Catchment Solutions

catchmentsolutions.com.au

Hilliards Creek Rock Ramp Fishway Monitoring Report

March 2017

Matt Moore

Catchment Solutions
www.catchmentsolutions.com.au
(07) 4968 4200

Catchment Solutions
www.catchmentsolutions.com.au
(07) 4968 4200

Information contained in this document is provided as general advice only. For application to specific circumstances, professional advice should be sought.

Catchment Solutions has taken all reasonable steps to ensure the information contained in this document is accurate at the time of publication. Readers should ensure that they make appropriate enquiries to determine whether new information is available on the particular subject matter.

For further information contact:
Matt Moore
Senior Fisheries Biologist
Catchment Solutions – Fisheries and Aquatic Ecosystems
Ph: (07) 4968 4214

Enquiries should be addressed to:
General Manager
Catchment Solutions Pty Limited
PO Box 815, Mackay Qld 4740
Tel: +617 4968 4200
Email: info@catchmentsolutions.com.au

Cover Image: Showing fish species recorded during fishway and fish community monitoring in Hilliards Creek, from top left to right; sea mullet, tarpon, typical habitat along Hilliards Creek upstream from the fishway, striped gudgeon, hypseotris sp. (top), empire gudegeon (middle), striped gudgeon(bottom), juvenile sea mullet, tarpon, spangled perch, Hilliards Creek rock ramp fishway.

Contents

Glossary of Terms

Diadromous - Diadromous fishes are truly migratory species whose distinctive characteristics include that they (i) migrate between freshwaters and the sea; (ii) the movement is usually obligatory; and (iii) migration takes place at fixed seasons or life stages. Diadromous species include species such as; Australian bass, long-finned eel, sea mullet, jungle perch, striped gudgeon and barramundi. There are three distinctions within the diadromous category: catadromous, amphidromous and anadromous.

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

Potamodromous - Fish species whose migrations occur wholly within freshwater for breeding and other purposes, such as spangled perch, western carp gudgeon, crimson-spotted rainbowfish and eel-tail catfish.

Executive Summary

- A fish barrier assessment was undertaken in 2014 throughout the Redland City Council (RCC) region by environmental consultants; Catchment Solutions. The fish barrier assessment and prioritisation project was part of a broader federally funded project titled: 'Reconnecting Aquatic Habitats Across the Greater Brisbane Urban Area'. The project involved identifying and priority ranking the most significant barriers (i.e. culverts, weirs, road crossings) impacting fish migration, and then constructing five fishways on highly ranked priority sites.

- The fish barrier assessment identified a weir on Hilliards Creek near in Ormiston as 27th most important fish barrier in South-East Queensland and equal 2nd in the RCC region. The height of the barrier combined with its location low down in the catchment close to the estuary meant that it was impeding life-cycle dependant fish migration along Hilliards Creek. Many economically important fish species were impacted by the barrier, including; sea mullet, jungle perch, Australian bass and long-finned eels. The location of this site on a popular walking trail meant that any potential waterway rehabilitation activities could be easily conveyed to the local community, providing invaluable educational opportunities.

- In early 2016 a rock ramp fishway was designed and constructed by Catchment Solutions to remediate the site and provide improved connectivity along Hilliards Creek. The rock ramp fishway consisted of nine ridges and pools interspersed by 80 mm drops to cater for the high proportion of weaker swimming juvenile diadromous species expected to utilise the fishway. Fishway monitoring was carried out to evaluate the success of the fishway over five days during low flow conditions from the 15th -19th of December, 2016.

- Fishway monitoring demonstrated that the fishway is successful at passing a wide range of fish species, size classes and life-stages with fish as small as 15mm and as large as 800mm able to ascend the fishway. On average 178 fish per day were recorded successfully migrating through the fishway. 11 species representing eight native and three exotic species were captured. Despite this, the total fish species richness and diadromous species abundance was lower than expected, considering the fishway is located in the lower reaches of the catchment in close proximity (~1.5 km's) to estuarine habitats.

- The principal reasons for the lower than expected total species richness and diadromous species abundance is attributed to a fish barrier located 200m downstream from the fishway site in Fellmonger Park. The causeway forms a low passability barrier to fish passage during low and medium stream flow conditions.

- The extent of the Fellmonger Park (FP) causeway barrier was confirmed during fish community monitoring, whereby diadromous fish (migrate between estuary and freshwater) were recorded at a catch rate ***four*** times higher downstream of the FP causeway when compared to upstream.

- It is **recommended** that the FP causeway is remediated with an appropriately designed fishway or alternatively removed. The rehabilitation of the FP causeway will improve waterway health of Hilliards Creek by building resilient native fish populations. This is particularly important due to key threatening process within this catchment such as habitat degradation and invasive pest fish species such as tilapia and mosquitofish.

- **Recommended** connectivity restoration works at the FP causeway will also improve social outcomes for the local community by increasing populations of economically important commercial, recreational and indigenous fishery species as jungle perch, sea mullet, Australian bass and long-finned eels.

Introduction

In March 2016, a rock ramp fishway was constructed on Hilliards Creek near Fellmonger Park (FP) in Ormiston. The fishway was constructed to enable fish to migrate past a 750mm high weir (Figure 1), which had been preventing and obstructing aquatic connectivity along Hilliards Creek for decades. The weir was constructed in the lower reaches of Hilliards Creek close to the sea and impacted crucial life-cycle dependant migrations of diadromous fish species between downstream estuarine environments and upstream freshwater habitats. Many of the most impacted fish species contribute significant societal values and are economically important, such as sea mullet and long-finned eels which form part of the regions commercial fishery, while other species such as Australian bass, jungle perch and tarpon are highly sought after by recreational anglers. Furthermore, sea mullet and long-finned eels have historically been established as important food sources for indigenous communities (Barnett and Ceccarelli, 2007).

The Hilliards Creek weir was highly ranked during a recent fish barrier prioritisation project conducted by Catchment Solutions (Moore, 2016 Greater Brisbane Fish Barrier Prioritisation). This site's close proximity to estuarine habitats (~1.5 kilometres), large area of blocked upstream habitat and large barrier height contributed to its high priority ranking. Through this process, the weir was ranked as the 27th most important fish barrier in South-East Queensland and equal 2nd in the Redland City Council region.

It is well documented that barriers to fish passage impact fish movements throughout waterways and can significantly reduce fish populations (Humphries and Walker, 2013). In collaboration with Redland City Council and the Australian Government, Catchment Solutions set about remediating the lack of fish passage at this site through the installation of a fishway. A nature-like rock ramp fishway was chosen as the most appropriate option to improve connectivity at this site. Rock ramp fishways are excellent at facilitating fish passage for the entire freshwater fish community; including small bodied native fish and economically important juvenile and adult diadromous fish species (Harris and Thorncraft, 1996; Turek *et al*., 2016). Rock ramp fishways provide a greater surface roughness and interstitial spaces (Turek *et al.,* 2016), are inexpensive and have a natural appearance when compared to their highly engineered, smooth sided, vertical-slot fishway counterparts.

Fish community monitoring was conducted using a boat electro-fisher pre and post fishway construction. This was undertaken to investigate the effects of the remediated fish barrier and determine the impact of the existing downstream FP causeway barrier on the health of the Hilliards Creek fish communities.

