Fish Friendly Fitzroy Project

Fitzroy Barrage Fishway

Sampling and Recommended Upgrades

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The Fisheries Collective

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The Fitzroy Barrage Fishway: Sampling and Recommended Upgrades report has been prepared with due care and diligence using the best available information at the time of publication. The Fisheries Collective and the Fitzroy Basin Association Incorporated (FBA) holds no responsibility for any errors or omissions and decisions made by other parties based on this publication.

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1. Summary

The Fitzroy River contains one of the most biodiverse and important fish assemblages in tropical eastern Australia with at least 30 species, including a variety of freshwater and estuarine/freshwater species. Almost all of these fish species migrate as part of their life-history with approximately half moving between the estuary and freshwater. The Fitzroy River tidal barrage, 60 km from the river mouth, is a major fish passage barrier and has contributed to fragmentation of fish migration pathways.

The Fitzroy barrage vertical-slot fishway provided adequate functionality in the 1990s but new technology is now available to vastly increase its functionality. The objective of the present report was to experimentally determine the suitability of various new hydraulic control innovations, including sills and keyhole slots, to provide significantly improved fishway hydraulics and potentially extend the range of fish species and sizes successfully using the existing fishway. These modifications have proven highly successful in other recent Australian fishways.

In 2014/15 a series of *in situ* experiments were undertaken to manipulate the hydraulic function of the fishway and 16 species of fish were collected and >1,000,000 individual fish were collected/observed. The super abundant small-bodied fish, dominated by empire gudgeons, could not ascend either the existing fishway or the existing fishway with modified low turbulence pools.

The major constraint was the limited tailwater tidal range of the fishway which only enabled fish to enter during high tide, for 2 hours per day, after which small-bodied fish were hydraulically ejected from the fishway. Hence, the experiment to test the improved pool hydraulics, created by the addition of sills and keyhole slots, were negated by the receding high tide.

The major learning from the field trials is that a tailwater stabilisation pool is required and this recommendation forms part of a fish passage ‘package’ of works that should be developed and implemented together to bring the Fitzroy barrage back to a nationally highest standard of fish passage. The two major components of the package are: (i) slightly modifying the existing vertical-slot fishway and (2) installing a cone fishway.

For the Fitzroy Basin Association, the value of the package of works if fourfold: (1) an extension of the operational time of the fishway from the current *2 hours/day to 24 hours/day*, (2) extension of the operational range from *39% to 95% of high tides*, (3) an exponential increase in the number of fish using the fishway, potentially *to millions per annum,* (4) extension of successful passage to the multitude of small-bodied fish (<45 mm long) from the current passage rate of *10% up to 80%*.

The package of works will take advantage of the enormous extra potential for fish passage at the Fitzroy barrage – the unprecedented ecological outcomes of which can extend fish passage to millions more fish and represents an outstanding ecological investment opportunity.

Major recommendations

Existing vertical-slot fishway

1. Modify the jet alignment of the existing vertical-slot baffles in the lower leg of the existing fishway to bring the design back to the original specification.

2. Install three extra baffles in the vertical-slot fishway exit channel and sills to reduce the hydraulic gradient of the existing fishway.

3. Install a tailwater control pool to stabilise the tailwater of the existing fishway and extend the operating time of the part-time (2 hours/day) vertical-slot fishway to full time (24 hours/day).

4. Install a sloping trash rack at the exit of the fishway.

New cone fishway

1. Install a cone fishway adjacent to the existing fishway which will extend fish passage to 80% of the biodiverse small bodied-fish and exponentially increase the number of fish passing per annum, potentially to millions of fish.

2. Install an additional section of lower leg cone fishway below the existing vertical-slot fishway to increase tidal operation range from 39% to 95% of high tides.

2. Background

The Fitzroy River contains one of the most biodiverse and important fish assemblages in tropical eastern Australia with at least 30 species, including a variety of freshwater and estuarine/freshwater species (Berghuis and Long 1999). Almost all of these fish species migrate as part of their life-history with approximately half moving between the estuary and freshwater (Stuart and Mallen-Cooper 1999). The Fitzroy River tidal barrage, 60 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 and reduced ecosystem function (Sheaves et al. 2014).

To improve fish passage, various fishways have been installed on the Fitzroy barrage since the barrage was first constructed in 1970, though the first two designs were largely ineffective (Kowarsky and Ross 1981; Byron and Toop 1993). In 1995, a vertical-slot fishway was installed which greatly improved passage of most fish species but the abundant small fish (<45 mm long) communities could not ascend and the operating time of the fishway was only for a small fraction of the downstream tidal range (Stuart and Mallen-Cooper 1999).

Post-construction monitoring of each of the design upgrades to the Fitzroy barrage fishway has been a key to incrementally improving the biological functionality and the historic intensity of the work also reflects the ecological significance of the site. For the Fitzroy Basin Association (FBA), a more cost-effective and contemporary approach to providing excellent fish passage was to conduct in-situ experiments, trialling newly available hydraulic control innovations with fish that are motivated to migrate under natural conditions. The advantage of this approach is that when the experimental period is complete, the field evidence can then be integrated into a new design which is fully optimised for the wide range of fish species and unique site hydraulic conditions at the Fitzroy barrage (Baumgartner *et al.* 2011).

The FBA have recently funded a project, under the 'Fish Friendly Fitzroy' project to improve passage at the Fitzroy barrage by conducting a series of targeted experiments to identify the most ecologically cost-effective design and operational solutions. The fishway experiments are based on two recent fish passage technology advances: (i) improvements in understanding how water turbulence effects migrating fish and (ii) new cone fishway design solutions that have shown great promise for Australian coastal fish species (Mallen-Cooper et al. 2008; Marsden 2011).

Improving connectivity and fish passage is likely represent an outstanding investment opportunity for the FBA, especially with clear monitoring objectives, from which major fish and fisheries outcomes can be demonstrated. The ecological outcomes of improving connectivity will also likely contribute to much broader river and estuary repair for the Fitzroy catchment (Creighton et al. 2015). The objective of the present report was to experimentally determine the suitability of various new fishway types and hydraulic control innovations to provide significantly greater barrage fishway operational time and extend the range of fish species and sizes successfully using the fishway.

At the Fitzroy barrage, a series of *in situ* experiments were undertaken to manipulate the hydraulic function of the fishway and these were completed in 2014/15. From these experiments, we identified the optimal design criteria to guide and inform the forthcoming 2015/16 fishway upgrade program.

Requirement for Monitoring

Evaluation of the Fitzroy barrage fishway is important to understand if fish are passing efficiently, for evaluating hydraulic functionality and also for determining broader ecological benefits to fish populations. In general, monitoring also contributes to a learning process to improve future tropical fishway designs. Monitoring is an essential process to demonstrate that the fishway conforms to the original hydraulic and biological design intent of the fish passage program (Figure 1).

At the Fitzroy barrage fishway, the monitoring objectives to test function are expressed as testable performance criteria. These include measuring the hydraulic function (e.g. % of time operational) and also the movement of particular fish species and sizes (e.g. % of the abundant small fish size classes which successfully ascend). Another measure of fishway function is changes to the upstream fish community but this long-term research question has not been directly included as an outcome of the present project due to project constraints.

Monitoring Hydraulic Function

The hydraulic function of the fishway is determined from both theoretical calculations of water velocity and turbulence (the energy dissipation of the water in a pool) and field based measurements of head loss between pools. These hydraulic parameters are important so that the target species of fish can use the fishway and include specific criteria to pass particular species and size classes of fish (e.g. the fishway will have low turbulence [<20 W/m3], low headloss (the elevation drop between fishway pools) and low maximum water velocities [1.2 m/s] to pass small fish [<50 mm long]). Hydraulic and physical measurements provide a rapid assessment of performance.

Monitoring Ecological Performance

Monitoring of fishways is usually done by cage trapping fish at the exit (top) and entrance (bottom) and then directly quantifying fishway function by using the proportional (%) passage success. The proportional passage can be compared for fish species diversity, abundance and sizes classes between the fishway entrance and exit. This is one of the most common methods of fishway assessment (e.g. Mallen-Cooper 1999, Stuart et al. 2008a). Although fish attraction to the fishway just as important but is much more difficult to assess and is therefore rarely done.

