Fish Passage at the Breakout Creek Fishway, River Torrens, South Australia.

Dale McNeil, Phillipa Wilson, Josh Fredberg & Simon Westergaard

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SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

April 2010

Report to the Adelaide & Mount Lofty Ranges Natural Resources Management Board

Government of South Australia
Adelaide and Mount Lofty Ranges Natural Resources Management Board

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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EXECUTIVE SUMMARY

The River Torrens in South Australia is a highly modified and regulated riverine system, due to a series of five major weirs located throughout the catchment. These weirs have caused major barriers to fish movement, and have disrupted the reproductive cycles of diadromous fish species which regularly inhabit these reaches for both spawning and feeding purposes. In particular, the 2.65 m weir at Breakout Creek, which is situated at the mouth of the River Torrens (Henley Beach), formed a significant barrier preventing the upstream movement of fish from the marine and estuarine habitats found below the weir to freshwater habitats found above the weir. Because of this, a 1-on-15 slope denil fishway was installed by the Torrens Catchment Water Management Board at the Breakout Creek weir in 2005, to allow for uninterrupted fish passage and migration.

This report outlines which species are successfully navigating the fishway, and which, if any, are unable to utilise the fishway to gain access to freshwater habitats. This assessment was conducted over a short term period (from the 25th of September to the 3rd of October), in 2008. Sampling with fish traps located at both the entrance and exit of the fishway (day/night), was timed to coincide with known migration periods of a number of diadromous fish species common in the River Torrens.

Nine species of fish successfully ascended the fishway, with diadromous species such as common galaxias (*Galaxias maculatus*) and congolli (*Pseudaphritis urvillii*) being found in greatest abundance. Also to note was the successful ascendance of both pouched lamprey (*Geotria australis*) and climbing galaxias (*Galaxias brevipinnis*), although only found in small numbers and uncommon to the area.

Factors which influenced the success of fish ascending the fishway were related to size class differences found in individual species. It was found that congolli, <30 mm, were unable to successfully ascend the fishway, whereas larger specimens (> 30mm) were successful. For carp gudgeons (*Hypseleotris sp*.), individuals as small as 24 mm were able to successfully ascend the fishway and on the other hand, a single large bodied yellow-eye mullet (*Aldrichetta forsteri*) at 310 mm was also successful. Larger fish, such as adult black bream (*Acanthopagrus butcheri*) and large yellow-eye mullet were not able to successfully navigate the fishway due to its confined design.

Water levels and flow patterns at the weir also had a major influence on the success of species ascending the fishway. Fish passage was greatest on a declining flow,

slightly lower than the 200 mm headwater level outlined in the fishway design. This can be attributed to either the increased efficiency of the fishway hydraulics (e.g. optimum water velocities and turbulence for an array of fish species at smaller size classes); or the ability for fish to locate the entrance of the fishway more readily.

This assessment provided a very short-term snapshot of the fishway operation and a longer-term assessment is recommended to fully assess the utilisation of the fishway by different species. Also, further research is necessary to ascertain the optimum operational conditions for various fishes to successfully ascend into the freshwater reaches of the lower River Torrens.

Acknowledgements

This work was undertaken largely due to the Peter ‘Pedro’ Schulz from the AMLRNRMB, who’s efforts ensured that the Torrens fishway exists and who managed the project for the Board, providing advice and additional data collection throughout the study. In retirement Pedro will be a great loss to the cause of freshwater management in South Australia. Thanks to Steve Gatti and Rehanna Kawalec from the AMLRNRMB for project management and review of the final report. Thanks also to SARDI staff including Michael Guderian who assisted with the fishway construction and field collection and Matt Pellizarre, who assisted with the field trials. Jason Tanner provided editorial revisions and Qifeng Ye provided overall project management. Finally, thanks to the ‘Bung Bandit’ the ultimate controller of fish passage in the River Torrens.

1 INTRODUCTION

The River Torrens in South Australia flows westward from the Mount Lofty Ranges across the Adelaide plains, draining into Gulf St Vincent (GSV) (Figure 1). The Torrens catchment has been largely modified from its natural state following European settlement of the Adelaide plains and Mount Lofty Ranges (MLR). This modification includes widespread clearance of terrestrial and riparian vegetation (Kraehenbuehl 1996) and the construction of an extensive number of water storages. These storages range from small farm dams to large reservoirs, which supply a range of water uses including irrigation, stock watering, and domestic, drinking and urban water supplies for the greater Adelaide area (Savadamutha 2002).

Flow regulation in conjunction with anthropogenic modification is widely acknowledged as a major cause for the deterioration of Australia's riverine ecosystems (Pollino *et al* 2004; Pusey and Arthington 2003). In addition, the construction of dams, reservoirs, road crossings and flood control structures frequently provide significant obstruction to the movement of freshwater fish both longitudinally and laterally across floodplain and wetland areas (Mallen-Cooper 1999, Schille & Bates 2000, Stuart *et al* 2008). In the River Torrens, there are a number of barriers to fish movement including Gumeracha weir, Kangaroo Creek reservoir, Gorge weir, City weir and the Breakout Creek weir. Also, approximately five less significant barriers are scattered between the above barriers all of which are located within Adelaide's metropolitan area.