Figure 1. Facing upstream towards Hilliards Creek weir, prior to fishway construction.

Partial Width Rock ramp Fishway Configuration

The full width nature-like rock ramp fishway extends 18m in length (Figure 2), and consists of nine ridges and pools (cells). The fishway was designed to operate at an optimal level during low and medium flows with a slope 1V:28.5H. Due to the proximity to estuarine habitats, drops between pools were set at 80mm to cater for weaker swimming juvenile diadromous and small-bodied species within the system. The drops between pools is governed (controlled) by the gap (V-slot) between the ridge rocks that the fish swim through. Fishway pools were approximately 2-3m^2 and ranged between 0.4 – 0.6 m in depth during low flows. This provided the resting areas and turbulence dissipation that juvenile and small bodied species require to negotiate their way through fishway. Ridges consisted of four slots, with each slot approximately 100-250 mm wide and 200-400 mm high, allowing the fishway to operate over a range of flow conditions. From our sampling, it was found that many small-bodied and juvenile fish were able to negotiate the fishway during the low to medium flow conditions, with the median size of all fish captured 32mm in length (n=819). In high flow conditions, the fishway 'drowns out', enabling fish to migrate past.

Figure 2. Showing a side view of the nature like rock ramp fishway (fishway trap located at exit).

Construction of the fishway involved two 21t excavators fitted with hydraulic rock grabs. The grabs were used to place the 200t of large, igneous rock ranging between 1 – 2.5m^3 and weighing up to 5t each, into specific positions to form the ridges and side walls of the rock ramp. Each ridge rock was methodically placed to form V-slots (the gap between the ridge rocks that the fish swim through), with the bottom of the 'V' set at the exact control height for each ridge. This was undertaken while ensuring each ridge rock was sufficiently embedded into the stream bed and each ridge rock maintained at least a 400mm distance from the stream bed to the control (V), and a further 200-400mm clearance above the control (Figure 3).

Figure 3. Facing upstream at the fishway; showing pools, ridges, and 'V'-slots (gaps between ridge rocks that fish swim through which also control the height of each pool).

Methods

Fishway Trap Monitoring

Fishway trap monitoring was carried out over five days during low flow conditions between the 15th -19th of December, 2016. Fishway trap monitoring was undertaken to evaluate the success of the fishway at facilitating fish passage past the barrier for all size classes of fish. Monitoring was undertaken by placing a purpose built fishway trap and wing-wall configuration at the upstream exit of the fishway (Figure 4), intended to capture fish once they had successfully ascended the fishway. A small number (n=10) of endemic juvenile (~40 mm) Australian bass were PIT tagged and released at the bottom of the fishway. This was undertaken to provide useful data on the ability of this recreationally important species to ascend the fishway in-case 'wild' specimens were not migrating at the time of sampling, or could not access the fishway due to barriers downstream, i.e. Fellmonger Park causeway. Monitoring results demonstrate that the fishway is operating successfully, with fish as small as 15mm moving through the fishway into upstream habitats.

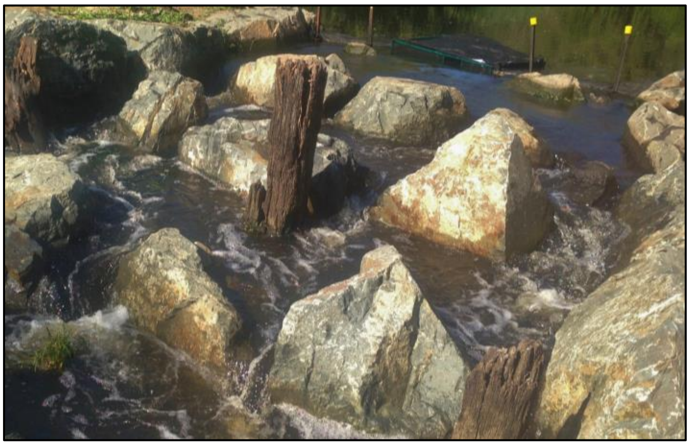

Figure 4. Showing fishway trap and wing wall configuration located at the fishway exit (foreground).

Fish Community Monitoring (electrofishing)

Fish community monitoring was undertaken pre fishway construction on the 3rd of November 2015 and post fishway construction on the 17th December 2016. Pre fishway fish community monitoring was undertaken to establish baseline condition of the Hilliards Creek fish populations at the monitoring sites prior to fishway construction. Post fishway fish community monitoring was undertaken at the same sites to provide a useful data set that could be used to make comparisons with the pre fishway fish community data. Three sites were selected pre fishway construction (Figure 6), these included; a site immediately upstream from the fishway (site 1), a middle site between the fishway and the existing FP causeway barrier (site 2) and a third site immediately downstream from the FP causeway barrier (site 3). Post fishway construction monitoring was undertaken at sites 1 and 3 (upstream and downstream of the FP causeway barrier).

For the purposes of data analysis, pre fishway monitoring at sites 1 and 2 were combined to become the upstream FP causeway site. Boat electrofishing was used to sample the larger, deeper waters where backpack electrofishing could not effectively be utilised. Boat electrofishing was conducted from the 3.7m vessel operating a Smith-Root 2.5 GPP electrofisher unit, equipped with a single boom arm, six dropper anode array and a hull cathode. A Senior Electrofishing Operator operated the vessel while a single dip netter aided in the collection of fish for identification and measurement. Sampling was carried out over a site reach spanning approximately 100m (where sufficient water was available), with care being taken to sample all macro and microhabitat types. The sampling effort consisted of a series of 300 second 'shots' where the boat was manoeuvred in and out from the riverbanks as well as parallel to the shore in deeper water.

Fishway and Fish Community Sampling Locations

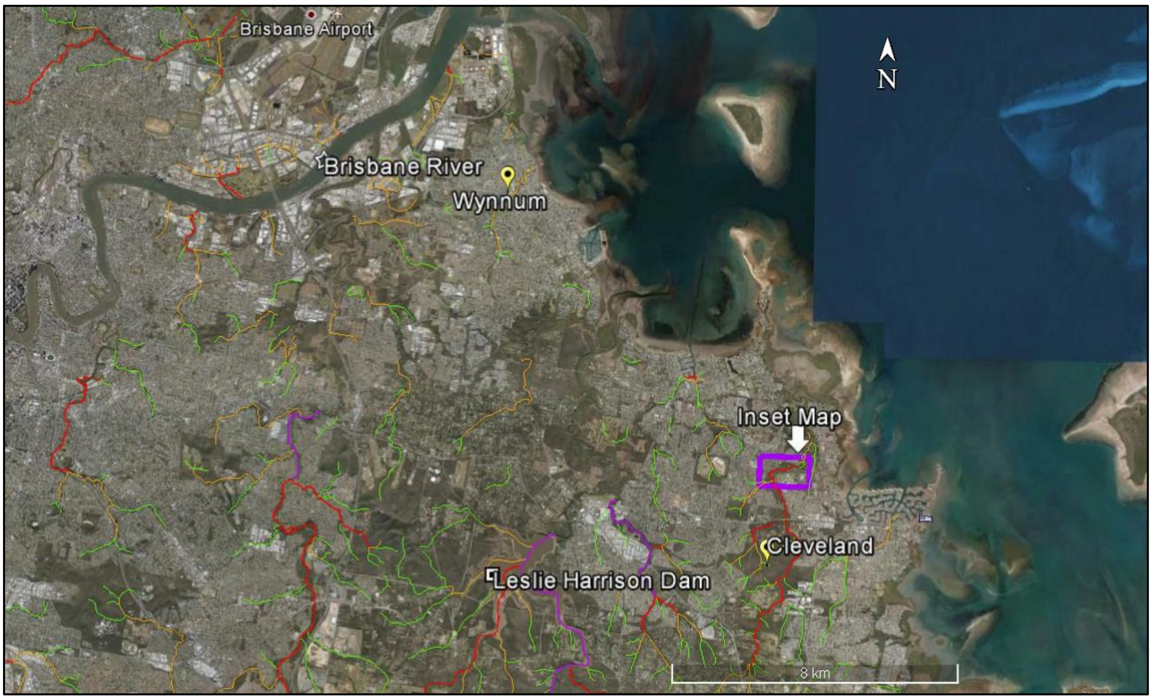

Figure 5. Overview map showing inset map location (sampling sites)