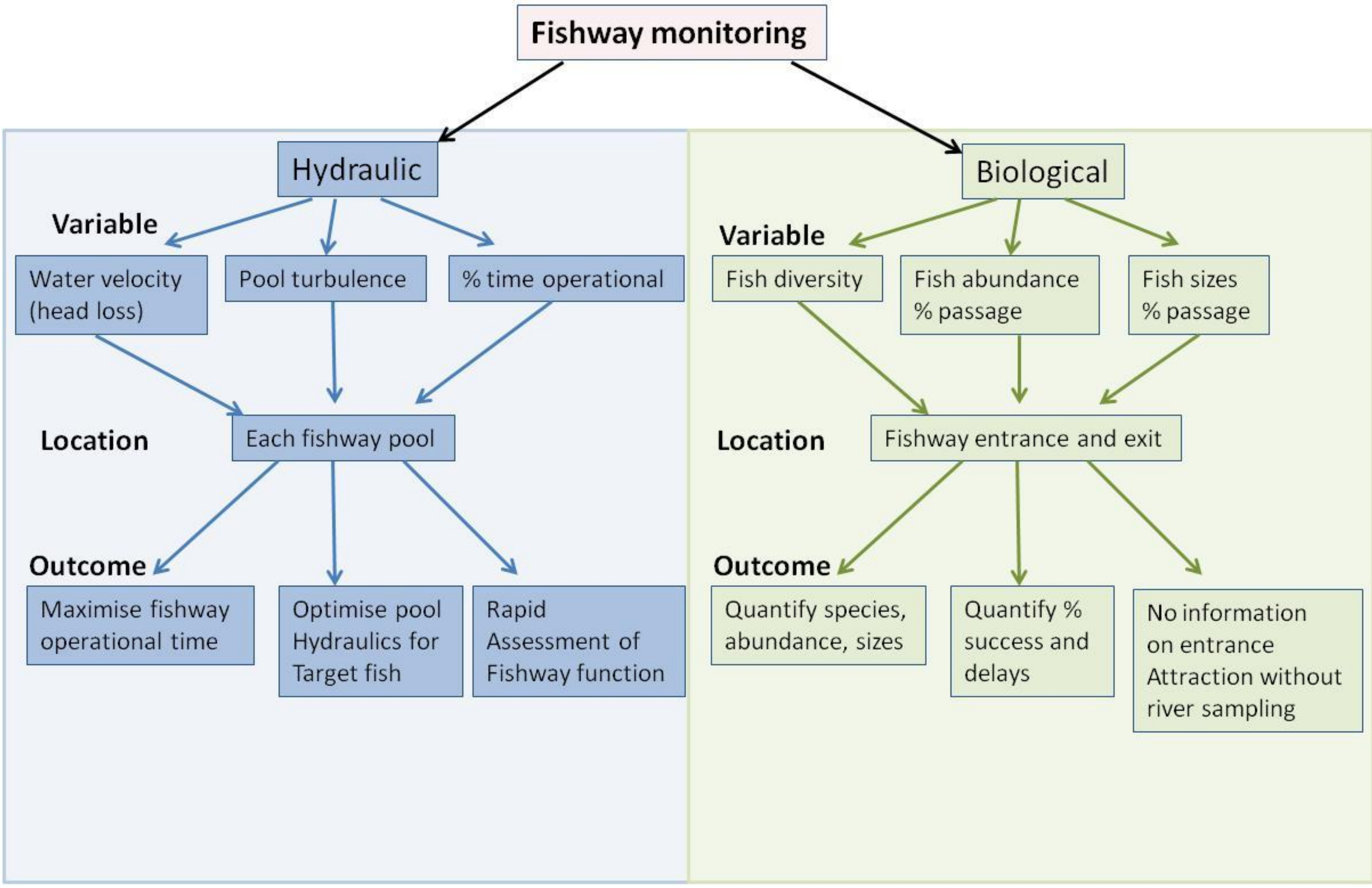

Figure 1. Monitoring pathway that have been undertaken at the Fitzroy Barrage Fishway.

Monitoring the Fitzroy Barrage Fishway

The experimental design for the current FBA fishway monitoring report is outlined in the project methods but the basic experimental logic is to utilise both hydraulic and biological measurables to determine the optimal fishway design for the unique fish community and range of flows. The four specific monitoring objectives are:

1. Can the fishway be optimized to pass a greater fish species diversity, abundance and size class range by testing a range of hydraulic improvement devices (e.g. sills, keyhole slots)?

2. What hydraulic parameters (e.g. water velocity [as indicated by headloss] and pool turbulence) influence fish passage success?

3. Can the operational range of the fishway be extended to cover a greater range of the tailwater conditions?

4. Can the barrage gates be integrated into the fishway function to optimize attraction of fish to the entrance?

3. Fish Community Monitoring

Methods

The assessment at the Fitzroy Barrage fishway was based on evaluating the successful passage of small fish with a total length less than 100 mm. A lightweight single cone trap was manufactured from steel rod covered with standard 70% shade-cloth with an average mesh diameter of 1.5 mm. Fish greater than 100 mm in length were excluded by a mesh panel with 25 mm square openings located in the entry of the cone trap. A sample of fish species and sizes classes attempting to enter the fishway was collected by placing the trap in the lower section of the fishway at the first pool above the limit for the daytime high tide as shown in Figure 2. 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 3.

At the conclusion of each exit or entry sample the trap was manually lifted out of the fishway and fish released into a 100 litre tank partly filled with aerated water. A sub-sample of 100 fish from each species were measured and released into the headwater pool. With the exception of noxious species who were euthanased, the remainder of the fish captured were counted and released into the headwater pool.

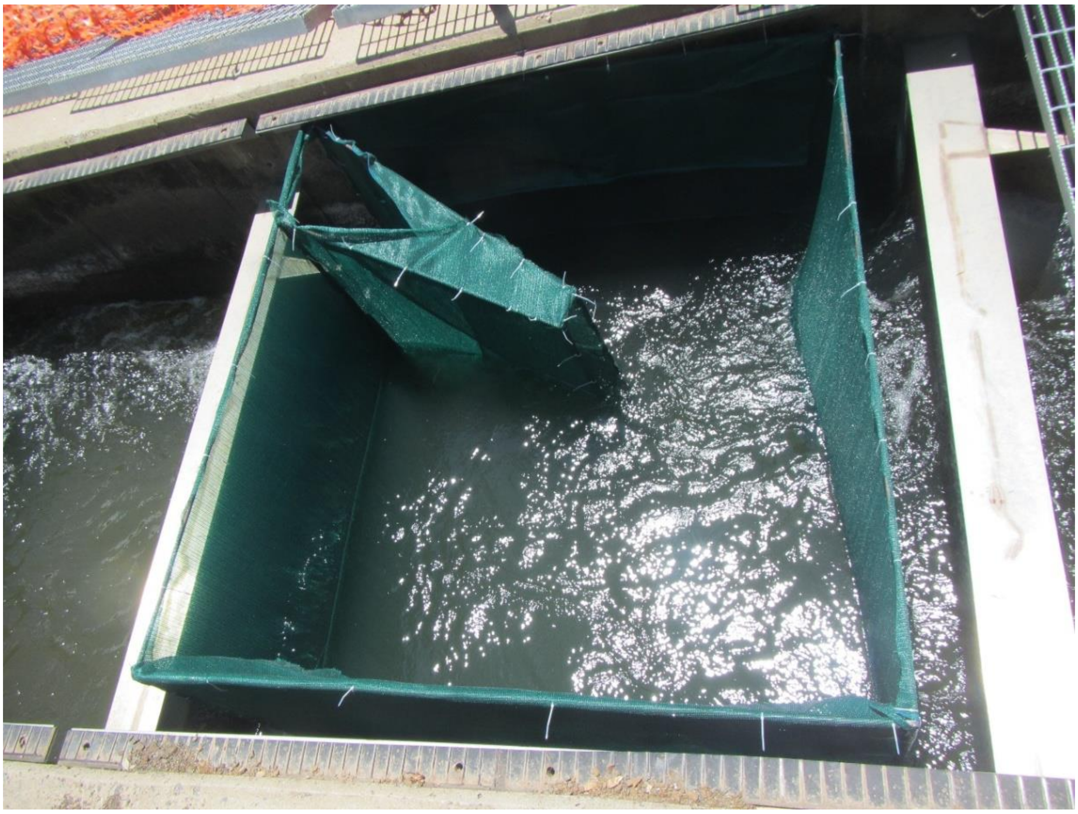

Figure 2. Fishway trap in entrance location.

Figure 3. Fishway trap in exit location.

Pilot trials were performed in December 2014 with the fishway in its standard configuration consisting of a 150 mm full length slot and 100 mm headloss between pools. Entry and exit samples over three hours during a daytime high tide were collected on 9th and the 10th of December respectively. The streamflow gauge at The Gap recorded a zero flow (DNRM data) and the fishway was the only flow release at the time of sampling.

Sampling in January 2015 assessed the success of fish passage at standard headloss using two slot modifications and the standard fishway configuration (no slot modification). Slots upstream of the high tide level for the day were modified with the temporary installation of either a keyhole slot insert or a mid-sill slot insert. The keyhole slot insert was a 600mm high piece of aluminium plate placed on the bottom of the fishway slot so as to partially narrow the slot width to 75 mm. The mid-sill insert was a 300mm high piece of aluminium plate fixed across the full width of the fishway slot at a central point between the fishway channel floor and water level.