Before European settlement and subsequent development of the Adelaide Plains, the River Torrens terminated in a complex of wetlands that ran northward behind coastal dunes, into West Lakes and the Port River Estuary (Holmes & Iverson 1976). In the early 20th century, the 'Breakout Creek' channel was constructed to drain the lower reaches of the river westward through the dunes and into GSV at West Beach. The construction of Breakout Creek and the draining of the coastal wetlands for urban development destroyed this coastal freshwater ecosystem leaving only remnant patches of biota persisting within a highly modified environment. This is dominated by highly engineered drainage networks, with little natural habitat value. The construction of the 2.65 m high Breakout Creek weir at the mouth of the River Torrens in the 1930's formed a significant barrier preventing the upstream movement of fish from the marine and estuarine habitats below (Hicks & Hammer 2004, Mallen-Cooper 2004) (figures 2 & 3). In combination, the draining of coastal wetlands and the construction of Breakout Creek weir also disrupted the natural gradient between freshwater, brackish and marine habitats, effectively restricting estuarine habitat in the River Torrens to around 20-30m between the weir and GSV (Bryars 2003).

The construction of Breakout Creek weir contributed to the native fish assemblage of the River Torrens being severely degraded, with only four of the sixteen historically recorded fish species surviving in the system by 2004, and only three native species persisting in the lower reaches (Hicks & Hammer 2004). Interestingly, all three of these remnant species represent different life history guilds relating to their use of lowland freshwater, estuarine and marine habitats. Flatheaded gudgeons (*Philypnodon grandiceps*) are a predominantly freshwater species, yet are occasionally found in estuarine/brackish habitats, whilst the blue spot goby (*Pseudogobious olorum*) is predominately an estuarine/brackish species occasionally found in freshwater habitats (Allen, *et al* 2002). The anadromous pouched lamprey (*Geotria australis*) lives its adult life entirely in marine systems, where it parasitises large fish, returning seasonally to freshwater where it spawns and where larval 'ammocetes' develop before migrating back to the sea (Allen, *et al* 2002).

The presence of these species in the lower River Torrens suggests that some connectivity may be maintained by seasonal high tides and storm surges (D. McNeil, P. Schulz, Personal Observation). These events however, would be infrequent and not necessarily timed with the seasonal migrational needs of freshwater diadromous fish found in the River Torrens catchment (McNeil & Hammer 2007).

The true status and composition of the lower Torrens fish population circa-2005 remains unclear, as no comprehensive fish surveys were conducted within this time, but instead our knowledge has relied largely on opportunistic observations and collections. Nevertheless, populations of diadromous fish species were reported to be present in the small area of estuarine habitat below the Breakout Creek weir (mouth of the River Torrens); these included common galaxias (*Galaxias maculatus*), congolli (*Pseudaphritis urvillii*) and pouched and short headed (*Mordacia morax*) lampreys (Bryars 2003, Mallen-Cooper 2004).

During 2005, a 1-on-15 slope denil fishway was installed by the Torrens Catchment Water Management Board at Breakout Creek (Figures 2 & 3). This fishway is 32.25 m in total length (including a 2 m turnaround pool and a 1 m exit), and has 0.56 m internal width (1.12 m in total) in an attempt to create upstream passage for species such as common galaxias, congolli and lampreys (Mallen-Cooper 2004). Whilst it was acknowledged that black bream (*Acanthopagrus butcheri*) and mullet (*Liza argentea* & *Aldrichetta forsteri*) are also likely to attempt passage, these species may not use the fishway due to its confined nature (Mallen-Cooper 2004). Following its construction, fish monitoring revealed that a number of species were present above the barrier that had not been recorded in recent times. These included an abundant adult and juvenile population of common galaxias and moderate numbers of juvenile congolli (McNeil *et al.* 2009) in addition to blue spot gobies and flatheaded gudgeons, which were previously recorded within the reach. This indicates that either these species were missed during previous surveys or had recolonised from marine or estuarine habitats via the Torrens Fishway.

Whilst diadromous species (fish that migrate between fresh and salt water) and euryhaline species (fish that can tolerate a wide range of salinities), are now present in the freshwater section of Breakout Creek, there has been no direct assessment of the function of the fishway. This report outlines an initial assessment project aimed at finding out which species are successfully navigating the fishway, and which, if any, are unable to utilise the fishway to gain access to freshwater habitat.

1.1 Aims

Specifically, this report aims to:

- Compare species successfully ascending the fishway at the mouth of the River Torrens (Breakout Creek weir), with those attempting to ascend; to assess fishway efficiency.
- Investigate any limitations to the size classes (including larval and juvenile stages) that can successfully ascend the fishway.
- Investigate any additional factors that might influence fish passage, including discharge rates and diel variability (day versus night).

