and moderate flow periods represent a significant period for fish movement in the area for small species such as empire gudgeon and perchlets and juveniles of larger species such as juvenile catfish, giant glassfish, bony bream, archer fish and grunters. The higher flows present opportunities for larger bodied fish such as freshwater sawfish, adult catfish and sub-adult barramundi to undertake migrations. In general, throughout the wet season whenever flows occur there will be fish migrations occurring.

1.5. The Requirement for Fish Passage

The construction of a barrier on a river can block or delay upstream fish migration and thus contribute to the decline and even the extinction of species that depend on longitudinal movements along the stream. Habitat loss or alteration, discharge modifications, changes in water quality and temperature, increased predation pressure as well as delays in migration caused by barriers are significant issues. Barriers to fish passage are identified as one of eight key threats to native fish populations (MDBC 2012). In regulated rivers throughout the world lack of fish passage is frequently identified as a major cause of the decline of freshwater fish (Barrett and Mallen-Cooper, 2006).

All fish utilise and depend on being provided with access to the aquatic habitat which supports all of their biological functions. Migratory movements of fish are described by two broad classifications; potamodromy and diadromy. Potamodromous species migrate solely within the freshwaters of a river system. Diadromous species migrate between fresh water and sea water and are further classified into catadromous, amphidromous and anadromous species. Catadromous species migrate to the sea for breeding and back to freshwater to feed and grow. Amphidromous fishes migrate between freshwater and the sea but not for the purpose of breeding. Anadromous species migrate into freshwater to spawn, with adults generally being resident in marine waters.

Regardless of migratory classification, all fish need to move along streams over scales of metres or hundreds of kilometres to:

- feed;
- spawn;
- seek shelter and refuge;
- enhance dispersal of young fish;
- counter downstream displacement following high flows;
- recolonise after droughts.

Movements can be regular seasonal migrations undertaken by much of the population or they can be less regular and less well defined. In tropical environments fish movement and migration occurs throughout the year and during high and low flows. Fish often respond very quickly to subtle movement triggers such as localised rainfall events.

1.6. Glenore Weir

Glenore Weir (Figure 3 & 4) was constructed in 1968 and is located about 103km from the mouth of the Norman River at Karumba. The weir is located just above the tidal limit of the Norman river, with a single large waterhole downstream, before tidal influence. The weir is a concrete overfall weir that was 2.1m high in its old configuration and has been raised to 3.68m as part of the current project. The new weir is 250m wide, with a central ogee crest and concrete and rock abutments. The weir forms a 3.3km long weir pool that provides the main water supply for the townships of Normanton and Karumba.

From 1968 to 2016 no fish passage was incorporated into the weir and the weir impacted on the migrations of fish communities during that time. As the weir was relatively small and drowned out on a regular basis this impact was not great, with many species of diadromous fish still found upstream of the weir. However, it was still recognised for the fish accumulations that occurred below the weir. The greatly enlarged new weir was deemed to be likely to have a much greater impact on fish migrations and as such was required to include fish passage in the design.

Figure 1. Glenore Weir prior to raising in 2016, wall height 2.18m.

Figure 4. Glenore Weir after raising in 2016, wall height 3.68m

1.7. Glenore Weir Fishway

While long recognised as a barrier to fish movement, it was not until the recent raising that Glenore weir incorporated fish passage into the design. The fishway was designed specifically for the fish communities of the Norman River and was based on successful designs used elsewhere in Queensland. The design needed to be capable of passing very small and juvenile fish (<20mm), as well as large fish such as freshwater sawfish (1.5m+), freshwater stingray (1m) and barramundi (600mm). The design also needed to be relatively maintenance free and have a fixed crest level that maintained water supply levels in the weir pool without draining the pool. To this end the precast concrete cone fishway design (Figure 5) was chosen as the most suitable fishway that could fulfil this brief. Other designs considered in the design evaluation phase included the vertical slot fishway and the trapezoid fishway, however these could not meet the fish size requirements.

Figure 2. Left bank side of Fitzroy River Barrage showing the fishway, Gate 1 and ogee crest structures. Image from Google Earth.

The cone fishway was incorporated into the left abutment of the weir and constructed perpendicular to river flow. It consisted of a 5.0m wide sloping channel into which 40 precast high/low cone baffles (Figure 6) were inserted. The downstream entrance to the fishway is located directly adjacent to the spillway and has a turning pool that directs flow downstream for maximum attraction.

Within the fishway channel, baffles were spaced 1.5m apart, with each baffle being 60mm lower than the next baffle upstream. The baffles consisted of high cones and low cones which enabled the design to cope with up to 900mm of headwater variation. During low flows fish could ascend through each of the 6 slots between the cones. As headwater rises the low cones become inundated, creating a wider channel suitable for large fish like sawfish. The high cones maintain reduced flow conditions that are suitable for smaller fish to ascend during higher headwater levels.