Commencing from 19th to 26th January exit samples consisting of three keyhole, two mid-sill and two no slot modification as well as one entrance trap sample and one dip-net sample were performed during daytime high tides. In order to prevent fish remaining in the fishway following the overnight high tide the fishway was turned-off at the end of each sample and not operated until the tide level had reached the fishway approach the next day. The trap was installed in the fishway prior to turning the fishway water back on. The fishway and barrage release gates were operational, the streamflow gauge at The Gap recorded an upstream flow ranging from 2,359.6 to 50,259.3 ML^{day-1} over the sampling period (DNRM data).

Sampling in February and March 2015 trialled the success of fish using the fishway with a full height slot that narrowed all slots upstream of the high tide mark to 75 mm. Timber stop-logs were placed in the upstream fishway channel to reduce inflow and subsequently headloss between the fishway pools. Trials on the 2nd and 3rd of February were abandoned due to very low numbers of fish migrating at the time and were recommenced from the 16th to 18th of February and again from the 16th to 19th of March.

Trials in February assessed the ability of small fish to exit the fishway over two samples each using 100 mm, 70 mm and 50 mm headloss between pools. The fishway was operated continuously and exit trap was installed into the fishway when the high tide level started to flood the approach channel. The fishway and release gates were operational throughout the trials, the streamflow gauge at The Gap recorded a mean daily flow ranging from 35,892.1 to 47,781.5 ML^{day-1} on the 2nd and 3rd of February and 6,775.9 down to 4,477.4 ML^{day-1} from 16th - 19th of February (DNRM data).

Trials in March repeated the February experiments with the full height keyhole slot but were affected by low headwater levels due to the partial emptying of the weir pool following poor water quality produced by floods during Cyclone Marcia two weeks prior. Two exit samples with a headloss level of 40 mm and one sample each of 29 mm, 70 mm and 32 mm were performed over daytime high tides. A sub-sample of fish aggregating at the fishway entrance on the rise of the tide were collected using a dip net with 2 mm diameter mesh at the start of each exit sample. Due to the low water level all of the barrage gates were closed and the fishway was only flow release point.

Analyses of fish lengths in trap catches and dip-net samples were performed in order to determine whether the fishway slot and headloss treatments had an effect on the size classes of fish that were successfully able to ascend the fishway. All species represented by greater than 30 individuals in each sample were tested using the non-parametric Kolmogorov-Smirnov test (α =0.05) for variation between fish lengths. The length frequency of fish species that were abundant in each sample was reviewed to determine differences in size classes between fish that successfully ascended the fishway and those attempting to ascend and is presented graphically.

Results

Over the duration of all trials 16 species of fish were captured either in the exit trap or at the entrance to the fishway during trapping or dip-netting samples (Table 1). Empire gudgeon were the most abundant species overall and were abundant during every sample particularly following the flood flow in March 2015 (Figure 4). Bony herring were the second most abundant species and were also present during every sample but only abundant during two of the March 2015 samples. Striped mullet were abundant during the December 2014 samples but were not captured or observed during any of the subsequent samples at the barrage. All other species captured over the 5 trial periods were present in low numbers.

The size range of fish species captured and measured over all samples is shown in Table 1, larger individuals from striped mullet, blue catfish, long-finned eel and barramundi were also observed ascending the fishway but were physically excluded from the entering the trap.

Table 1. Species, number and size range of fish captured at the fishway over all samples. *= larger size classes excluded from sampling.

Common name	Species	Exit	Entry	Size range
empire gudgeon	*Hypseleotris compressa*	13,122	>1,000,000	9-106
bony herring	*Nematalosa erebi*	276	164	22-90
striped mullet	*Mugil cephalus*	42	92	36-145*
long-finned eel	*Anguilla reinhardtii*	63	13	40-135
glass perchlet	*Ambassis agassizi*	43	24	14-80
banded grunter	*Amniataba percoides*	12	39	32-117
fly-specked hardyhead	*Craterocephalus stercusmuscarum*	10	18	17-55
eastern rainbowfish	*Melanotaenia splendida*	20	8	15-62
Hyrtl's tandan	*Neosilurus hyrtlii*	6	0	160-195
Tilapia	*Oreochromis mossambicus*	2	2	12-23
Gambusia	*Gambusia holbrookii*	3	0	22-32
gizzard shad	*Nematalosa come*	0	2	21-23
mouth almighty	*Glossamia aprion*	1	0	68
leathery grunter	*Scortum hillii*	1	0	46
blue catfish	*Arius graeffei*	abundant*		
barramundi	*Lates calcarifer*	present*		

Figure 4. Accumulation of large numbers of empire gudgeons below the Fitzroy Barrage fishway during sampling.

Unmodified slot configuration

The data from the December 2014 sampling of the fishway in its standard configuration were analysed to determine differences in size class for abundant species entering and exiting the fishway. The Kolmogorov-Smirnov tests for empire gudgeon and bony herring indicated that there was a significant difference between size classes attempting to enter the fishway compared to those that successfully ascended. Length frequency graphs (Figure 5 & 6) indicated that larger size classes were captured at the exit of the fishway than at the entrance. The results from the Kolmogorov-Smirnov test for striped mullet indicated that there was no significant difference between size classes at the exit and entrance of the fishway (*D=0.167 P=0.389*).

Data from the length frequency graph for bony herring indicated that most fish were 80 mm in length or larger whereas most fish in the entrance samples were less than 80 mm in length (Figure 5). For empire gudgeons most fish in the exit samples were 25 mm or larger whereas most fish in the entrance samples were 30 mm or smaller (Figure 6). For striped mullet, size classes between 71-80 mm were well represented in both exit and entrance samples with the entrance sample representing both the largest and smallest size classes of fish captured (Figure 7).

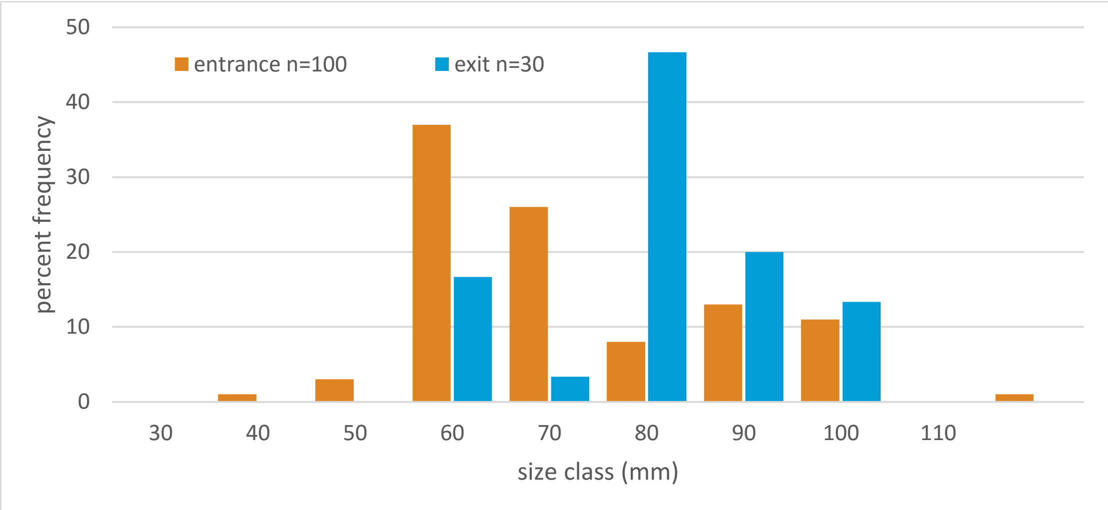

Figure 5. Length frequency of bony herring captured in the December 2014 entrance and exit trap samples.

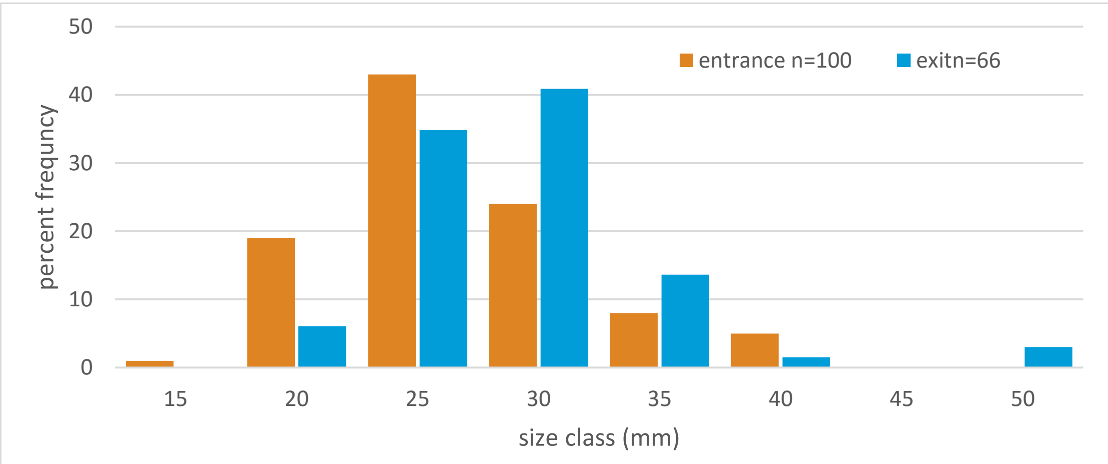

Figure 6. Length frequency of empire gudgeons captured in the December 2014 entrance and exit trap samples.