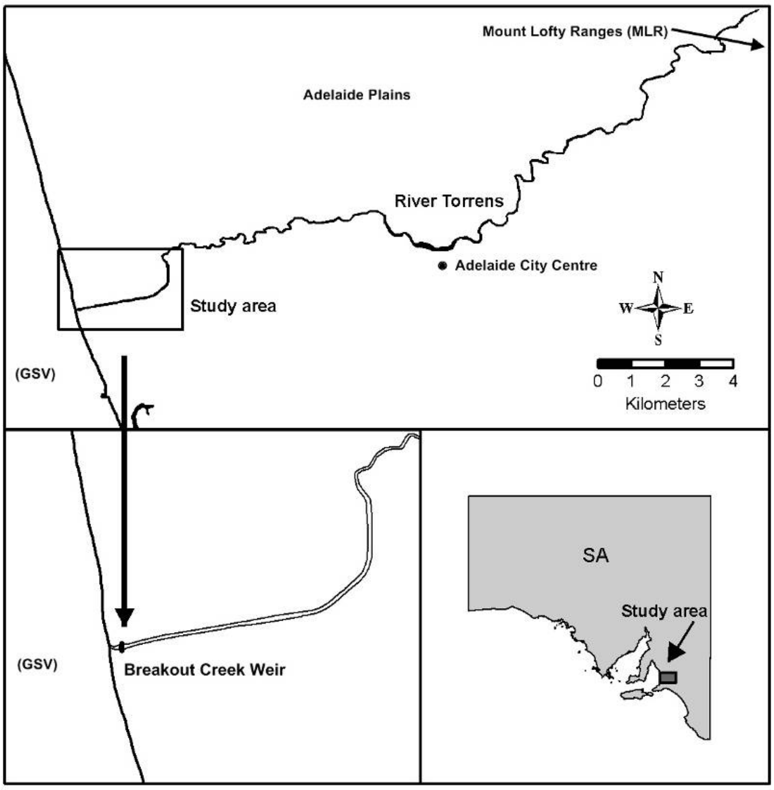


Figure 1. Map of the Study Site (Breakout Creek Weir, River Torrens, South Australia)

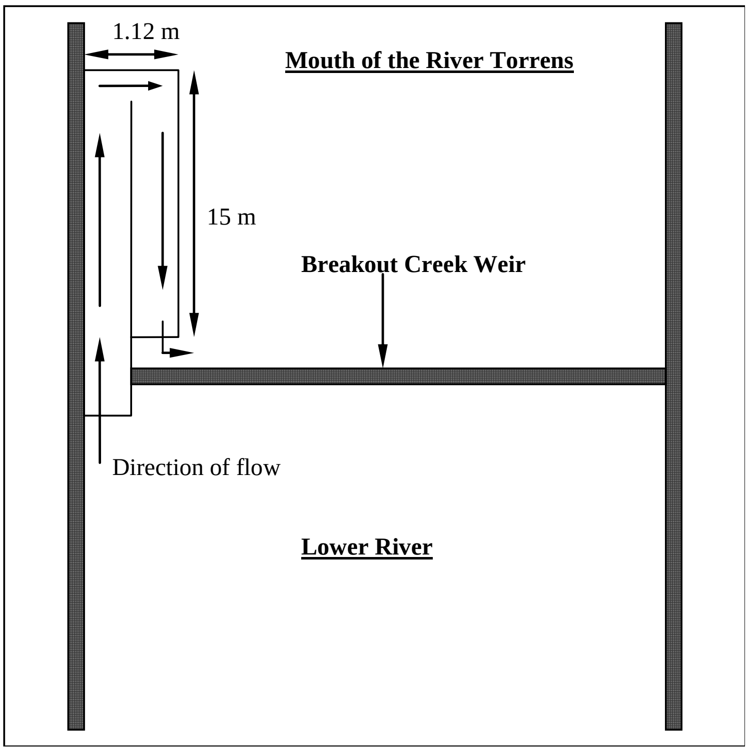


Figure 2. A schematic layout of the denil fishway located at Breakout Creek, River Torrens, South Australia.

Figure 3. The River Torrens Fishway at Breakout Creek Weir, Henley Beach.

Figure 4. Fyke net set above fishway exit showing freshwater just overtopping the weir at high tide. Fishway is obscured to the left of picture.

2 METHODS

2.1 Breakout Creek Fishway

A detailed representation of the physical nature (dimensions) and hydraulics of the Breakout Creek fishway, situated at the mouth of the Torrens River is presented in the report; “A Concept design for a fishway on the Torrens River Outlet Weir (Breakout Creek)” (Mallen-Cooper 2004).

2.2 Pilot study - October 2007

A pilot study was conducted in October 2007 to assess the feasibility of fish-way trapping and provide direction for fish trap design. This four-day pilot was conducted between the 15th and 19th of October, and provided baseline information for the type of species likely to be targeted, and only assessed fish exiting at the top end of the fishway (fishway exit). Sampling was conducted using a standard 3 mm mesh fyke net with a 3 m cod end and 4 m wings (Figure 4). The opening of the fyke net was fixed to the fishway exit and the wings wrapped around the junction to seal any gaps due to net misalignment. The net was then set for approximately 22 hours on a daily basis and catch measured (total length (mm) of each species) and abundance for each species was recorded prior to re-setting.