The upper most baffle of the fishway has an invert level set 200mm lower than the crest level of the weir. This promotes low flows to go through the fishway and creates the best possible attraction conditions at the fishway entrance.

In addition to the cone fishway on the left abutment a rock ramp fishway was constructed on the right abutment. This fishway consists of a 15m wide, 45m long low-slope ramp of rock concreted in place (Figure 7). The rock ramp fishway does not become engaged until significant flows occur in the system, with a control level of

3.99m. This ensures that fishways on the weir operate from commence to flow until near drownout of the weir.

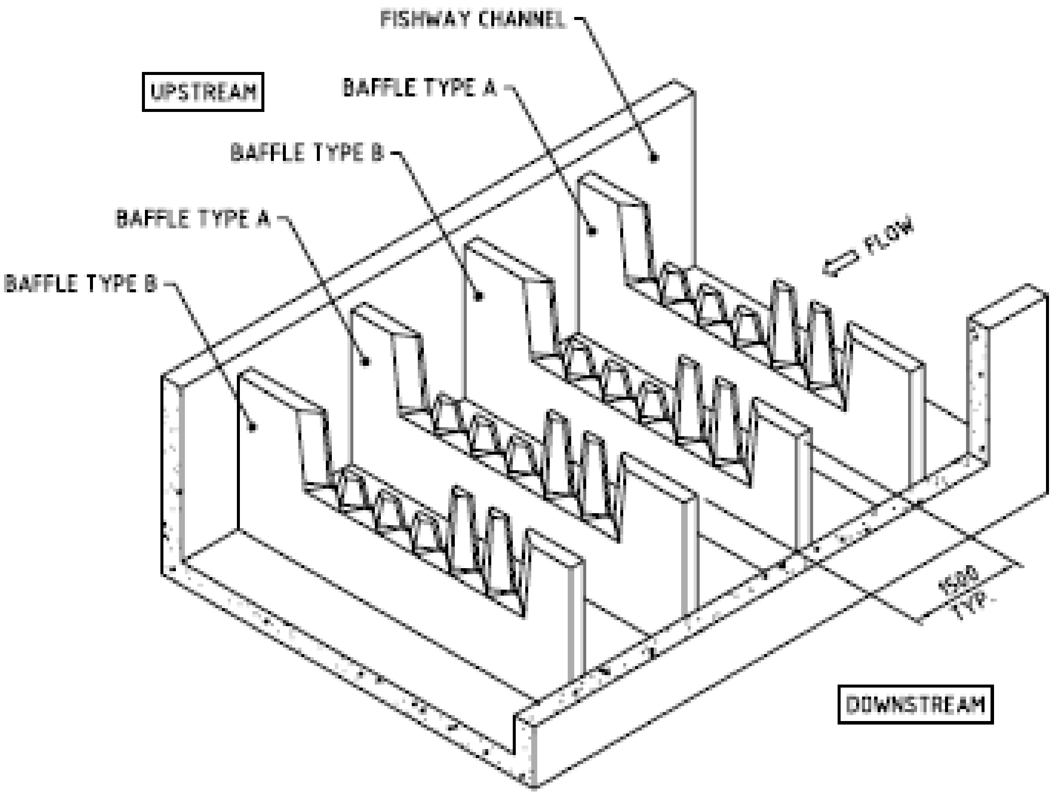

Figure 6. Illustration of the layout of pre-cast cone baffles within the fishway channel.

Figure 7. Secondary rock ramp fishway on the right abutment.

2. Methods

The assessment of the Glenore Weir cone fishway was based on evaluating the successful passage of all fish passing through the fishway during the first wet season of operation for the fishway. This was completed by comparing the fish community composition and size at the entrance to the cone fishway with that from exit of the fishway. In this way, the passage success of different species and different life stages of those species could be compared. The hypothesis behind this sampling methodology is that an efficiently operating fishway will have similar fish communities and size ranges at the top of the fishway (successful ascent) and the bottom of the fishway (attempting ascent). This direct top/bottom fishway comparison methodology is useful when sampling by necessity must be carried out over a short timeframe, as to detect changes to fish communities in the river upstream and downstream of the fishway may require many years of sampling.

To complete this sampling two lightweight single cone traps were manufactured from steel square tube and covered with standard 70% shade-cloth with an average mesh diameter of 1.5 mm (Figure 18). The traps had a single horizontal cone with a 150mm opening that collected fish from three cone slots, covering either the low cone or high cone section of the channel. This trap could collect fish as small as 10mm in length, while still capturing larger fish and not becoming clogged with algae that could affect fishway operation.