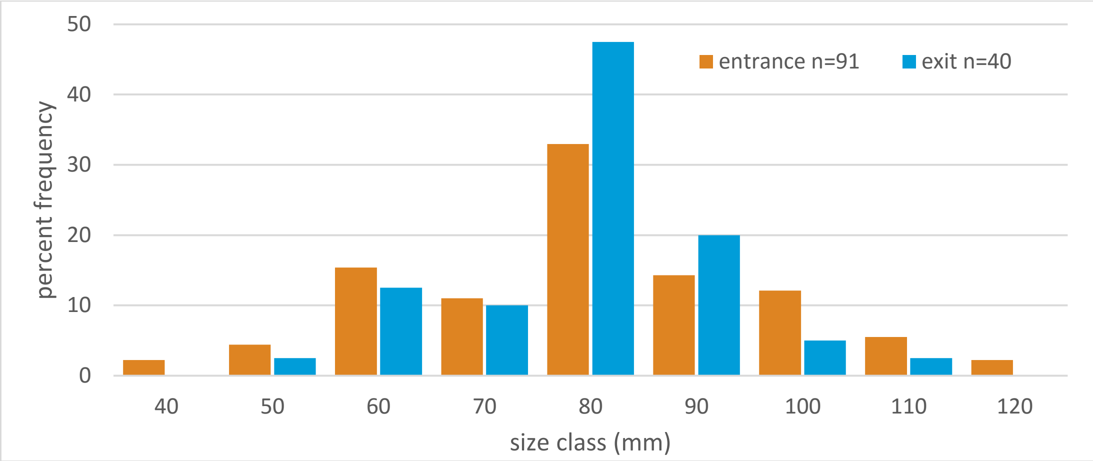

Figure 7. Length frequency of striped mullet captured in the December 2014 entrance and exit trap samples.

Partial modified slot configuration

Length data from the January 2015 sampling of the fishway with keyhole, mid-sill and standard configuration fishway slots was compared between treatments. The Kolmogorov-Smirnov test on empire gudgeons captured in the exit trap showed no significant difference between lengths for keyhole and mid-sill fish (D=0.114 P=0.480) but determined a significant difference for fish lengths between standard and keyhole and standard and mid-sill slot treatments The Kolmogorov-Smirnov test also indicated significant difference between the size of fish captured in the exit trap (pooled) and the entrance samples.

Length frequency data for empire gudgeons from all 3 slot treatments and the exit samples is provided in Figure 8. The length frequency data demonstrates that 89% of all empire gudgeons at the entrance of the fishway were less than 20 mm in length, whereas fish in the keyhole and mid-sill exit samples were more evenly spread between medium and larger size classes. Fish captured in exit samples from the standard slot configuration were larger with 97% being greater than 25 mm in length.

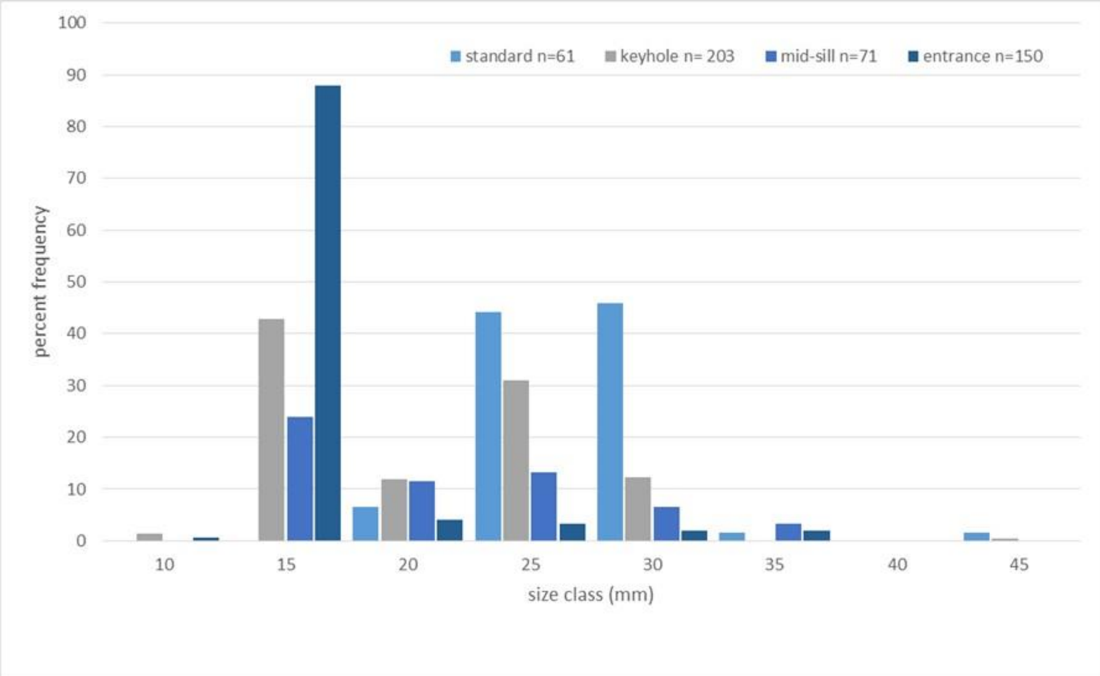

Figure 8. Length frequency data for empire gudgeons from all 3 slot treatments and exit samples.

Full modified slot configuration

Length data from the February 2015 sampling with a full length 75 mm wide slot was compared between three headloss variables. The Kolmogorov-Smirnov test on empire gudgeons captured in the exit trap indicated a significant difference between lengths of fish captured in the entrance for all three treatments. The length frequency data for all three treatments demonstrates that the majority of fish captured in the entrance trap were predominantly less than 20 mm in length, whereas the majority of fish that were captured in the exit trap were 25 mm or greater in length (Figures 9, 10 & 11).

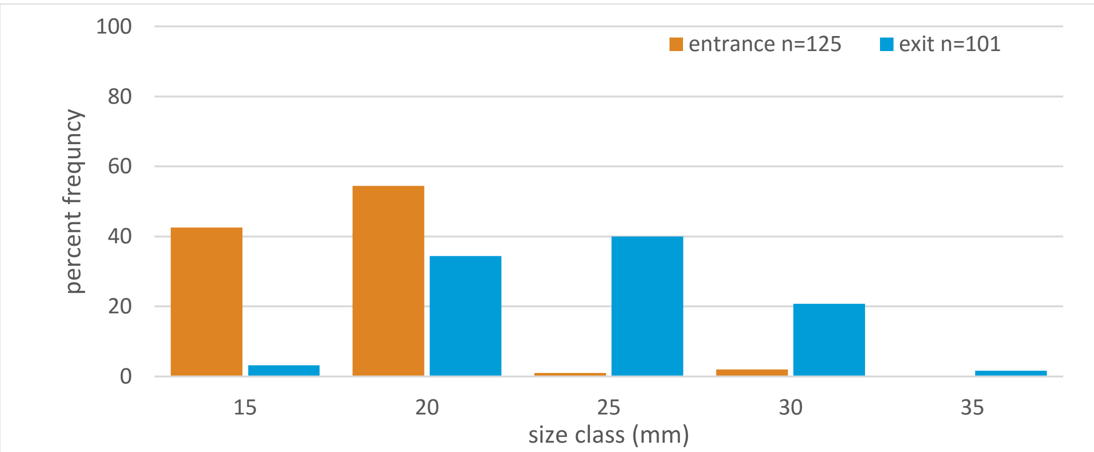

Figure 9. Length frequency of empire gudgeons captured in the February 2015 entrance and exit trap samples with 40 mm headloss.