2.1 Trap design and construction

Fish traps for both the top (exit) and bottom (entrance) of the fishway were designed and constructed at SARDI Aquatic Sciences. The exit trap (650mm X 370mm) was designed to attach flush with the top of the fishway, accounting for the particular characteristics of the exit structure. This trap consisted of a 2mm nylon mesh with square aluminium hoops, and three funnels preventing the exit of trapped fish in each of the four sections. An internal aluminium mesh frame prevented the collapse of the net due to water pressure and fouling (Figure 5A). The cod end, 5m in length (Figure 5B) was tied to a permanent aluminium trash rack, which prevented fouling by debris. The trap was affixed to the fishway exit via an aluminium angle frame, which bolted onto the fishway exit structure.

Figure 5. Exit trap for the top of the fishway showing A: attachment mechanism and B: closable cod end for removing fish catch.

The entrance trap (1465mm tall, 325mm wide, 865mm long), was designed to slide flush inside the fishway directly inside the entrance. The trap was clad with perforated sheet aluminium (3 mm holes) with meshed funnels (3 mm gauge mesh) with a funnel opening of 95mm^2 (Figure 6A). A small latched door at the rear of the trap allowed access to the catch once the trap was removed from the fish-way (Figure 6B). This trap was designed to be lowered into the fishway (Figure 6C), allowing fish to enter as normal, capturing fish attempting to move upstream after moving through the entrance aperture.

Figure 6. Entrance trap for the bottom of the fishway showing A: entrance funnels through which fish enter the fishway, B: rear door for removal of catch showing a variety of fishes from a trial run and C: The entrance trap slides flush into the bottom of the fishway without obstructing the entrance.

2.2 Fishway Assessment- September/October - 2008

The fishway assessment was conducted the following year between September 25th and October 3rd, 2008. Due to the limited timeframe, sampling was timed to coincide with known migration periods of a number of diadromous fish species common in the River Torrens (Bice et al 2007, McNeil & Hammer 2007). Sampling was alternated between the two traps, with a day and a night set period for each trap type. This was performed until three replicates had been established for each set type. This included three day (9.00am-4.30pm) upstream replicates (exit trap), three night (4.30pm-9.00am) upstream replicates (exit trap), three day (9.00am-4.30pm) downstream replicates (entrance trap) and three night (4.30pm-9.00am) downstream replicates (entrance trap). When nets were pulled catches of fish were transferred into buckets and identified to species. The abundance of each species as well as total length of individual fish (mm), reproductive condition and the presence of disease or parasites was recorded. For abundant species a sub-sample of 50 randomly selected fish was measured.

2.3 Water quality and river level

Water quality parameters such as; Temperature (°C), pH, Total Dissolved Solids (ppt) and Dissolved Oxygen (ppm), were measured using a TPS 90FL-T multi-meter above and below the fishway prior to the traps being pulled. The strength and depth of the halocline below the fish-way was also measured. This was done by measuring Total Dissolved Solids (ppt), at three depths (surface, 0.5m, 1.2m) at a point three meters downstream from the point of outflow of the fish-way (see Appendix 1). Water levels were recorded as a surrogate for river discharge, which could not be explicitly recorded at the time. This was done by measuring water surface levels above the weir using the spillway lip (the point of general weir spillage) as a zero value, with water levels below this recorded as negative values and water levels exceeding the spillway lip recorded as positive values. It should be of note that water continues to flow through the fish way at sub-spillway levels up until approximately 200 mm below the weir crest (Mallen-Cooper 2004).

3 RESULTS

3.1 Fishway Assessment

In total 12,064 individual fish from twelve species were captured within the Torrens fishway over the two sampling events (Table 1). In the pilot study conducted in October 2007 (exit trap only), 986 fish from seven species were trapped after successfully ascending the fishway, whilst in September/October 2008 a total of 11,076 fish were caught, comprising of ten different species from both entrance and exit traps combined (Table 1).

3.2 Fishway success

In total, nine fish species successfully ascended the fishway. Importantly, four species of diadromous fish; common and climbing galaxias, congolli and pouched lamprey, were found to utilize the fishway successfully. Whilst the climbing galaxias and pouched lamprey results are from single fish, common galaxias (n=6975) and congolli (n=3322) made up the vast majority of the catch both in exit and entrance traps (Table 1).

Other fishes that were able to successfully ascend the fishway include four species of predominantly freshwater fish, flatheaded gudgeon (*Philypnodon grandiceps*), carp gudgeon (*Hypseleotris sp1*), the introduced goldfish (*Carassius auratus*) and common carp (*Cyprinus carpio*), all of which ascended in low numbers (Table 1). The only estuarine species recorded successfully ascending the fishway was the yellow-eye mullet (*Aldrichetta forsteri*) (n=7), during the October 2007 pilot study. In the fishway assessment of 2008, large numbers of yellow-eye mullet were captured at the entrance of the fishway but were not recorded at the exit. Similarly, three other estuarine species, black bream (*Acanthopagrus butcheri*), flat-tail mullet (*Liza argentea*) and blue spot goby (*Psuedogobius olorum*) entered the fishway in low numbers but were not recorded successfully ascending the fishway (Table 1).

Only the entrance and exit data from the 2008 fishway assessment were used to calculate percent success, as only the exit was sampled in 2007. Pouched lamprey and climbing galaxias (CPUE of 0.014 fish/hour for each species) were only represented by a single individual each in the exit trap, and so success rates could not be calculated for these species (Table 1). Twenty-nine carp gudgeons were found in the entrance trap (CPUE of 0.403 fish/hour) compared to only four caught at the exit trap (CPUE of 0.028 fish/hour), indicating an ascendancy success rate of approximately 6.8% (Table 1).