Figure 3. Cone fishway traps located at the exit of the fishway during a top sample.

A sample of fish that had successfully ascended and exited the fishway was obtained by placing the trap immediately upstream of the last fishway baffle as shown in figure 8. Traps were installed to prevent fish escaping from the fishway, with a tight fit against the baffle walls to prevent escape. A sample of fish that were attempting to ascend the fishway was obtained by placing the trap immediately upstream of the first fishway baffle that displayed a headloss at the bottom of the fishway. As the tailwater was relatively stable throughout the sampling period this generally meant the bottom sample trap was placed in the 1st resting pool upstream of ridge 10.

Traps were set for 2hrs in either the top or bottom of the fishway in a randomised paired top/bottom sample, for a total top/bottom paired sample time of 4hrs. The 4hr paired sample was undertaken in both the morning (7.30am to 11.30 am) and afternoon (12.30pm to 4.30pm). This increased sampling effort to account for diurnal movements, reduced escapement from the traps and reduced the effects that fish schooling could have on the sampling.

At the conclusion of each 2hr sample the trap was manually lifted out of the fishway and fish released into a 100-litre tank partly filled with aerated water. All fish captured during fishway sampling were identified to species level, counted and a sub-sample of 50 fish from each species were measured to the nearest millimetre (fork length for forked-tail species, total length for all other species). Fish were then released into the headwater pool.

Figure 9. Cone fishway traps located first resting pool of the fishway during a bottom sample.

3. Results

Over the duration of the sampling, 27 species of fish were captured either in the top or bottom of the cone fishway (Table 2). Bony bream species (*Nematalosa come and Nematalosa erebi*) were the most abundant species overall, accounting for 28% of the total catch. Macleay's Glassfish (*Ambassis macleayi*) were the second most abundant species (9.5% of catch), while longtom (*Strongylura krefftii*), 7.8% of the catch, spangled perch (*Leiopotherapon unicolor*), 6.5% of the catch and giant glassfish (*Parambassis gulliveri*), 4.2% of the catch, were the next most abundant species. All other species where found in lower numbers, with no other species forming greater than 3% of the total catch.

Despite relatively similar sampling intensity, more fish were captured at the exit of the cone fishway than at the entrance, with the exit of the fishway accounting for 67% of the total catch. This is further reflected in the catch rate, with the catch rate from the bottom of the fishway (14.1 fish/hr) being lower than that from the top of the fishway (25.3 fish/hr).

The top of the cone fishway captured one less species in total (23 species) than the bottom of the fishway (24 species). Four species, Common Ponyfish, (Leiognathus equulus), unidentified goby (*Glossogobius sp.)*, toothless catfish *(Anodontoglanis dahli)* and sleepy cod *(Oxyeleotris lineolatus)* were only captured in the bottom of the fishway. While three species, Flathead goby (Glossogobius giuris), Hyrtl’s tandan (Neosilurus hyrtlii) and Tarpon (Megalops cyprinoides) were only captured at the top of the fishway. All of these species except the common ponyfish were captured in very low numbers (<2 individuals).

The data from the entrance and exit of the cone fishway was compared to determine differences in size classes for abundant species entering and exiting the fishway.

Bony Bream

Data from the length frequency graph for bony bream indicates that a sizable proportion of fish of the smallest size classes were successfully ascending the cone fishway (Figure 10). Generally, a higher percentage of smaller fish were found at the entrance of the fishway, however due to the relatively small sample size some variation could be expected. The cone fishway successfully passed fish as small as 30mm, but sampling indicates that these smaller fish may be slightly inhibited in their movement upstream.

Table 2. Species and number of fish sampled from top and bottom of the cone fishway.

Species	Common Name	Fishway Location	
		Bottom	Top
Diadromous			
Ariopsis graeffei	Lesser salmon catfish	1	5
Ariopsis paucus	Carpentaria catfish	2	5
Leiognathus equulus	Common Ponyfish	10	0
Toxotes chatareus	Seven-spot archer fish	4	5
Glossogobius giuris	Flathead goby	0	1
Glossogobius sp.	goby	2	0
Lates calcarifer	Barramundi	7	17
Ambassis macleayi	Macleay's Glassfish	73	36
Potadromous			
Parambassis gulliveri	Giant glassfish	1	47
Anodontoglanis dahli	Toothless catfish	1	0
Ariopsis berneyi	Berney's catfish	1	2
Neosilurus hyrtlii	Hyrtl's tandan	0	1
Neosilurus sp. nov.	Undescribed catfish	4	28
Amniataba percoides	Barred grunter	9	2
Leiopotherapon unicolor	Spangled perch	13	61
Scortum ogilbyi	Gulf grunter	2	3
Liza alata	Diamond mullet	3	2
Liza subviridis	Greenback mullet	3	7
Oxyeleotris lineolatus	Sleepy cod	1	0
Oxyeleotris selheimi	Giant gudgeon	2	1
Glossamia aprion	Mouth almighty	3	1
Melanotaenia splendida inornata	Chequered rainbowfish	6	18
Megalops cyprinoides	Tarpon	0	1
Nematalosa erebi	Bony bream	131	130
Nematalosa come	Bony bream	51	16
Strongylura krefftii	Longtom	39	50
Thryssa scratchleyi	Freshwater anchovy	2	1
	Total Number of Fish	369	777
	Total Sampling Time (hrs)	26.25	30.66
	Catch Rate (Fish/Hour)	14.1	25.3
	Total Number of Species	24	23