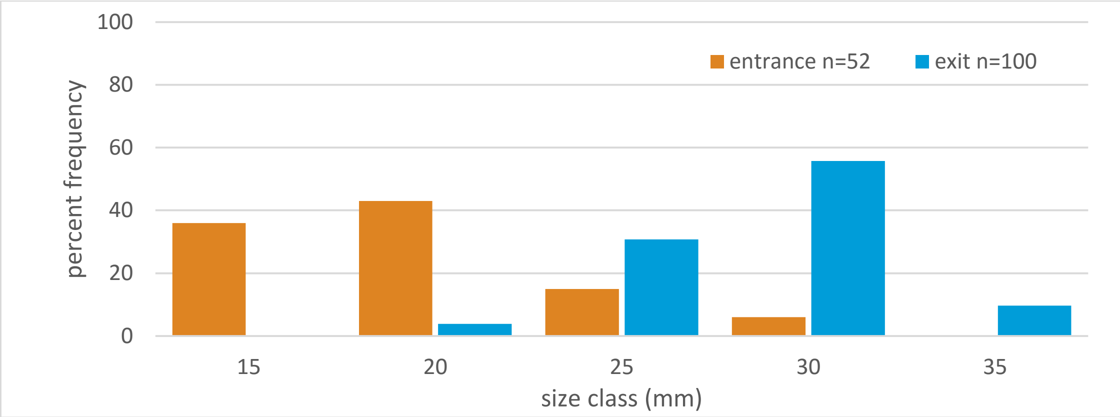

Figure 10. Length frequency of empire gudgeons captured in the February 2015 entrance and exit trap samples with 70 mm headloss.

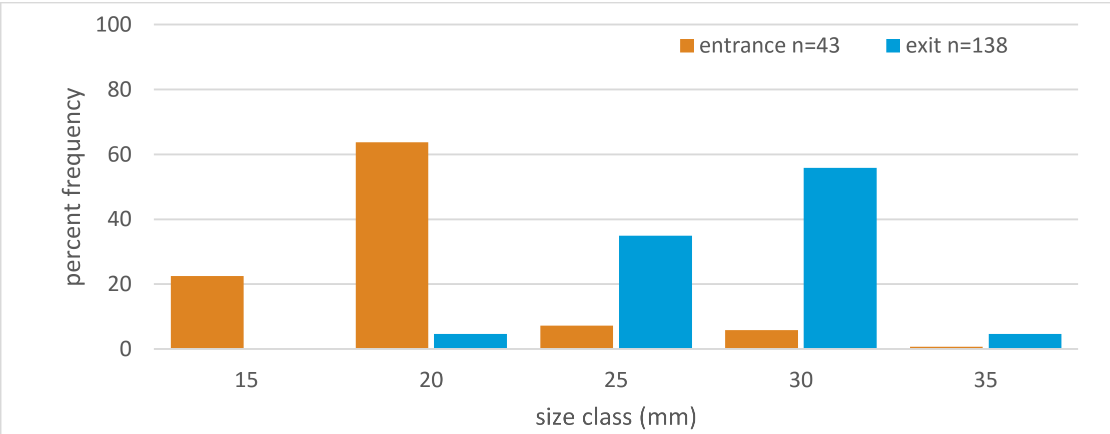

Figure 11. Length frequency of empire gudgeons captured in the February 2015 entrance and exit trap samples with 100 mm headloss.

The March 2015 data provided replicates of the full length 75 mm wide slot at a lower range of headloss variables. The earlier flood flow created a large migration predominantly of empire gudgeons that were all attracted towards the fishway entrance during a rising tide. Large numbers of small fish were observed aggregating at and around the fishway extending for 30 m across the river channel (Figure 4).

The Kolmogorov-Smirnov test on empire gudgeons captured in the exit trap showed significant difference between lengths of fish captured at the entrance for all headloss variables. The length frequency data for all headloss treatments (pooled) show that the majority of fish captured at the entrance and in the exit trap were predominantly 20 mm or less than in length, however there was substantially more fish larger than 25 mm in length captured in the exit trap than collected at the fishway entrance for all samples (Figure 12).

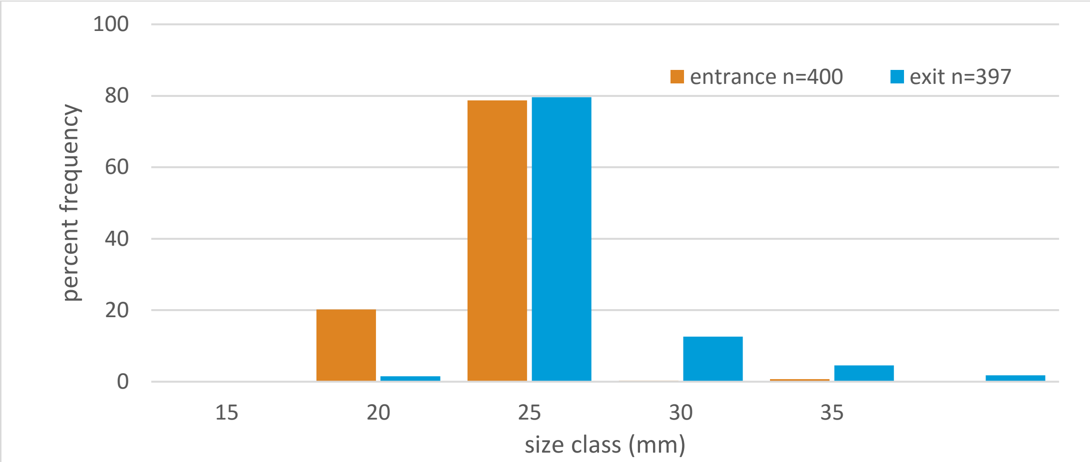

Figure 12. Pooled length frequency of empire gudgeons captured in the March 2015 entrance dip net and exit trap samples.

Observational data

Blue catfish were observed predating on small fish within the fishway during all samples but were particularly obvious and prevalent during the March 2015 samples. During a night-time high tide in March, blue catfish were observed to position themselves within the fishway pools along the wall and feed on aggregations of small gudgeons as they attempted move up the fishway. As the increase in tide increased the water level and reduced velocity in the fishway the gudgeons moved further up the fishway and the catfish also moved upstream to the point where they started to aggregate again. Other predators such as ox-eye herring (*Megalops cyprinoides*), barramundi, eels, sharks and trevally were observed feeding on small fish during the rise of the tide.

Discussion

Passage of small-bodied fish in the existing fishway

Passage of fish within the existing barrage fishway was limited to fish >45 mm long, which in tropical biodiverse rivers can still exclude hundreds of thousands of individuals per year. Restricted passage of the smallest size classes confirms previous studies of vertical-slot fishways, in both tropical and temperate rivers, where small-bodied species remain as a significant design challenge (Stuart and Mallen-Cooper 1999; Stuart and Berghuis2002; Barrett and Mallen-Cooper 2006; Stuart et al. 2008; Baumgartner et al. 2014).

At the Fitzroy barrage, the purpose of modifying the slots, with keyhole and mid-sill treatments, was to reduce discharge and thereby turbulence (energy dissipation) within the fishway pools. These modifications were based on recent research, on the Murray River, which showed that reduced pool turbulence enhanced passage of significantly more carp gudgeons, bony herring, unspecked hardyhead and Murray rainbowfish (Mallen-Cooper et al. 2008; Baumgartner et al. 2014). Despite the hydraulic changes at the existing Fitzroy barrage fishway the modified slots did not result insignificantly more small gudgeons ascending.

Hydraulic constraints to small-bodied fish passage

The hydraulic reasons which influenced the passage success of small-bodied fish were complex and related to the unique site-specific features of the Fitzroy barrage. A major constraint was the broad tailwater tidal range which only enabled fish to enter during high tide, for a few hours per day, after which small-bodied fish were hydraulically ejected from the fishway. Hence, the improved pool hydraulics of the experimental mid-sills and keyhole slot modifications were negated by the receding high tide. To more closely replicate the success of the Murray River trials, an intervention is required that sets a permanent minimum tailwater height and this will be a major solution for improving fish passage at the Fitzroy barrage. Hence, inclusion of a low wall to maintain tail water levels will dramatically increase the operational range of the fishway.

The generic constraints of vertical-slot fishways for very small fish (<45 mm long) is that they are designed to operate for medium and large fish and hence must have a reasonable headloss between pools (usually 100-150 mm), for entrance attraction, and a reasonable minimum depth (usually 1.0 m). By contrast, small-bodied fish (<40 mm long) require low headloss (e.g. <60 mm) and low depths (e.g. 0.3 m). Shallow pools can be especially advantageous for small fish because boundary effects (where water slows due to adhesion and viscosity) take over from normal streaming flow. Small-bodied fish use these hydraulic micro-habitats to aid their ascent which is why shallow rock and cone fishways pass many small-bodied fished fish (Marsden et al. 2003; Power and Marsden 2006; Marsden 2011; Baumgartner et al. 2012).

For the Fitzroy Basin Association, finalising the experimental *in situ* field trials have been an excellent achievement because they identified that the small fish issues at the barrage cannot be resolved by modifying the existing fishway. Instead, the field trials clearly demonstrated two major outcomes: (i) that a dedicated fishway specifically designed for small fish is required, and (ii) slight slot modifications and continued operation of the existing fishway will continue to provide an effective passage solution for medium and large fish. In summary, the field trials have provided a clear and logical path for a future modest investment opportunity to provide significantly greater barrage fishway operational time and extend the range of fish species and sizes successfully passing the structure.