Congolli and common galaxias were the most abundant species collected from both the entrance and exit of the fishway, and as a result, their patterns of use were analyzed in more detail than for the less common species. Whilst 3029 congolli entered the trap below the weir in the 2008 fishway assessment (CPUE of 42.069 fish/hour), only 17 were recorded from the exit trap (CPUE of 0.236 fish/hour), indicating a very low success rate for this species (~0.6%) (Table 1). At the same time, a total of 6310 common galaxias were recorded in the entrance trap (CPUE of 87.639 fish/hour), compared to 1467 caught in the exit trap (CPUE of 20.375 fish/hour), indicating a success rate of ~23% (Table 1).

Table 1. Catch Summary October 2007 & 2008 sampling, total caught and CPUE (fish/hr) for entry (downstream) and exit (upstream) and inferred percent success of passage through fish-way.

		2007		2008				
		Exit		Entrance		Exit		
Common Name	**Scientific Name**	**Total catch**	**CPUE**	**Total catch**	**CPUE**	**Total catch**	**CPUE**	**% Success**
Carp gudgeon sp (FW)	*(Hypseleotris spp)*	4	0.04	29	0.40	2	0.02	6.8
Flathead gudgeon (FW)	*(Philypnodon grandiceps)*	2	0.02	4	0.05	-	-	0
Carp (FW)	*(Cyprinus carpio)*	13	0.15	-	-	-	-	-
Goldfish (FW)	*(Carassius auratus)*	2	0.02	-	-	-	-	-
Common galaxias (D)	*(Galaxias maculatus)*	665	7.00	6310	87.63	1467	20.37	23.2
Climbing galaxias (D)	*(Galaxias brevipinnis)*	-	-	-	-	1	0.01	-
Congolli (D)	*(Pseudaphritis urvillii)*	293	3.45	3029	42.06	17	0.23	0.6
Pouched lamprey (D)	*(Geotria australis)*	-	-	-	-	1	0.01	-
Yellow-eye mullet (EST)	*(Aldrichetta forsteri)*	7	0.076	197	2.736	-	-	-
Flat-tail mullet (EST)	*(Liza argentea)*	-	-	14	0.194	-	-	0
Black bream (EST)	*(Acanthopagrus butcheri)*	-	-	1	0.014	-	-	0
Blue spot goby (EST)	*(Pseudogobius olorum)*			5	0.069	-	-	0

*** Note: (FW) = Freshwater species, (D) = Diadromous species, and (EST) = Estuarine species**

3.2.1 Fish size and fishway success

For common galaxias, the size distribution of fish entering the fishway and those successfully exiting the fishway, appear to be similar (Figure 7). The exception was that juvenile fish (< 40mm in length), entered the fishway in low numbers but were not recorded at the exit. This has lead to a statistically significant difference between the mean size of fish entering the fishway versus fish exiting the fishway (Kolmogorov-Smirnov (K-S); D =0.186, P <0.001). These size classes however, represent a tiny proportion of the overall catch of common galaxias with the differences in mean length between common galaxias caught from the entrance (44.4 ± SD 2.2) and exit traps (45.2 ± SD 1.9) only being small.

A similar but more prominent pattern was observed in congolli where all individuals successfully ascending the fishway were over 30mm in length, whilst fish as small as 17mm were collected from the entrance trap (Figure 8). The difference between the mean size of congolli caught in entrance and exit traps was significant (K-S; D=0.896, P<0.001). Unlike the common galaxias, the proportion of juvenile congolli that did not successfully navigate the fishway represents the vast majority of fish entering the trap seeking upstream migration. Accordingly, the mean length of fish from the entrance trap (24.9 ± SD 3.5) was lower than the mean size of congolli caught at the exit trap (32.2 ± SD 2.2).

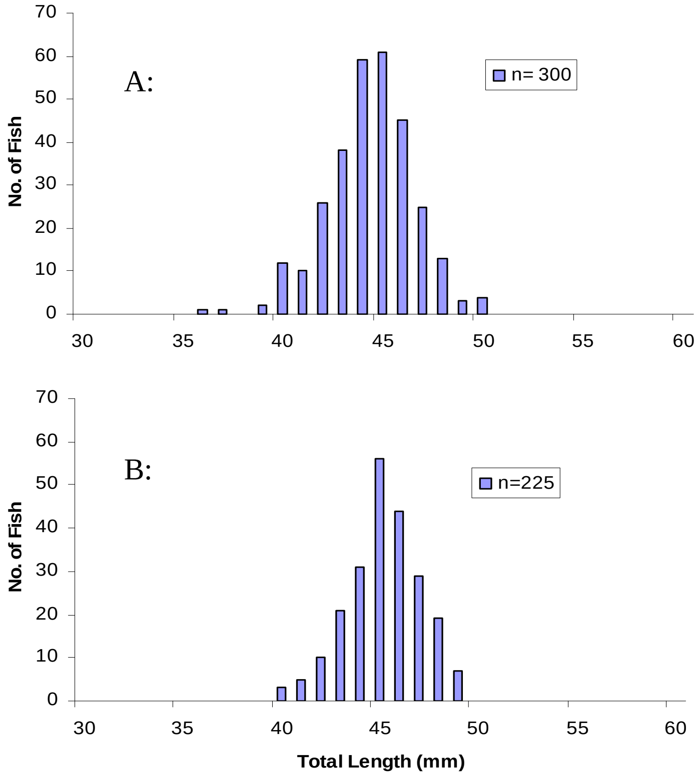


Figure 7**.** Length frequency distribution for *Galaxias maculatus* (n=525) from A: the entrance trap and B: exit trap in October 2008 (TL-mm).