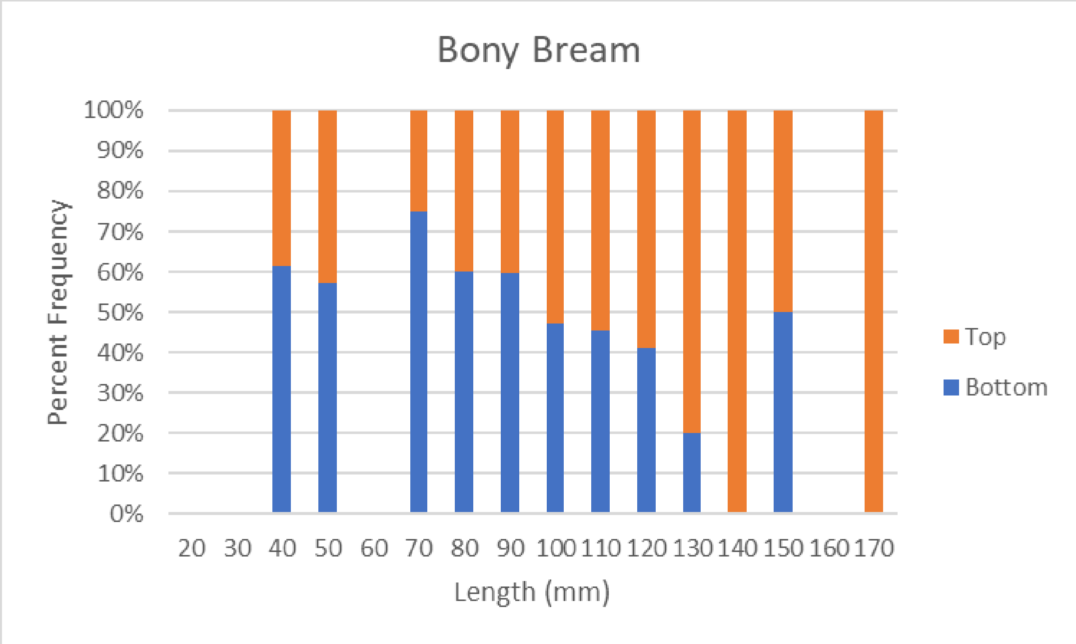

Figure 4. Length frequency of bony bream from entrance and exit trap samples.

Ambassid Species

Data for Macleay's glassfish and giant glassfish were combined to allow analysis and due to the difficulty of identifying these species apart at these small sizes. The combined length frequency for both species indicated that all size classes were successfully ascending the cone fishway (Figure 11). Fish as small as 10mm were captured at the top of the fishway and indicted that these species could successfully ascend.