The cone fishway was specifically developed to pass the abundant small-bodied fish of Queensland's tropical rivers and has since proven effective in a wide range of locations (Marsden 2001; Baumgartner et al. 2012). Empire gudgeons, as a model of the weakest swimming species, have passed through the low depths and low velocity cone fishways much more efficiently than in any other style of fishway.

A dedicated small fish fishway

The flooding in March 2015 provides a good example of the significant rise in fish numbers which entered the existing fishway when the tailwater was high and the value for money of investing in a dedicated fishway for small-bodied fish. Millions of fish, mainly empire gudgeons, were present and trying to migrate upstream and it is these fish that the cone fishway will be designed to pass. For the Fitzroy basin Association, the investment in the cone fishway will represent a likely exponential increase in overall fish numbers using the fishway, from several hundred thousand fish per annum to millions per annum. The enormous extra potential of the fishway to pass more fish, by numbers, is driven by six species: empire gudgeons, juvenile bony herring and sea mullet, fly-specked hardyhead, eastern rainbowfish and glass perchlet. It can be expected that up to 80% more fish of each species would pass the Fitzroy barrage through a cone fishway.

The potential ecological outcomes of extending the operational range of the fishway to millions of fish is likely to be a crucial component of restoring connectivity between the Fitzroy River and its estuary and rehabilitating native fish communities. Below are detailed the specific technical modifications for (1) low cost refinements to greatly improve the operation of the existing fishway and (2) a new cone fishway to pass the super abundant small-bodied fish. These solutions are part of a fish passage ‘package’ and should be developed and implemented together to bring the Fitzroy barrage fishway back to the highest fish passage standard.

4. Low cost upgrades to the existing fishway to enhance fish passage

Overview

When the Fitzroy Barrage was constructed in 1970, a pool-and-weir fishway was included on the right (southern) bank. This pool and weir fishway consisted of 15 pools, on a slope of 1v-on-20h with a head difference between the pools of 0.15 m (Keane 1997). In 1987, the fishway was modified with the addition of internal baffles, after the original design was shown to be ineffective (Kowarsky and Ross 1981).

The re-designed fishway was also ineffective (Byron and Toop 1993), the fishway was again modified in 1994. Modifications included removing all the existing baffles, extending the height of the channel and installing vertical-slot baffles made of marine plywood into the channel (Figure). This vertical slot fishway consisted of 16 baffles, with drops between baffles of 0.097 m.

Figure 13. The refurbished Fitzroy Barrage Fishway during high tide in 1995

In 2013, the fishway was repaired after sustaining significant damage in an earlier flood event. This repair included replacing all of the damaged baffles in the lower section of the fishway, with full stainless steel baffles. Grid mesh covers were also placed over the length of the lower section of the fishway (Figure 14).

Figure 14. The latest configuration of the barrage fishway 2014.

The sampling conducted in the 2014/2015 wet season demonstrated that the current fishway does not efficiently pass very small (<45 mm long) fish. As such a variety of upgrade options are available to improve the function of the fishway and improve fish passage for small fish. A wide range of fishway upgrade options were discussed in the 2014 report “Fitzroy Barrage Fishway Upgrade: Literature Review and Options Analysis”. The field sampling has narrowed down the upgrade options reviewed in that report to a small number of low cost refinements that will significantly improve fish passage.

The upgrade options recommended in this report focus on rectifying different issues of the existing fishway. Some modifications are within the existing fishway channel, while others are outside the original fishway footprint. Through realignment of the baffle slots, installing extra baffles, the stabilisation of the tailwater of the vertical slot fishway, extending the fishway to a lower tide level and through construction of a new cone fishway channel, the fishway complex at the barrage will be more amenable to the passage of small and medium fish or a greater period of time.

Current Fishway Design Issues

Issue: Baffle alignment

The current fishway design is suitable for fish >45mm long, especially at high tide. However, the internal baffle design does have some limitations that could be improved through modifications to the existing baffle arrangement.

The existing vertical-slots produce an unfavourable recirculation pattern within the pools of the fishway and do not fully utilise the capacity of the pool to dissipate the turbulence within the fishway, leading to high turbulence levels that reduces passage of fish.

Solution: Realignment of the existing slots

The jet of water from the slot should be directed across the pool to optimise energy dissipation as shown in Figure 15.This creates better slot conditions for both small and large fish as water does not gather momentum as it moves from slot to slot. The modification can be easily accomplished with retro-fitted plates to refine the slot geometry.

Figure 15. The Fitzroy Barrage slot jet (left) does not use all of the pool to dissipate turbulence. The Sheepstation Creek Fishway (right) has a better slot jet angle and provides better conditions for small and large fish.

Issue: Reducing headloss in the existing fishway

Throughout the length of the existing fishway, the vertical-slot baffles create small steps between the pools which allow fish to sequentially ascend past the entire weir height. The current fishway has 97 mm steps between pools, which is greater than is currently recommended for a tidal interface vertical-slot fishway. New vertical-slot fishway designs generally have head loss between pools of 50-60 mm, so adjusting these high head loss within the existing fishway towards those recommended for new designs would be desirable.

Solution: Extending the vertical-slots into the upper fishway channel

The upper leg of the existing fishway channel currently holds only three baffles and the trash rack, while over half the channel is open to the headwater. Increasing the number of baffles that are within this section of the channel from three to six, will reduce the headloss of each of the baffles over the entire length of the fishway (Figure 16). This would reduce the current head loss of 97 mm down to 86 mm, a significant change that is likely to assist the passage of smaller fish.

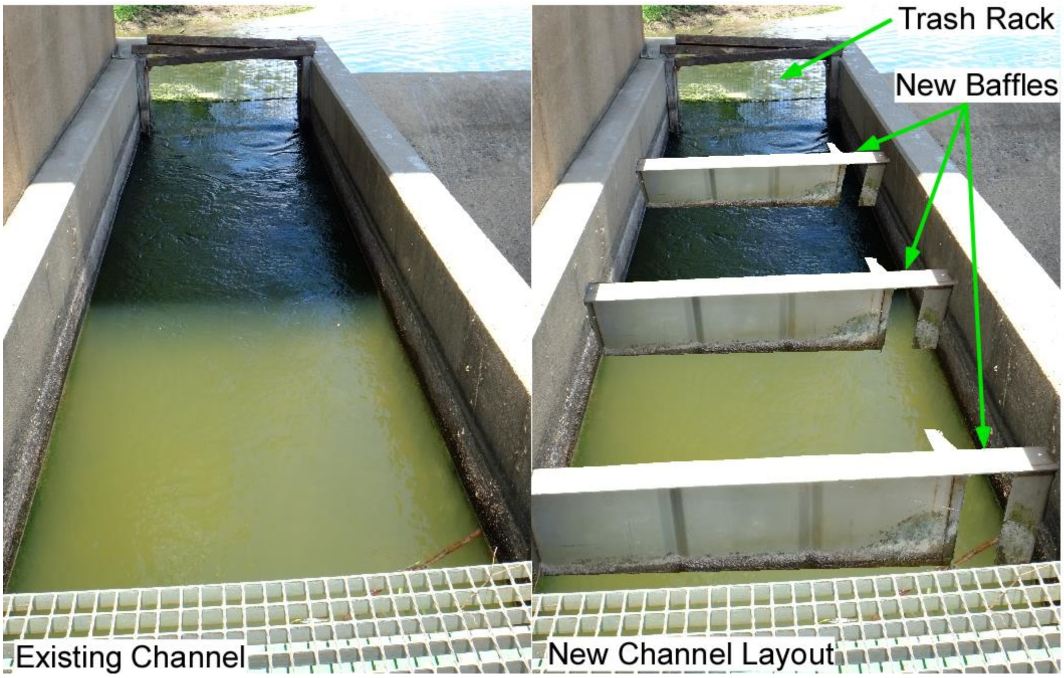

Figure 16. Existing channel (left) and proposed new configuration (right).

The trash rack that is currently located within the existing channel will need to be relocated to the exit of the fishway channel to accommodate the new baffles. This will also supply the opportunity to update the trash rack design to a new sloping design that will require less cleaning and maintenance, similar to the design in Figure 17.

Figure 17. Sloping trash rack design similar to that proposed from the Fitzroy Barrage.

Issue: Uneven Headlosses within the Existing Fishway

As a result of the new baffles being installed into an existing fishway channel there are some inconsistencies in the floor levels which creates variations in the head losses between the pools, further exacerbating the issues of the excess baffle headloss. Installation of the extra baffles, into the upper channel, enables an opportunity to even out the head losses between pools which will then create an even hydraulic gradient.