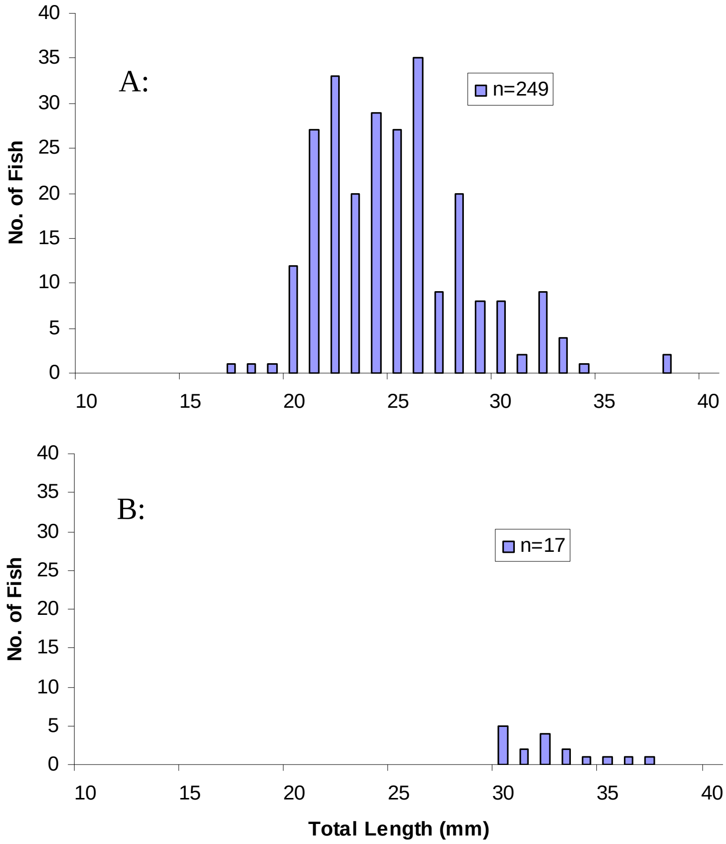


Figure 8. Length frequency distribution for *Pseudaphritis urvilii* (n=266) from A: the entrance trap and B: exit trap, in October 2008 (TL-mm).

The minimum and maximum length of fish that successfully ascended the fishway was species specific, ranging between 24 mm (carp gudgeons) and 310 mm (yellow-eye mullet) (as seen in Table 2). The only large bodied fish (> 100 mm) to successfully ascend the fishway was a single yellow eye mullet in 2007. Larger individuals of small bodied species; namely flatheaded gudgeons (72 mm) and congolli (89 mm), were also caught in the exit trap, indicating that adult (flatheaded gudgeons) and sub-adult (congolli) individuals can successfully ascend the Breakout Creek fishway (Table 2). Also of note, minimum size ranges of all diadromous species reveal that juvenile recruits from these 3 species (common galaxias, climbing galaxias and congolli), are able to successfully ascend the fishway and move into freshwater habitat (Table 2).

Table 2. Size ranges (mm-TL) for fish species captured in exit traps after successfully ascending the fishway in 2007 and 2008.

Common name	**Minimum size (mm)**	**Maximum Size (mm)**
Carp gudgeon species 1	24	40
Flathead gudgeon	65	72
Carp	25	39
Goldfish	26	35
Common galaxias	40	49
Climbing galaxias	39	39
Congolli	30	89
Yellow-eye mullet	51	310
Flat-tail mullet	N/A	N/A
Black bream	N/A	N/A
Blue spot goby	N/A	N/A

3.3 Flow and fishway success

Whilst the 2008 trial lasted a little over a week, it was conducted in response to rainfall and flows received in the River Torrens (~40.4ML/day), which was required for the fishway to function. The trial began with flows overtopping the weir by approximately 40 mm, but dropping to only 20 mm above the weir height after the first 24 hours and stabilising at this level until after the 96 hour point of the trial (Figure 9). At this point, additional rainfall caused a peak in flow that caused water level to rise to ~ 60 mm above the weir, after which the flow gradually declined with water level falling to below weir height after ~ 50 hours. Water levels continued to decline until the 180h point after which it stabilised approximately between 55 mm and 65 mm below the weir height. The trial was conducted following a dodge tide under building tidal height, peaking just before the end of the trial (Figure 9).