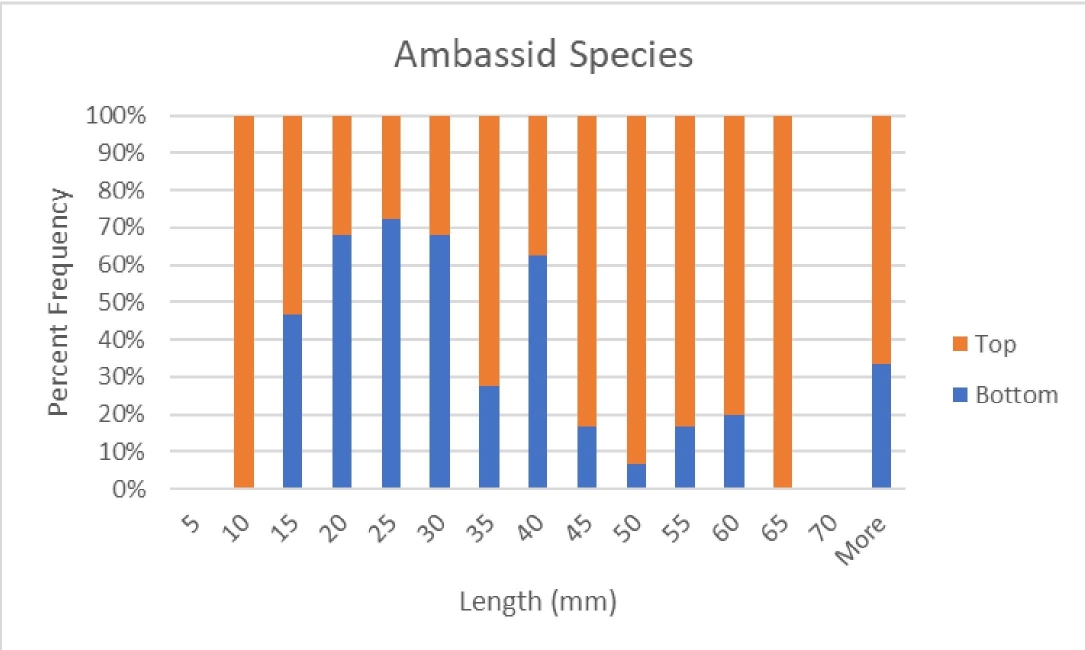

Figure 115. Length frequency of long-finned eels captured in the March 2016 entrance and exit trap samples.

Longtom

Data from the length frequency graph for longtom indicated that most fish passed through the cone fishway successfully, with even small fish successful (Figure 12). Longtom, being a long thin species were generally larger than other species that ascended the fishway, but the largest and smallest of this species could ascend the fishway.

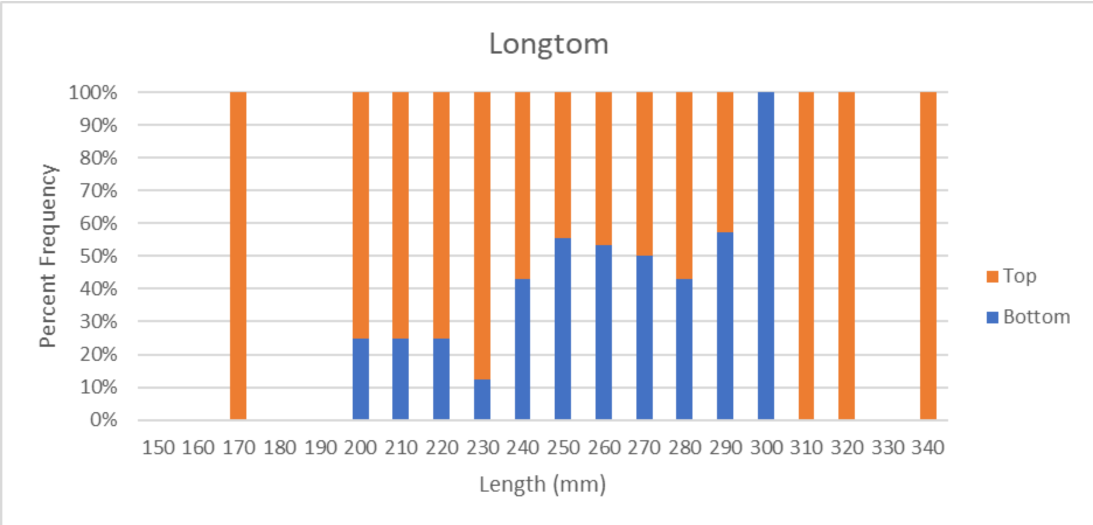

Figure 126. Length frequency of longtom from both entrance and exit trap samples.

Many other species successfully ascended to the top of the fishway, but their total numbers were too low to allow length frequency analysis. However generally for these species, all size classes could successfully ascend to the top of the fishway. In Table 3 the largest and smallest fish for each species recorded from the top and bottom samples are presented. Note that only species that were not present in either one of the traps have dissimilar size ranges, with all species captured in both locations having generally comparable size ranges.

Table 3. size range of all species captured from top and bottom sampling of the cone fishway.