Solution: Addition of Slot Sills

It will be necessary to install sills into the bottom of each of the slots in the fishway, both new and old. These are required to create an even artificial floor slope throughout the fishway and thus an even hydraulic gradient. If the existing control (floor) of each baffle was not modified after the addition of the extra baffles upstream, the fishway cannot hydraulically adjust to the new baffle installation. The installation of the sills in the bottom of each of the slots will ensure an even 86 mm drop between every pool. The size of the metal sill is expected to be quite small, less than 200 mm, with baffles heights becoming smaller towards the top of the fishway (Figure 18).

Figure 18. A sill placed in the base of a vertical slot.

Issue: Fishway Dewatering after High Tide

The ascent of small fish in the Fitzroy Barrage Fishway is demonstrably hindered by the tidal range over which the fishway operates. Effective fishway operation only occurs on approximately 39% of high tides, with the remaining 61% of high tides not reaching high enough to achieve design headloss within the fishway. During the high tides fish can access the fishway, fish are able to enter the fishway and pass along its length. However, after these high tide conditions recede there is no tailwater at the base of the fishway and water is drained from the fishway channel, creating high velocities and high turbulence (Figure 19).

Small fish can enter the fishway on 39% of high tides, but if they are not able to ascend through the fishway before the tide drops away from the entrance, conditions in the fishway become too turbulent. This forces fish to drop back downstream out of the fishway entrance and into the downstream channel. Once in the shallow waters of the entrance channel, fish are quickly picked off by predators who await this daily event. The daily tidal flushing affects the efficiency of the fishway to pass small fish and increases natural mortality from predators at the site.

Figure 19. Once the tide drops away the fishway ceases to function and small fish cannot enter or remain in the fishway.

Solution: Tailwater Pool Stabilisation

Installing a stabilisation pool in the tailwater, at the downstream entrance of the fishway, will ensure basic functionality at all times, independent of the tide. By providing a fixed tailwater level, turbulence levels in the existing fishway will not increase as now occurs with the falling tide. *A tailwater stabilisation pool will increase the time fish have to ascend the fishway from approximately 2 h per day to 24 h.*

The stable tailwater pool could be provided as a standalone modification through construction of a permanent sill at the fishway entrance (Figure 20). If a cone fishway extension to a lower tide level is considered, then the stable tailwater pool could be incorporated into this design as a resting pool at the top of the lower leg (Figure 20). It is proposed that the pool will have a control level at 2.05m, which will ensure the vertical-slot fishway maintains a 100 mm headloss throughout all pools at all times.

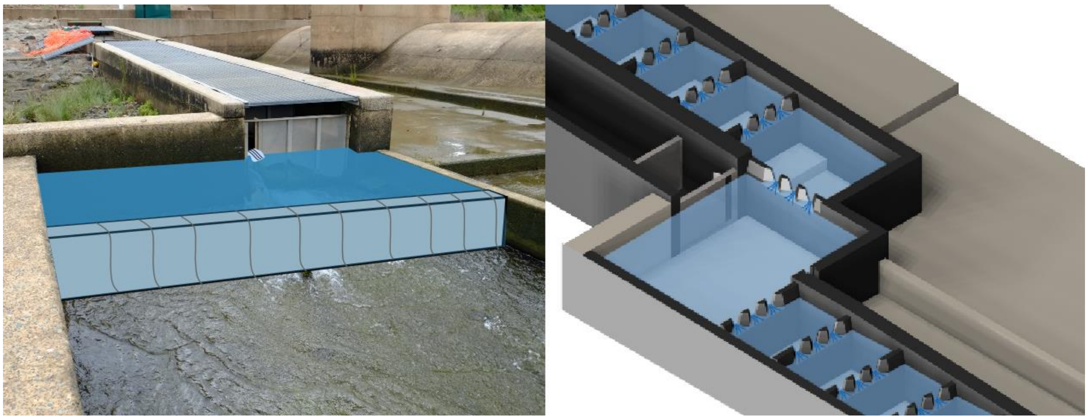

Figure 20. Proposed designs to stabilise tailwater levels, construction of a permanent sill (left) and as a resting pool in a new cone fishway (right).

5. A cone fishway to increase fish passage at the Fitzroy Barrage

Issue: Passage of small fish

The results of the sampling conducted in 2014/15 within the vertical-slot fishway demonstrated that the current fishway cannot be modified to pass small fish effectively without compromising the passage of the large species. As such if small fish passage is to be achieved at the Fitzroy Barrage a new fishway designed specifically to pass small fish will be required.

Solution: Small Fish Fishway

To achieve passage for small fish will require a fishway design that is specifically suited to small-bodied fish. This fishway will have low turbulence and low head losses between pools, with particular design features that assist small fish to ascend (Marsden et al. 2003; Marsden 2011; Baumgartner et al. 2012). The cone fishway design has been shown to be suitable for providing passage of small fish in other tropical locations (Figure 21) and would be suitable for the Fitzroy Barrage. This design utilises micro-roughness elements and sloping slot floors to maximise the optimal boundary layer conditions for the passage of small fish (Figure 22).

Figure 21. A concrete cone fishway installation on the Flinders River in the Southern Gulf of Carpentaria, 50km west of Normanton.

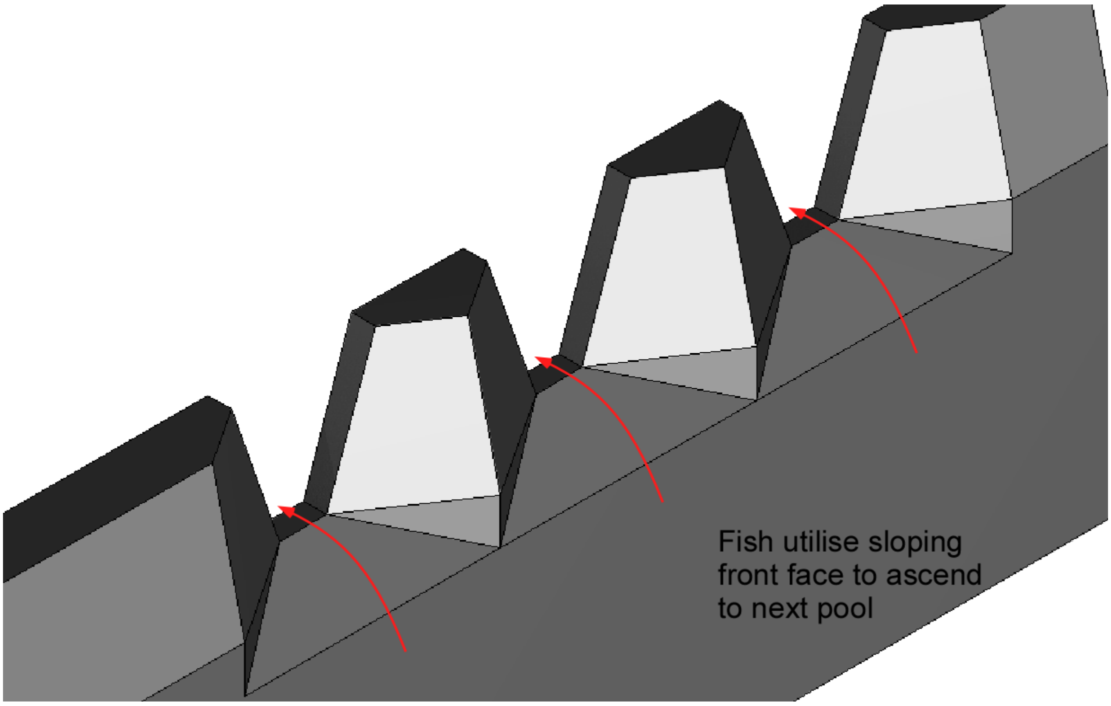

Figure 22. Cone fishway slot detail showing sloped slot faces that small fish utilise to ascend from pool to pool.

The new cone fishway would be placed adjacent to the existing fishway on the weir apron (Figure 23). The cone fishway would have an entrance that is incorporated into the tailwater control pool that will also stabilise water levels at the base of the vertical-slot fishway. The cone fishway will then extend upstream along the inside wall of the existing fishway, exiting into the upper channel of the vertical-slot fishway. This layout is highly efficient in terms of cost and functionality.

The cone fishway channel would be 2.4 m wide and contain 20 cone baffles with 1.5 m long pools, each with an 80 mm head loss. The entrance of the cone fishway would be adjacent to the entrance to the vertical slot fishway, ensuring that fish which are unable to enter the vertical-slot fishway have an alternative route to the upstream weir pool. The exit of the fishway channel would be at the upper end of the existing channel, where a slot would be cut into the existing wall to allow water to enter the new cone fishway. The slot will be sized to ensure low velocities that fish are able easily swim against.