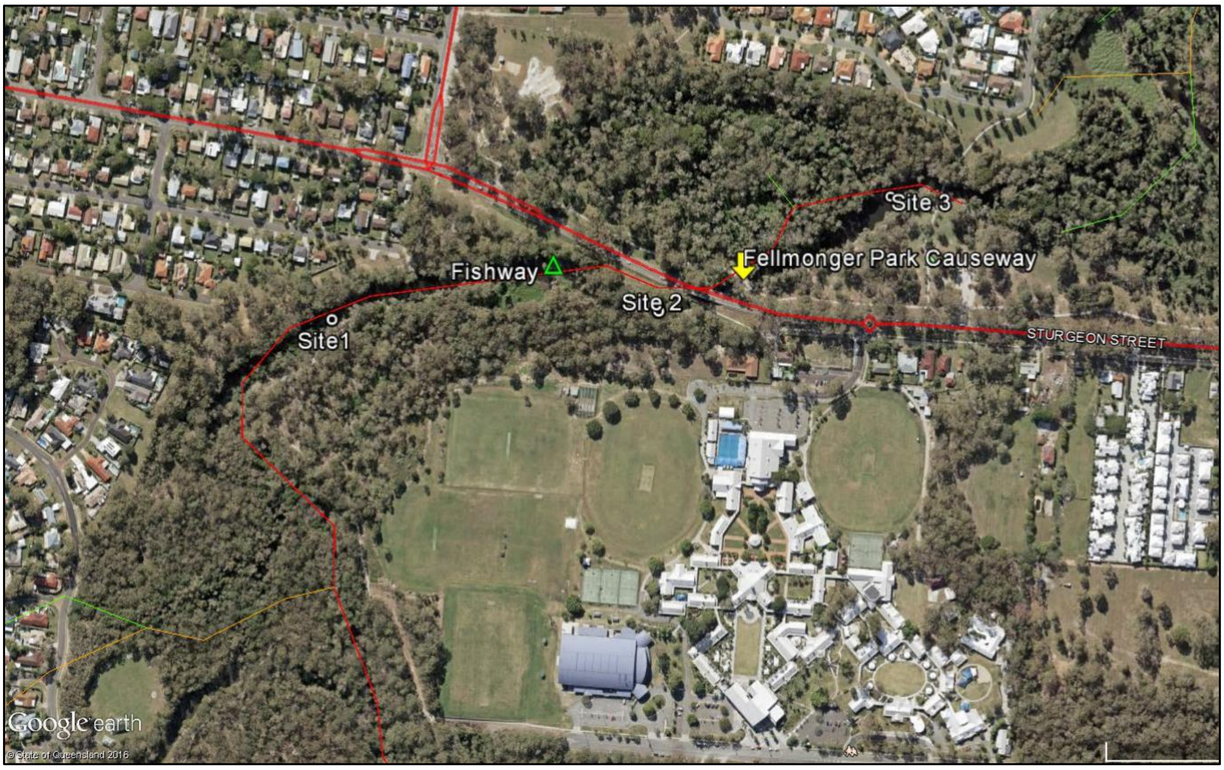

Figure 6. Inset map showing fish community monitoring sites, fishway and Fellmonger Park Causeway barrier.

Results

Fishway Monitoring

In total, 809 individual fish representing 11 species (eight native and three introduced) were recorded (Table 1). Fish were monitored successfully ascending through the fishway at a catch rate of 177.66 fish/day. Significantly, very small juvenile diadromous fish species (Figure 7) were able to migrate through the fishway, including a 19mm empire gudgeon, 35 mm Australian bass, 38 mm striped gudgeon, 38 mm sea mullet and a 60 mm long-finned eel. Overall, the median size of all fish captured was just 32mm. The smallest size potamodromous (wholly freshwater) species included 15 mm exotic *Gambusia*, 20 mm *Hypseleotris* sp. and a 20 mm fly-specked hardyhead. The small size of fish species able to successfully ascend through the fishway is significant (and used as an indicator of fishway success), as they possess weaker swimming abilities when compared to larger bodied species. The largest fish species recorded migrating through the fishway included an 800 mm long-finned eel and a 329mm tilapia (Figure 7).

Table 1. Showing fishway monitoring catch results; fish species, migration classification, minimum, median and maximum size, total individuals, and catch per unit effort (CPUE) number of fish captured per day).

Migration Classification	Common Name	Species Name	Size Min (mm)	 Median (mm)	 Max (mm)	Total Individuals	CPUE (fish/day)
Diadromous	Empire Gudgeon	*Hypseleotris compressa*	19	42	81	84	18.22
	Striped Gudgeon	*Gobiomorphus australis*	38	41	51	6	1.30
	Sea Mullet	*Mugil cephalus*	38	49	51	72	15.62
	Australian Bass*#	*Macquaria novemaculeata*	35	35	35	1	0.22
	Longfin Eel	*Anguilla reinhardtii*	60	73	800	5	1.08
Potamodromous	Hypseleotris species	*Hypseleotris sp.*	20	29	43	357	77.44
	Fly-specled Hardyhead	*Craterocephalus ster.*	20	34	71	252	54.66
Pest Fish (Potamodromous)	Gambusia	*Gambusia holbrooki*	15	23	35	40	8.68
	Tilapia*	*Oreochromis mossambicus*	329	329	329	1	0.22
	Platy*	*Xiphophorus helleri*	64	64	64	1	0.22
Overall min, median, max, total individuals/CPUE (fish/hour)			**15**	**32**	**800**	**819**	**177.66**
Total Species			**10**				

#fishway research stocking, *only one individual sampled

Note: CPUE –Stands for Catch per Unit Effort. CPUE = the number of fish recorded in the fishway trap divided by the effort (time) the trap was set. It provides a standardised rate of fish migration for different sample periods. For CPUE (fish/day) = Total individuals/number of days (24 hr period).

Figure 7. Typical size of juvenile sea mullet captured migrating through the fishway (left), and typical trap haul consisting predominantly of *Hypseleotris* sp., empire gudgeon, fly-specked hardyhead, sea mullet and one large adult (female) tilapia (right).