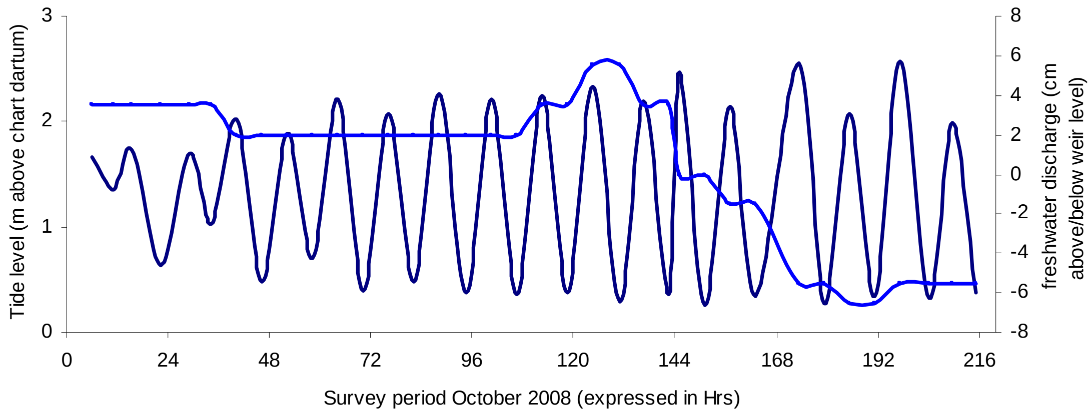
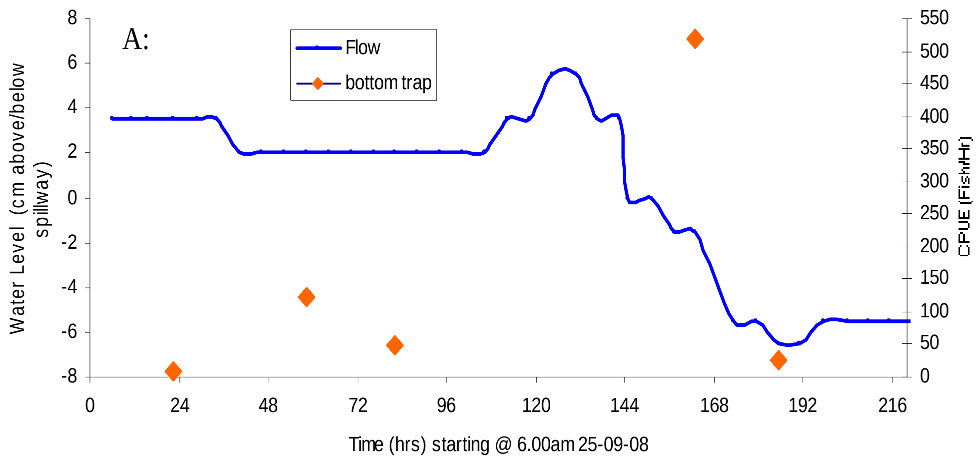


Figure 9. Water level (cm-light blue line) in relation to the top of Breakout Creek Weir (0 = weir crest height) during the 2008 trial period, overlain with tidal cycles (m-dark blue line).

For common galaxias and congolli, catch rates in both entrance and exit traps were high enough to examine the relationship between river-flow and the use of the Torrens fishway. Both species showed very similar patterns in relation to flow (Figures 10 & 11), with greater abundances of fish entering the fishway following the initial drop in flow that occurred between 24 and 48 hours (Figure 10). Entry rates decreased again under stabilized flows (~ 20mm over weir) but rose sharply after ~120 hours, however, decreasing again as flows stabilized at a low level, ~ 60mm below weir height. Congolli, however, continued to enter the fishway in significant numbers under low flow conditions, whilst galaxias entry into the fishway was drastically reduced (Figure 10B).

The relationship between successful use of the fishway and river flows were also similar between these two species (Figure 11). Both species (although slightly higher for common galaxias) provided low to reasonable catches in the exit trap leading up to the 192 hour point, at which time flow levels had decreased and stabilized at ~60mm below weir height. Under these low flow conditions, both species were caught in very high numbers exiting the top of the fishway. Therefore, for both species, large numbers of fish entered the fishway under declining flow conditions as general flows over the weir crest ceased (Figure 12) and fishway flows accordingly decreased. This was immediately followed by a peak in fish successfully ascending the fishway over the next 48 hours under relatively low flow conditions.