Issue: Low Tide Operation

The operating range of the current vertical-slot fishway is severely limited by the tides encountered at the Fitzroy Barrage. As a result fish can only enter the fishway 8% of the time, or for around 703 hours per year. The fishway does not operate at all on 61% of tides, these being the lower high tides of the lunar cycle. This affects the numbers of fish that can find, ascend and remain in the fishway. To improve the operation of the fishway as a whole, a fishway extension that operates to a lower tide level will be beneficial.

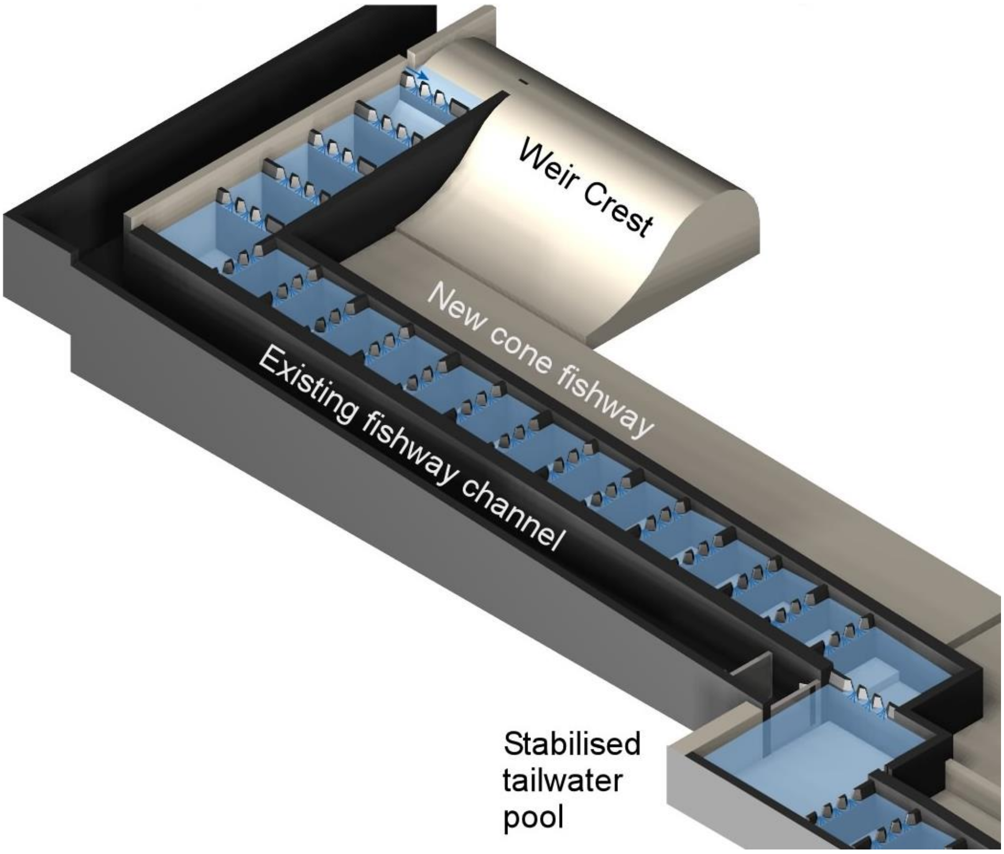

Figure 23. Proposed small fish fishway adjacent to the existing vertical slot fishway.

Solution: Lower Leg Fishway extension

The most appropriate option for achieving an extended operational range is through the construction of a lower leg cone fishway that operates whenever the tide reaches the height of the downstream apron, through to drown out of the vertical slot fishway tailwater control pool. A new lower leg channel would be created against the existing channel wall below the vertical-slot fishway, hence optimising cost. This channel would be broken up with a series of cone baffles 1.5 m apart with the same dimensions as the upper leg (Figure 24).

The depth of the pools will vary, with those closest to the downstream entrance being the shallowest, this ensures that there is no need to excavate into the concrete apron. The shallow depth is not expected to have any effect on small-bodied fish moving through the fishway. This design configuration will ensure an extra 1 m of tidal operation, providing extra time on the rise and recession of the tide for fish to enter the fishway. Specifically, this will increase access to the fishway from 8% of the time to 33% of the time per day and from 39% of high tides to 95% of high tides. This will significantly improve the operation of the fishway and allow fish more time to complete their migrations.

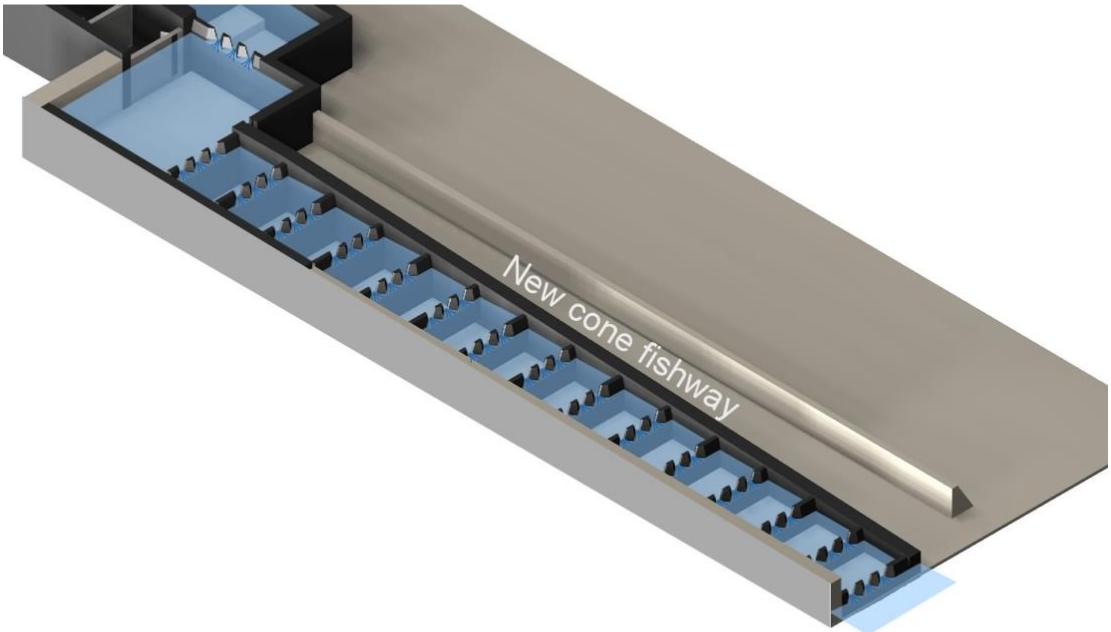

Figure 24. Proposed lower fishway extension that would increase the tidal operation range of the fishway.

6. Conclusion

The Fitzroy barrage vertical-slot fishway provided adequate functionality in the 1990s but new technology is now available to vastly increase its functionality. The experimental field trials have identified that the small fish issues at the barrage cannot be resolved by (i) slightly modifying the existing vertical-slot fishway and (2) installing a cone fishway.

For the Fitzroy Basin Association, the value of these modifications can be summarised as four major fish passage outcomes: (1) an extension of the operational time of the fishway from the current part-time (2 hours/day) *to full time* (24 hours/day), (2) extension of the operational range from 39% to 95% of high tides, (3) an exponential increase in the number of fish using the fishway, potentially *to millions per annum,* (4) extension of successful passage to the multitude of small-bodied fish (<45 mm long) from the current passage rate of *10% up to 80%*.

The field trial recommendations are part of a fish passage 'package' and should be developed and implemented together to bring the Fitzroy barrage fishway back to the highest fish passage standard. The package of works will take advantage of the enormous extra potential for fish passage at the Fitzroy barrage – the unprecedented ecological outcomes of which can extend fish passage to millions more fish; this represents an outstanding ecological investment opportunity.

The potential of new fish passage technology is a crucial component of restoring connectivity between the Fitzroy River and its estuary, in rehabilitating native fish communities, and in restoring a major Australian tropical river.

7. Recommendations

Below are the six major recommendations are part of a fish passage ‘package’ that should be implemented simultaneously to bring the Fitzroy barrage back to a nationally highest standard of fish passage.

Existing vertical-slot fishway

1. Modify the jet alignment of the existing vertical-slot baffles in the lower leg of the existing fishway to bring the design back to the original specification.
2. Install three extra baffles in the vertical-slot fishway exit channel and sills to reduce the hydraulic gradient of the existing fishway.
3. Install a tailwater control pool to stabilise the tailwater of the existing fishway and extend the operating time of the part-time (2 hours/day) vertical-slot fishway to full time (24 hours/day).
4. Install a sloping trash-rack at the exit of the fishway.

New cone fishway

1. Install a cone fishway adjacent to the existing fishway which will extend fish passage to 80% of the biodiverse small bodied-fish and exponentially increase the number of fish passing per annum, potentially to millions of fish.
2. Install an additional section of lower leg cone fishway below the existing vertical-slot fishway to increase tidal operation range from 39% to 95% of high tides.

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