Common Name	Bottom (size – mm)		Top (size – mm)	
	Smallest	Largest	Smallest	Largest
Diadromous				
Lesser salmon catfish	300	440	133	470
Carpentaria catfish	220	220	328	358
Common Ponyfish	12	30	-	-
Seven-spot archer fish	21	67	33	110
Flathead goby	-	-	135	135
goby	32	38	-	-
Barramundi	187	380	155	500
Macleay's Glassfish	12	60	12	50
Potadromous				
Giant glassfish	108	108	10	122
Toothless catfish	270	270	-	-
Berney's catfish	220	220	185	205
Hyrtl's tandan	-	-	220	220
Undescribed catfish	80	97	75	428
Barred grunter	29	108	22	96
Spangled perch	48	108	38	110
Gulf grunter	65	104	24	66
Diamond mullet	115	150	114	120
Greenback mullet	135	161	125	170
Sleepy cod	354	354	-	-
Giant gudgeon	220	258	225	225
Mouth almighty	125	125	130	135
Chequered rainbowfish	45	51	46	55
Tarpon	-	-	178	178
Bony bream	33	148	32	210
Bony bream	21	255	30	305
Longtom	195	426	170	308
Freshwater anchovy	58	58	28	28

4. Discussion

At Glenore weir, a new complimentary cone and rock ramp fishway was constructed to assist the passage of fish past the new weir constructed for Normanton's water supply. The new cone fishway was determined by this study to be quite successful, with large numbers of large and small fish successfully ascending the fishway. No sampling was undertaken of the rock ramp fishway as flows in the river were not sufficient to engage this fishway. In general, the sampling of the cone fishway indicated that it was suitable for almost all species, with only one species (ponyfish) appearing to be unable to ascend the fishway.

4.1. Increased Fish Passage

The operation of the new fishway has greatly increased the opportunity for fish to pass the weir into the Norman River upstream. Prior to the construction the new weir and fishway, fish passage was blocked by the existing Glenore Weir, which did not include any fish passage. Fish passage could only occur at the site when drown out flood flows occurred. These allowed fish to swim over the weir into the pool upstream. Based on the gauged data from the site and the estimated drown out flow for the weir of 232 cumecs (SMEC 2014), passage past the weir would have been available for 16% of the time the river flowed during the wet season previously. Meaning that for 84% of the time fish could not pass the weir despite there being flow in the river.

With the installation of the fishway, that operates from commencement of flow through to the drownout of the new weir, fish have full passage for the entire wet season. Since the duration of flows within this system are relatively short compared to many other streams, ensure 100% passage availability is critical to ensuring fish communities can maintain productivity.

4.2. Fish Numbers

Although sampling was undertaken throughout the wet season, the sampling was relatively brief and partially compromised by the right abutment breach. It therefore can only provide a snapshot of the fish communities that would be migrating past Glenore Weir. However, the fish passage rate achieved during sampling still indicates that a considerable number of fish would have passed the fishway into the Norman River upstream.

Extrapolating from the sampling data it is likely that the cone fishway on Glenore Weir will pass at least 70,000 fish annually, contributing to significant restoration of fish numbers of the lower Norman River catchment. This increase in fish numbers is likely to significantly enhance fish communities upstream of the weir over the coming years and validates installing the new fishway.

The economic benefit to the Norman River and the Carpentaria Region of the new fishway is difficult to measure without extensive before and after studies of the fisheries. However, the addition of more than 70,000 fish annually to the river upstream will likely have a positive impact on fisheries in the region. With many of the species captured during the sampling being commercially or recreationally important species, providing these fish with access to freshwater nursery habitats upstream can only improve the productivity of this system. Hence, providing improved access for these species through the Glenore Weir cone fishway will help to boost populations and in the long-term provide major benefits to the Norman River recreational fishery.

4.3. Small Fish Passage

Several species were captured in large enough numbers that allowed comparison of their length frequencies between the entrance and exit of the fishway. This is a good reference to determine if any life stages, particularly small sizes, are inhibited in their movement through the fishway. The results of this analysis indicated that the cone fishway could successfully pass smaller fish. Species such as the bony bream could pass the cone fishway as small as 30mm, with no significant difference between entrance and exit samples. Glassfish species (Figure 13) also had comparable results, with glassfish as small as 10mm ascending the cone fishway.

Figure 13. Juvenile giant glassfish and adult Macleay's Glassfish from the exit trap.

Increasing passage of these smaller fish is critical to the long-term survival of these species. The lack of passage for small fish has been identified at several other fishway sites as leading to declines in fisheries (Stuart 1999, Marsden et. al. 2017). Delaying their successful passage and forcing these fish to congregate below a weir is likely to have disastrous consequences on their mortality.

As an example, the Fitzroy Barrage on the Fitzroy River near Rockhampton has extensive predation of small fish from other animals such as birds, catfish (Figure 14), barramundi and bull sharks. These predators can quickly deplete the stocks of juvenile fish delayed while passing the barrage, negatively affecting the production of the whole river system. With the fishway in operation at Glenore Weir, no accumulations of these small fish were detected below the weir, a good indicator that the fishway is allowing free passage of these fish. Successfully passing these fish through the cone fishway will increase survival rates and increase the productivity of fisheries above and below the weir.