Native fish represented 94.9% of the total catch (eight species), while pest fish; *Gambusia* (n=40), tilapia (n=1) and swordtails (n=1) made up the remaining 5.1% of captures. Pest fish species richness comprised 27.3% of all fish species recorded, with native fish making up 72.7%. Diadromous fish comprised 45.5% of the total species captured, and 20.5% of total individuals. Whereas, potamodromous fish species comprised 54.5% of the total species captured, and 79.5% of total individuals.

Figure 8. Showing adult empire gudgeon (top), juvenile sea mullet (middle) and adult *Hypseleotris klunzingeri* (bottom).

Hypseleotris species (unable to be positively identified in the field- specimens sent to the Qld Museum for correct identification which revealed the presence of both *H. klunzingeri* (Figure 8) and *H. species 1*) were the most abundant species representing 43.5% of the catch at an average of 77.4 fish/day moving through the fishway. Fly-specked hardyhead were the second most abundant species, representing 30.7% of the catch at a capture rate of 30.8 fish/day, followed by the diadromous empire gudgeon (Figure 8) and sea mullet (Figure 8) representing 10.2% and 8.8% of the catch at a catch rate of 18.2 and 15.6 fish/day respectively.

Fish Community Monitoring

Pre Fishway Construction

Downstream Fellmonger Park Causeway barrier

Diadromous species; empire gudgeon and sea mullet were the two most abundant fish monitored downstream of the FP causeway barrier with catch rates of 13.56 and 13.22 (fish/min) respectively (Table 2). Followed by pest fish tilapia at a catch rate of 1.38 (fish/min) and *Hypseleotris* sp. and fly-specked hardyhead all sharing a catch rate of 0.39 fish/min.

Upstream Fellmonger Park Causeway barrier

Empire gudgeon recorded the highest abundance upstream of the FP causeway barrier at a catch rate of 3.83 fish/min, followed by sea mullet, tilapia, *Gambusia* and fly-specked hardyhead at catch rates of 2.82, 0.60, 0.52 and 0.48 respectively (Table 2).

Post Fishway Construction

Downstream Fellmonger Park Causeway barrier

Empire gudgeon recorded the highest catch rate downstream of the FP causeway barrier at a catch rate of 6.80 fish/min, followed by sea mullet, long-finned eel, tilapia and *Gambusia* with catch rates of 6.80, 4.40, 2.20 and 1.38 fish/min respectively (Table 2).

Upstream Fellmonger Park Causeway barrier

Sea mullet recorded the highest abundance upstream of the FP causeway barrier at a catch rate of 3.20 fish/min, followed by empire gudgeon, *Hypseleotris* sp. and *Gambusia* at catch rates of 1.40 and 1.20 fish/min respectively (Table 2).

Table 2. Showing migration classification and catch rates of all fish species monitored during pre and post fishway fish community monitoring upstream and downstream of FP causeway barrier.

Migration Classification	Common Name	Species Name	Downstream Fellmonger Park causeway barrier		Upstream Fellmonger Park causeway barrier	
			CPUE (fish/min)		CPUE (fish/min)	
			Pre fishway	Post fishway	Pre fishway	Post fishway
Diadromous	Empire Gudgeon	*Hypseleotris compressa*	13.56	17.80	3.83	1.40
	Striped Gudgeon	*Gobiomorphus australis*	0.79	0.10	0.08	0.10
	Sea Mullet	*Mugil cephalus*	13.22	6.80	2.82	3.20
	Freshwater Mullet	*Trachystoma petardi*			0.08	
	Tarpon	*Megalops cyprinoides*		0.30		0.10
	Longfin Eel	*Anguilla reinhardtii*		4.40	0.16	0.60
Potamodromous	Hypseleotris species	*Hypseleotris sp.*	0.39	0.10	0.28	1.20
	Crimson-spot. Rainbow fish	*Melanotaenia duboulayi*		0.20		
	Spangled Perch	*Leiopotherpon unicolor*			0.16	0.40
	Bony Bream	*Nematalosa erebi*	0.05			
	Purple-spotted Gudgeon	*Mogurnda adspersa*	0.10			
	Fly-specked hardyhead	*Craterocephalus stercusmuscarum*	0.39		0.48	
	Eel-tail catfish	*Tandanus tandanus*	0.05		0.04	
Pest Fish	Gambusia*	*Gambusia holbrooki*		1.38	0.52	1.20
	Tilapia*	*Oreochromis mossambicus*	1.38	2.20	0.60	0.90
Overall CPUE (fish/min)			**29.92**	**37.79**	**9.07**	**9.72**
Total Species (15)			**9**	**9**	**11**	**9**

Comparison between Upstream and Downstream Fellmonger Park Causeway Monitoring Sites

Pre Fishway Construction Fish Monitoring

Diadromous fish species; empire gudgeon, sea mullet and striped gudgeon were captured at considerably higher catch rates downstream of the FP causeway when compared to upstream (Figure 9). Four fish species; freshwater mullet, long-finned eel, spangled perch and *Gambusia* were only recorded from the upstream site, whilst bony bream and purple-spotted gudgeon were only recorded at the downstream site.

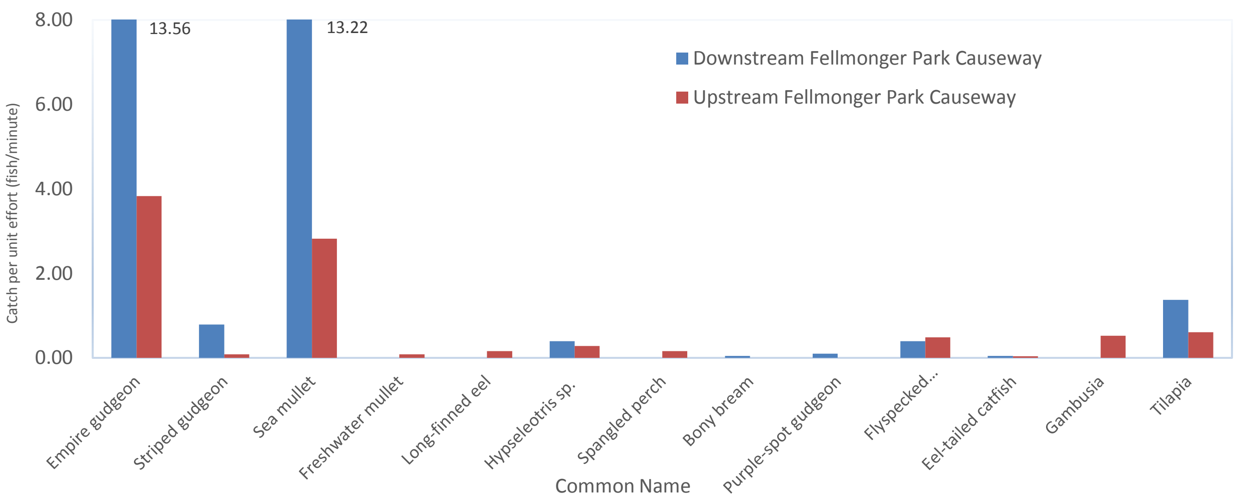

Figure 9. Showing comparison fish catch rates between upstream and downstream FP causeway barrier sites.

Post Fishway Construction Fish Monitoring

Diadromous species; empire gudgeon, sea mullet, long-finned eel and tarpon were all recorded at higher catch rates (fish/min) downstream of the FP causeway (Figure 10). Pest fish species *Gambusia* and tilapia were also recorded at a higher catch rate downstream of FP. Potamodromous fish species; *Hypseleotris* sp. and spangled perch were recorded at higher catch rates upstream of FP.

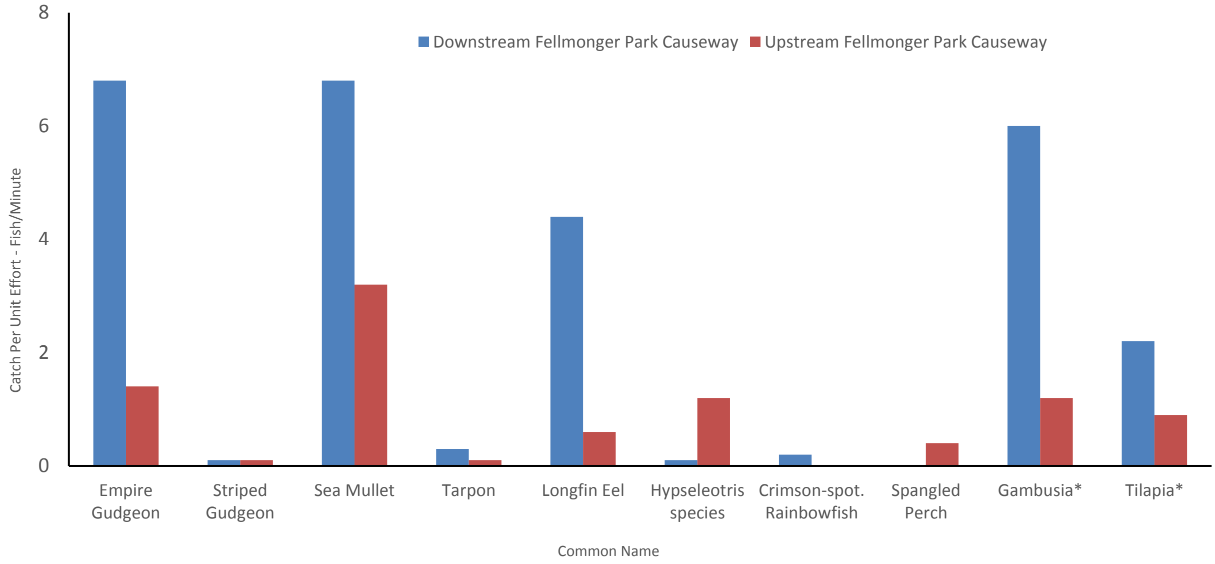

Figure 10. Showing comparison fish catch rates between upstream and downstream FP causeway sites.

Combined Pre and Post Fishway Fish Community Monitoring

Diadromous species; empire gudgeon, sea mullet, striped gudgeon, tarpon and long-finned eel were recorded at higher catch rates downstream of the FP causeway. Potamodromous fish; *Hypseleotris* sp., spangled perch and fly-specked hardyhead were recorded at higher catch rates upstream of the FP causeway (Figure 8).

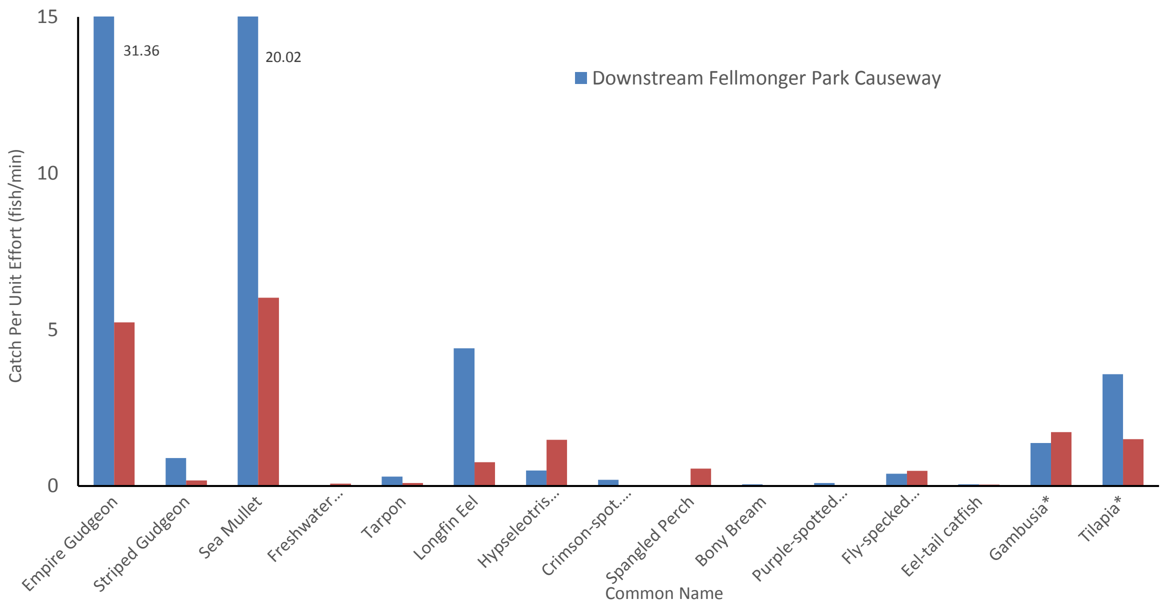

Figure 11. Showing comparison fish species catch rates between upstream and downstream FP causeway barrier sites during post fishway construction fish community monitoring.

Total catch rates for all fish species pooled were over three times higher (Figure 12) downstream of the FP causeway (32.37 fish/min) compared to upstream of FP (9.33 fish/min).

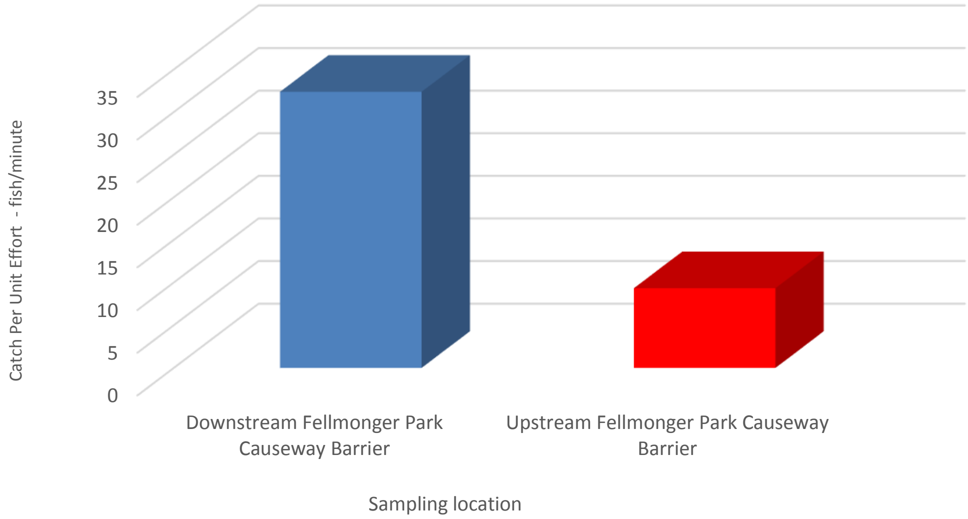

Figure 12. Showing pooled pre and post fishway monitoring data for fish species at downstream and upstream FP causeway sites.