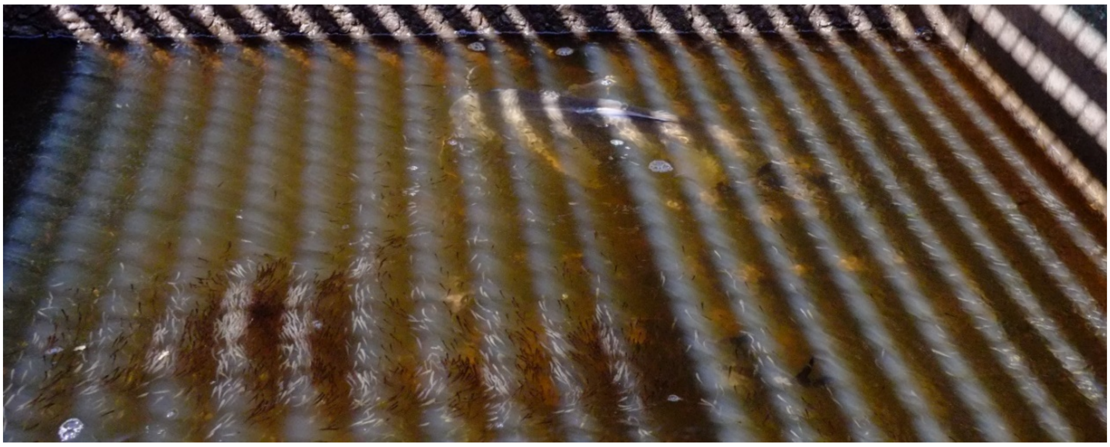

Figure 14. Large predators consume copious quantities of juvenile fish that are unable to pass migration barriers.

4.4. Large Fish Passage

The passage of large fish through the cone fishway was also quite successful, with moderate numbers of barramundi, longtom, catfish and large bony bream observed moving through the cone fishway during the sampling. Adult freshwater stingrays (Figure 15) were also observe moving upstream within the fishway, the first time this species has been recorded using a fishway. Although not captured in the sampling stingray were observed moving through several slots as they progressed upstream. Although wider than the slots, the stingray could fold back its wings as it passed through the slot to make a successful ascent.

Freshwater sawfish were not observed during the sampling. As this species is listed as endangered and is quite rare it is not unexpected that it was not encountered. Further sampling of the system for sawfish is warranted to determine if they are found in the system (highly likely given the multiple reports from local fishermen during sampling) and if they can successfully ascend the fishway for which it was specifically designed.

Figure 15. Adult Freshwater stingray using the fishway.

4.5. New Fish Species

The sampling of the cone fishway also revealed a new species of catfish (Figure 16) that has not been recorded migrating previously and has only been recently been discovered. The undescribed species is thought to be a member of the Neosilurus family, although some reports suggest that it may be a member of the Porochilus family. The species has only been recorded as adults in the upstream reaches of the Norman River previously, so the capture of this species in the lower Norman River extends the known range for this species.

Previously only adults had been collected from the river upstream, so the presence of an adult and multiple juveniles during fishway sampling is the first record of juveniles of this species. The movement of adults and juveniles through the fishway also greatly enhances the knowledge of this species. The sampling shows that there is potential for a downstream spawning migration of adults followed by an upstream dispersal migration of juveniles and adults. This highlights the need to maintain free passage along the river system for both adults and juveniles.

Figure 16. Adult and juvenile Neosilurus catfish of an undescribed species.

While not a species new to science the capture of giant glassfish successfully ascending the fishway is the first record of this species undertaking migrations. Previous information recorded that this species bred in July in the upper reaches of streams (Merrick and Schmida 1984). However, the sampling at Glenore Weir captured both adults and juveniles (Figure 17) successfully ascending the fishway. The movement of juvenile giant glassfish at this time (February/March) contradicts the previous records for recruitment of this species and may point to dispersal migrations of this species occurring during the wet season that have not previously been recorded.

Figure 17. Adult (left) and juvenile (right) giant glassfish that successfully passed through the cone fishway.

4.6. Effects of the Weir Abutment Breach

The sampling of the fishway during the 2017 wet season was affected by the breach of the right abutment that occurred early in the season. This breach passed much of the volume of water flowing through the site past the weir and around through a new channel on the right abutment. The water from this breach entered the tailwater pool well downstream of the weir. When fish are migrating, they are attracted to large flows at barriers as these point to flow paths past the barrier. The large flow created by the right abutment breach would have negatively affected the movement of fish to the fishway entrance as the flow would have attracted large numbers of fish away from the weir. Even though good numbers of fish were attracted to the fishway and successfully ascended, the presence of the breach would have reduced the number of fish that could find the fishway entrance.

Figure 18. Breach around the weir on the right abutment.