Total catch rates pooled for diadromous fish species only were over four times higher (Figure 13) downstream of the FP causeway (56.97 fish/min) compared to upstream of FP (12.37 fish/min)

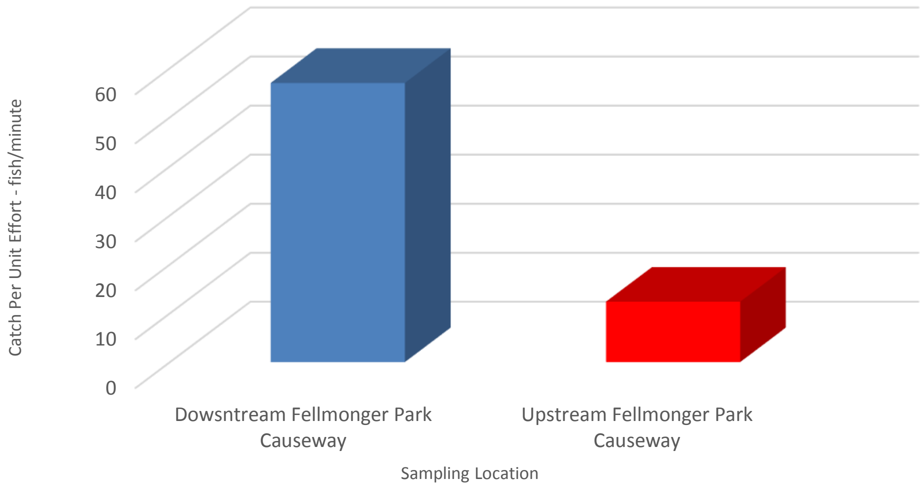

Figure 13. Showing pooled pre and post fishway monitoring data for diadromous fish species at downstream and upstream FP causeway sites.

Discussion

Fishway Monitoring

Monitoring results demonstrate that the fishway is successfully ascendable by a wide range of fish species, at varying size classes and life-stages. On average 178 fish per day successfully migrated through the fishway during the monitoring period. Significantly, small-bodied juvenile diadromous species were able to ascend the fishway, including; 19mm empire gudgeon, 35mm Australian bass, 38mm striped gudgeon, 38mm sea mullet and a 60mm long-finned eel. Generally, juvenile (Rodgers *et al*., 2014) and small bodied fish (Domenici, 2001) possess weaker swimming abilities than adults and larger-bodied species, so capturing these fish species at such a small size and during their juvenile life-stage is a great indication that the fishway is operating as desired. Water velocity and turbulence are limiting factors that affect the ability of fish to move through waterways and are extremely important factors that must be addressed when designing fishways. To counteract the natural variability in flow conditions, fish exhibit different swimming modes. Generally these modes fall within three widely recognised categories (adapted by Domenici and Blake 1997):

- Sustained – swimming more than 200 minutes
- Prolonged – 15 seconds – 20 minutes, and
- Burst - <15 seconds

Burst speed is used by fish to negotiate fast velocities (Webb, 1984; Ch.6) and is probably the most common swimming mode utilised by fish to swim through the 'V' slots (gaps between ridge rocks) when ascending to the next pool in a fishway. However, burst speed requires the use of anaerobic muscle fibres, which can only be used for brief periods before running out of metabolic fuel and therefore, high speed swimming through the 'V' slots results in fatigue and can usually only occur for short durations (Turek, *et al.,* 2016). With this in mind, the Hilliards Creek fishway was designed with small headloss drops between ridges to reduce the velocity fish have to swim through to reach the next pool. Fishway pools were then designed to be as deep and wide as possible to dissipate turbulence and provide adequate resting areas for fish to recover from fatigue. Providing these critical design features allowed weaker swimming fish to successfully ascend the Hilliards Creek fishway using a burst speed and rest strategy, whereby they use their burst speed to swim through the higher velocities experienced in the 'V slots (gaps between the rocks), before resting and regaining their energy in the deep fishway pools.

Effect of Barriers Downstream – Fellmonger Park Causeway

Generally, adult and large-bodied fish species possess greater swimming abilities than small-bodied and juvenile fish species (Rodgers *et al*., 2014; Domenici, 2001). This is because larger fish have more muscle to propel them through the water (Tillinger and Stein, 1996). This potentially enables large bodied species to negotiate higher velocities often associated with elevated flow events. Anecdotal evidence collected whilst monitoring fishways throughout Queensland by the author has indicated that large bodied fish species are more prevalent in catch results during elevated flow events. It may be that high flows cue movement for some adult fish species. Flow conditions experienced during the fishway monitoring period consisted of low base-flow conditions. This potentially explains the low capture numbers of larger-bodied fish species such as adult sea mullet, spangled perch, bony bream and catfish species during the sampling period.

Another possible reason for the low numbers of adult fish captured during the monitoring period could be due to a low passability fish barrier located 200m downstream in FP (Figure 14). This particular barrier consists of a ~1m high pedestrian causeway with two ~900mm pipe culverts submerged and positioned underneath the causeway. One of these pipe culverts is completely blocked. The other pipe culvert is partially blocked with debris, but still allows water to pass through. The water velocities experienced through this pipe (the entire creek discharge during low and medium flow events pass through one 900 mm pipe), combined with the distance that fish are required to swim through this velocity (~10m), and a lack of light penetration within the pipe (Obrien, 2000), is likely to be preventing or obstructing successful passage of fish. Fish are able to use 'burst speed' to negotiate relatively high velocities for a short distance, such as through the 'V' slots of the fishway. However, fish are potentially unable to maintain burst speed through pipe culverts over such a long distance, such as the pipe culvert beneath the FP causeway. The barrier effects associated with the FP causeway are further confounded in lowland habitats where high proportions of migrating fish consist of weak swimming juvenile and small bodied species, and don't possess the muscle to propel them past the barrier.

Therefore, some fish are potentially only able to negotiate this barrier during high flow events when the barrier is 'drowned-out', but only if fish are fortunate enough to be;

- Located downstream of the barrier, and
- Actively migrating upstream at the time of 'drown-out', and
- Located in close enough proximity to the barrier to be able to ascend during the small window of opportunity that the barrier is 'drowned-out', and
- Possess a swimming ability to negotiate the hydraulic conditions (velocity and turbulence) presented at the site during 'drown-out'.

'Drown-out' conditions may only occur a few times during the year and potentially only for a very short duration. Duration of peak discharge (drown-out) in built-up urban areas such as Hilliards Creek has potentially been altered as a consequence of increased impermeable surfaces which may reduce infiltration and increase run-off. This potentially causes the stream to rise and fall quickly, reducing the total time period that this barrier would experience 'drown-out' conditions and therefore reducing the opportunity for fish to ascend the barrier. The low passability causeway barrier in FP did not experience 'drown-out' conditions during the monitoring period, which potentially compromised the monitoring results. It's highly possible that a high proportion of the fish which moved through the fishway during the monitoring period were located within the 200m long pool between the fishway and the downstream causeway (FP).