Later in the season the breach was sealed and normal attraction flows occurred at the site. Under these conditions, fish could easily find the fishway entrance as it was directly adjacent to the spillway and the flows that occur there (Figure 19).

Figure 19. Location of the fishway entrance adjacent to the spillway of the weir.

Even though the cone fishway was sampled in less than ideal circumstances with the right abutment breach, it still recorded fish passage comparable to other fishways in Queensland (Marsden et. al. 2017). Due these circumstances during sampling, the maximum passage rate of 25 fish/hour is likely to be only a fraction of the highest likely rate of passage.

5. Conclusion

The construction of the cone fishway on the newly raised Glenore Weir has vastly increased the passage of fish species within the Norman River and will contribute to maintaining and improving the fish communities upstream of the weir. The modest investment in the cone fishway has increased fish passage rates to more than 70,000 fish per year. For the Carpentaria Regional Council, the Glenore Weir fishway has been a significant step forward in restoring the environmental values of the Norman River upstream of the weir and can be summarised as

1. Improved fish passage past the weir, with access increased from 16% of flows to 100% of flows that occur in the river.
2. A reduced reliance on flood flows to provide passage as passage will now be provided the fishways whenever there is flow in the river,
3. an exponential increase in the number of fish passing, with at least 70,000 extra fish able to use the fishway when previously none would pass due to the pervious weir,
4. the successful passage of a multitude of small-bodied fish (<45 mm long) very few of which would have survived predation below the weir previously,
5. the successful passage of large fish past the weir that would have been restricted in their passage due to the weir.

Building on these achievements with further fish passage improvements at other barriers in the region, such as at Walkers Creek, fish communities in the streams of the Carpentaria Regional Council area can be maintained and even enhanced to provide opportunities for the large number of recreational and commercial anglers that utilise the streams of the region.

6. Recommendations.

The Glenore Weir fishway has met its design requirements for the passage of fish past the new weir, but could be further complemented with:

- Direct monitoring of sawfish communities in the Norman River to determine if this species can successfully migrate past Glenore Weir.
- Investigation of fish passage options for other barriers in the region, particularly;
    - Providing fish passage at the old causeway upstream of the railway line on the Norman River (downstream Glenore Weir).
    - Providing fish passage at the old causeway upstream of the Karumba Road on Walkers Creek.
    - Maintenance of the fishways on the Flinders, Bynoe and Little Bynoe Rivers to ensure they meet their design objectives.

7. References

Barrett J. and Mallen-Cooper M. (2006) The Murray River's 'Sea to Hume Dam' fish passage program: progress to date and lessons learned. Ecological Management & Restoration7: 173–183.

Burrows, D.W. & Perna, C. (2006) A Survey of Freshwater Fish and Fish Habitats of the Norman River, Gulf of Carpentaria. Report No. 06/31 Australian Centre for Tropical Freshwater Research. James Cook University, Townsville, Queensland, 39 pp.

Hydrobiology Pty Ltd, (2005), Ecological and Geomorphological Assessment for the Gulf and Mitchell Water Resources Plan. Consultant Technical Advisory Panel Report to The Queensland Department of Natural Resources and Mines.

Marsden, T., Berghuis, A. and Stuart, I. (2017) Fitzroy Barrage, Cone Fishway Upgrade and Monitoring Report. Report to the Fitzroy Basin Association for the Fish Friendly Fitzroy Project. The Fisheries Collective, 49pp.

MDBA (2012). Key threats to native fish. Flyer for the Murray-Darling Basin Commission (MDBC). Source: http://www.mdba.gov.au/sites/default/files/archived/mdbc-NFS-reports/2196_fact_sheet_Key_threats_to_native_fish.pdf.

Peverell, S. (2009) Sawfish (Pristidae) of the Gulf of Carpentaria, Queensland. Masters (Research) thesis, James Cook University. 163pp

Pusey, B.J., Kennard, M.J. and Arthington, A. (2004). Freshwater Fishes of North-Eastern Australia. CSIRO publishing: Collingwood, Victoria.

SMEC (2014) Glenore Weir, Concept Design for Raising of Glenore Weir, Fishway and Pump Station. Report to Carpentaria Regioanl Council. 82pp.

Stuart, I.G. and Mallen-Cooper, M. (1999). An assessment of the effectiveness of a vertical-slot fishway for non-salmonid fish at a tidal barrier on a large tropical/subtropical river. Regulated Rivers: Research and Management 15:575-590.

Wetlandinfo (2017) Norman River drainage sub-basin — facts and maps, WetlandInfo, Department of Environment and Heritage Protection, Queensland, viewed 29 May 2017, <https://wetlandinfo.ehp.qld.gov.au/wetlands/facts-maps/sub-basin-norman-river/>.