This may also explain why diadromous fish, which are unable to complete their life-cycle within this downstream pool (spawn in the sea), occurred in considerably lower abundance, comprising only 19.1% of the total native individuals when compared with native potamodromous (wholly freshwater) fish which comprised 80.9% of the total native individuals. These results were recorded despite a higher number of diadromous species being captured during the monitoring period. Wholly freshwater potamodromous fish are theoretically able to complete their entire life-cycle within the downstream pool. This may explain why these species were represented by a higher abundance when compared to diadromous species, as they do not have to swim to the sea to breed, only to be blocked on their return migration by the FP causeway. Small numbers of diadromous species were captured during monitoring, however, it's plausible that these fish migrated past the downstream causeway barrier during 'drown-out' conditions which occurred two weeks prior to fishway monitoring (3rd, 6th and 7th of December), with a small percentage of 'stragglers' still migrating upstream through the fishway during the sampling period.

Figure 14. Fellmonger Park Causeway Barrier.

Empire gudgeon are migratory species, in-which a proportion of adults are believed to move downstream during summer rainfall events into lower freshwater and upper estuarine reaches to spawn before returning to freshwater (Catchment Solutions, unpublished data). Juvenile empire gudgeon (12-20mm) spawned from this life-cycle migration, undertake mass migrations upstream into freshwater habitats during low flow events shortly after (Pusey *et al.,* 2004). Fishway monitoring revealed that the vast majority of empire gudgeon (96.4%) were recorded migrating through the fishway during the first few days of monitoring (first 64% of monitoring time), closer to the recent drown out flow event, when compared to the final monitoring days. This potentially indicates that these fish had migrated past the FP causeway during the series of 'drown-out' events experienced on the 3rd, 6th and 7th of December and fishway monitoring captured the last migrating individuals on their upstream migration, with proportionally far higher capture rates closer to the drown-out period.

Further indication that the FP causeway is potentially impeding fish movement along Hilliards Creek was the average size of empire gudgeon captured migrating through the fishway, which equated to 42 mm. Pusey *et al*., (2004) suggest empire gudgeon are reproductively mature between 40 – 50 mm. Pusey *et al*., (2004) goes on to suggest that adult empire gudgeon undertake mass migrations during flow events. This is further supported by over 10 years of fishway monitoring by the authors. It's probable that a proportion of the stronger swimming, reproductively mature, empire gudgeon were able to ascend past the FP barrier during 'drown-out' conditions experienced on the 3rd, 6th and 7th of December, ten days prior to the commencement of fishway monitoring. However, weaker swimming juvenile empire gudgeon (12-20 mm) potentially missed their opportunity to migrate past the barrier, as they tend to migrate during low flows and on the recession of high flow events, by which time the causeway was no longer 'drowned-out', and fish passage was once again blocked by the causeway.

Australian bass are another example of a species which potentially missed their opportunity to migrate past this barrier during the infrequent 'drown-out' period. Australian bass are diadromous, whereby adults migrate downstream during high flows in winter/spring to spawn in lower estuarine habitats before returning to freshwater (Harris, 1986). Juveniles migrate into freshwater during low flows two to three months later at around 40mm in length (Mallen-Cooper, 2000). The high flows that stimulate movement of adult bass potentially 'drown-out' low level barriers such as the FP causeway, enabling adult bass to undertake an upstream return spawning migration. However, juvenile bass, which move on low flows are obstructed by low level weirs and causeways (Mallen-cooper, 2000), like the one located in FP. Over time, these conditions have the potential to significantly reduce naturally sustaining Australian bass populations, leaving waterways with small populations of remnant adult Australian bass (Mallen-cooper, 2000). Therefore, low passability barriers such as the FP causeway, over time have the potential to significantly reduce important native fish populations upstream of the barrier (Bunn and Arthington, 2002), particularly diadromous species.

One of the ten juvenile PIT tagged Australian bass released at the bottom of the fishway was captured at the top of the fishway during the monitoring period. This specimen was a very small 35 mm Australian bass, and demonstrates that fish of this small size are able to successfully ascend the fishway. This specimen was captured on the second last day of monitoring. A longer fishway trap monitoring period may have resulted in further captures. There is potential that the fish tagging procedure adversely affected the swimming ability or disrupted and/or delayed the upstream migration response of the released Australian bass and contributed to the low recapture rate.

Fish Community Monitoring

Pooled pre and post fishway fish community monitoring results showed that catch rates of all species detected were more than three times higher (32.37 fish/min) downstream of FP causeway compared to catch rates upstream of FP causeway (9.33 fish/min). Pooled catch rate differential between upstream and downstream FP was even greater for diadromous fish species, with the downstream catch rate (56.97 fish/min) more than four times higher than upstream (12.37 fish/min). It is clear from these results that the FP causeway is blocking and/or impeding fish migration along Hilliards

Creek. Of particular concern, is the causeway's location in the lower reaches of the catchment in close proximity to estuarine habitats (~1.5km's), combined with the high number of diadromous species found to occur in Hilliards Creek. Just under half (43%) of the native fish community recorded in the study were diadromous. All diadromous fish species require unimpeded access between their rearing and spawning habitats (Turek, 2016). Diadromous species also play key roles in maintaining the balance of aquatic ecosystems, often sitting at the top of the aquatic food web i.e. long-finned eel, tarpon and Australian bass, and thus have strong influence on predator- prey relationships.

Diadromous species are also recognised as contributing significant societal values. Historically, sea mullet and long-finned eels have been established as important food sources for indigenous people (Barnett and Ceccarelli, 2007). Today, both sea mullet and long-finned eels form important commercial fisheries, with sea mullet comprising the most important in-shore net commercial fishery in South-east Queensland (Williams, 2002). Diadromous species are also important recreationally, in-particular Australian bass and tarpon which are highly sought after sportfish by freshwater anglers

Although information regarding predator – prey relationships of high order diadromous species (Australian bass, tarpon, long-finned eels) and pest fish species (tilapia, platy, *Gambusia*) is limited, it's highly likely that these key native predator species would predate on pest fish species within Hilliards Creek. Kennard *et al.,* (2005) found pest fish to be a useful indicator of waterway health and a good indicator of degraded stream conditions. It's plausible to suggest that by improving connectivity along Hilliards Creek through the remediation of the FP causeway, that high order diadromous predator species would have the opportunity to complete their life-cycle, increase their populations within Hilliards Creek and potentially assist in controlling pest fish. The restoration of diadromous fish communities through the remediation of the FP causeway with an appropriately designed fishway could potentially improve the health of Hilliards Creek's aquatic ecosystems while also providing flow-on societal benefits to the local community through increased recreational, commercial and indigenous fishery opportunities.

Conclusion

Monitoring of the Hilliards Creek full width nature-like rock ramp fishway demonstrates that the fishway is successful at passing a wide range of fish species, size classes and life-stages. Fish as small as 15mm and as large as 800mm were able to ascend the fishway. 11 species representing eight native and three exotic species were captured. Fish species richness was lower than expected, considering the fishway is located in the lower reaches of the catchment. Following the river continuum theory, lowland river reaches generally exhibit higher species richness than upper reaches, due to the addition of complex habitats and the transfer of energy through the catchment (Arthington *et al.,* 2013). Diadromous fish richness was also lower than expected considering the fishways close proximity (~1.5 km's) to estuarine habitats.

The principal reasons for the lower than expected total species richness and diadromous species abundance is attributed to the FP causeway. This major barrier to fish passage along Hilliards Creek is located 200m downstream from the fishway site. The causeway forms a low passability barrier to fish passage during low and medium flow conditions. Only during peak river discharge, with elevated stream flow conditions is the causeway drowned-out, providing intermittent passage past the barrier for some size classes of certain fish species. However, fish are only able to ascend past the causeway if; their migration occurs during high flow events, are located downstream, ready to migrate at the exact time the causeway drowns out and possess swimming abilities sufficient to negotiate the high velocities and turbulence associated with drown-out conditions.

Confounding this situation is that drown-out events occur sporadically and only a few times a year, and juvenile and small bodied species prefer to migrate during low flow events when the causeway poses a formidable barrier to fish passage. Therefore, this causeway presents a major barrier to juvenile diadromous and small bodied species, while presenting extremely limited opportunities for adult and larger bodied species to ascend past. The extent of this barrier is also evident in the fish community monitoring results, whereby diadromous fish were recorded at a catch rate four times higher downstream of the FP causeway when compared to upstream.

Further aquatic connectivity issues in the form of weed choke barriers may also occur downstream of FP (close to the estuarine-freshwater interface) and require further investigation. Weed choke barriers can severely reduce fish passage in small creeks and waterways. These types of fish barriers are commonly associated with altered flow regimes (increased base flows) and high nutrient run-off (Perna and Burrows, 2005). Increased flows emanating down Hilliards Creek from the water treatment plant combined with additional nutrient inputs associated with highly urbanised catchments have the potential to provide suitable conditions for emergent macrophytes such as *Typha* (bulrush) to proliferate. In unmodified catchments, these aquatic macrophytes are controlled by dry periods, but in catchments with modified flow regimes and high nutrients they have the ability to proliferate uncontrolled, causing significant habitat degradation. Similar weed choke issues are widespread throughout the lower Burdekin region in Central QLD due to perennial irrigation flows and associated high nutrient runoff from sugar cane farming (Perna and Burrows, 2005). This has caused major barriers to fish passage throughout this region, and requires mitigation measures to restore connectivity and habitat function.

Recommendations

- Undertake fish passage options analysis for the FP causeway, either:
  1. Fish Passage Options Assessment (Preliminary) – Cost/benefit analysis, taking into consideration the Development Application approval process. This could also include a preliminary design and preliminary budget.
  2. Fish Passage Options Assessment (Detailed) – Undertake cost/benefit analysis, community consultation and the development of a concept design. Undertake detailed design, engineering, flood modelling (if required) and Development Approval process. This option provides RCC with a fully costed 'shovel ready' project. RCC can then apply for offset funding/NRM State and Federal funding to assist with construction/project delivery.

- Restore connectivity past the FP through the construction of a fishway or complete removal of the causeway (bridge replacement). The removal of the FP causeway or the retro-fitting of a fishway may potentially include the installation of additional culverts, which would potentially assist in alleviating flooding issues associated with this causeway.

- Investigate potential weed choke (Typha) barriers located downstream from FP close to the freshwater/estuarine interface.

- Continue to restore connectivity throughout RCC waterways through the removal of fish barriers. Removing barriers in-conjunction with other aquatic habitat rehabilitation activities such as improving water quality run-off, planting of riparian vegetation and the installation of large woody debris will assist in improving the health of waterways and build more resilient native fish communities. Native fish populations that have access to good quality connected in-stream habitats are far better equipped to manage the threats posed by invasive pest fish i.e. tilapia, mosquitofish and platy's.

References

Arthington AH, Kennard MJ, Pusey BJ & Balcombe SR (2013). Assemblages. In 'Ecology of Australian Freshwater Fishes'. (Eds P. Humphries and K. F. Walker.) pp. 245-258. (CSIRO Publishing: Melbourne, Vic., Australia.)

Barnett, B. and Ceccarelli, D. 2007. *As far as the eye can see: Indigenous interests in the East Marine Planning Region*. A report produced by C&R Consulting, Department of Environment and Water Resources, Canberra.

Bunn, S.E. and Arthington A.H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management* 30, 492-507.

Koehn, J. D., and Crook, D. A. (2013). Movement and migration. In 'Ecology of Australian Freshwater Fishes'. (Eds P. Humphries and K. F. Walker.) pp. 105–130. (CSIRO Publishing: Melbourne, Vic., Australia.)

Domenici, P. (2001). The scaling of locomotor performance in predator–prey encounters: from fish to killer whales. Comparative Biochemistry and Physiology. *A. Comparative Physiology 131*, 169–182.

Harris JH (1986) Reproduction of the Australian bass, *Macquaria novemaculeata* (Perciformes: Percichthyidae) in the Sydney Basin. Aust J Mar Freshwater Res 37:209-235.

Kennard MJ, Arthington AH, Pusey BJ and Harch BD (2005) Are alien fish a reliable indicator of river health? Freshwater Biology 50,174-193.

Mallen-Cooper, M. (2000). 'Taking the Mystery out of Migration in Fish Movement and Migration', in Australian Society for Fish Biology Workshop Proceedings, eds. D.A. Hancock, D.C. Smith and J.D. Koehn, pp. 101-111.

Moore, M. (2016) Greater Brisbane Fish Barrie Priorisation Project. http://reefcatchments.com.au/water/greater-brisbane-urban-fish-barrier-prioritisation-process/

O'Brien, T. (2000) Overcoming physical barriers to fish migration. In: Hancock, D. A., Smith, D. C. and Koehn, J. D. (eds.), *Fish movement and migration Australian Society for Fish Biology Workshop Proceedings, Bendigo, Victoria, September 1999*. Australian Society for Fish Biology, Sydney, pp. 129–134

Webb, P. W. (1984b). Body form, locomotion and foraging in aquatic vertebrates. *Amer. Zool*. 24, 107–120

Perna C. and Burrows D. (2005) Improved dissolved oxygen status following removal of exotic weed mats in important fish habitat lagoons of the tropical Burdekin River floodplain, Australia. Marine Pollution Bulletin 51, 138–148

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

Rodgers, Essie M., Cramp, Rebecca L., Gordos, Matthew, Weier, Anna, Fairfall, Sarah, Riches, Marcus and Franklin, Craig E. (2014). Facilitating upstream passage of small-bodied fishes: linking the thermal dependence of swimming ability to culvert design. *Marine and Freshwater Research*, *65* 8: 710-719.

Tillinger, T. N., and O. R. Stein. (1996). Fish passage through culverts in Montana: A preliminary investigation. Montana State University Civil Engineering Department. 50 p.

Thorncroft, G.A. and Harris, J.H. (1996) Assessment of rock-ramp fishways. Technical Report. May 1996.

Turek, J., Haro, A. and Towler, B. (2016). Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes. Technical Memorandum, http://www.habitat.noaa.gov/pdf/Final_Federal_Interagency_Technical_Memorandum_Fish_Passage_Guidelines.pdf

Williams, K.E. (2002). Queensland's Fisheries Resources. Sea Mullet: Current Condition and Recent Trends 1988-2000. Information series QI02012, pp153-165. Department of Primary Industries and Fisheries, Brisbane

Catchment Solutions

CATCHMENT SOLUTIONS

PHONE	(07) 4968 4200
EMAIL	info@catchmentsolutions.com.au
WEB	www.catchmentsolutions.com.au
ADDRESS	Suite 4/85 Gordon St │Mackay Queensland 4740

FIND
YOUR
SOLUTION.