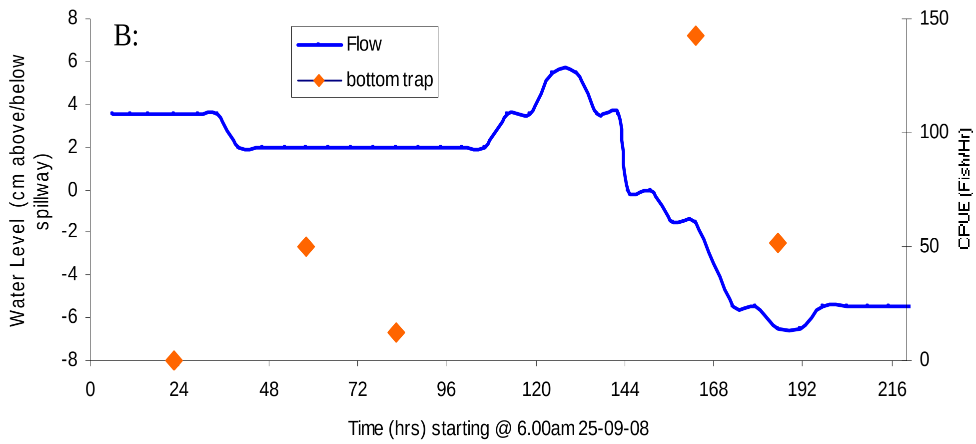
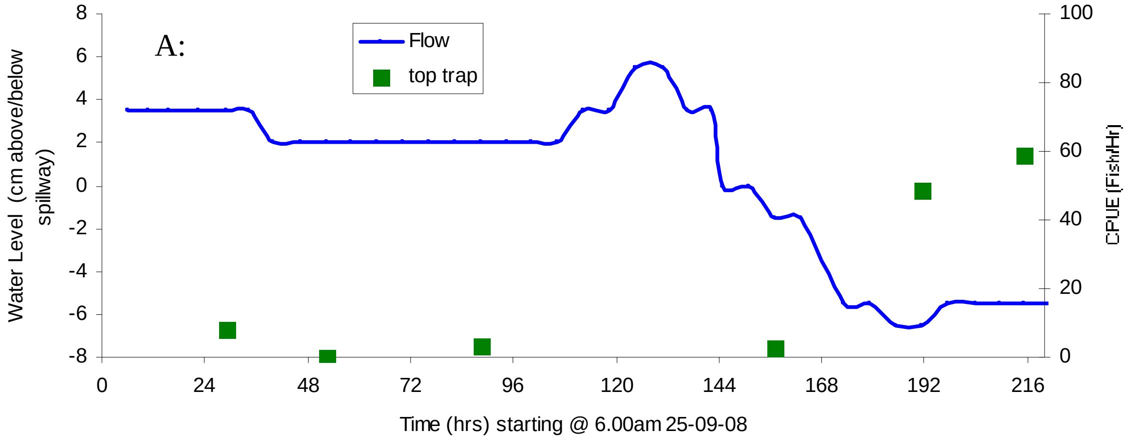


Figure 10. Entrance trap CPUE (Standardised-Fish/Hour) for A: *Galaxias maculatus* and B: *Pseudaphritis urvillii* in relation to water level at the Breakout Creek Weir crest during the 2008 trial.



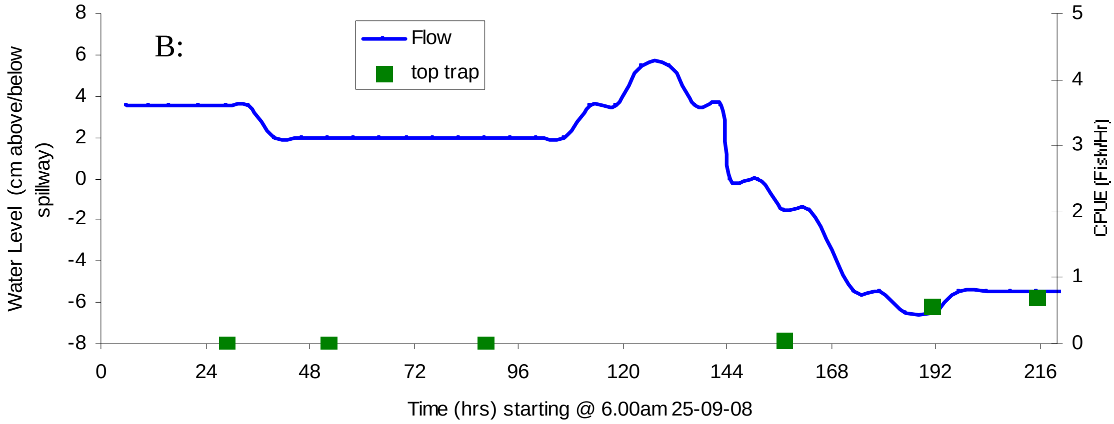


Figure 11. Exit trap CPUE (Standardised-Fish/Hour) for A: *Galaxias maculatus* and B: *Pseudaphritis Urvillii* in relation to water level at the Breakout Creek Weir crest during the 2008 trial.

Figure 12. Breakout Creek Weir just above zero-water level, with flow just overtopping the weir crest. Higher abundances of common galaxias and congolli were collected in the exit trap at or below this flow.

3.4 Diel patterns in movement

For both common galaxias and congolli, fish entered the fishway in higher numbers during the daytime compared to night, however this result was not supported statistically due to the low number of replicates (n=3 for each trap/diel combination), and hence no significant differences were found (*G. maculatus* (unequal variance t-test (df2) t=2.91, P=>0.05 and *P. urvillii* (unequal variance t-test (df2) t=2.35, P=>0.05) (Figure 13). In the exit trap, day and night catches were similar for both species, and again no significant differences were found (*G. maculatus* (unequal variance t-test (df2) t=2.13, P=>0.05 and *P. urvillii* (unequal variance t-test (df2) t=2.13, P=>0.05) (figure 13). For both species, there were differences in the entrance and exit catches during the day, with higher catches in the entrance trap. At night the entrance and exit trap catches were similar for G. maculatus, but for *P. urvillii*, day catches were higher in the entrance over exit trap.

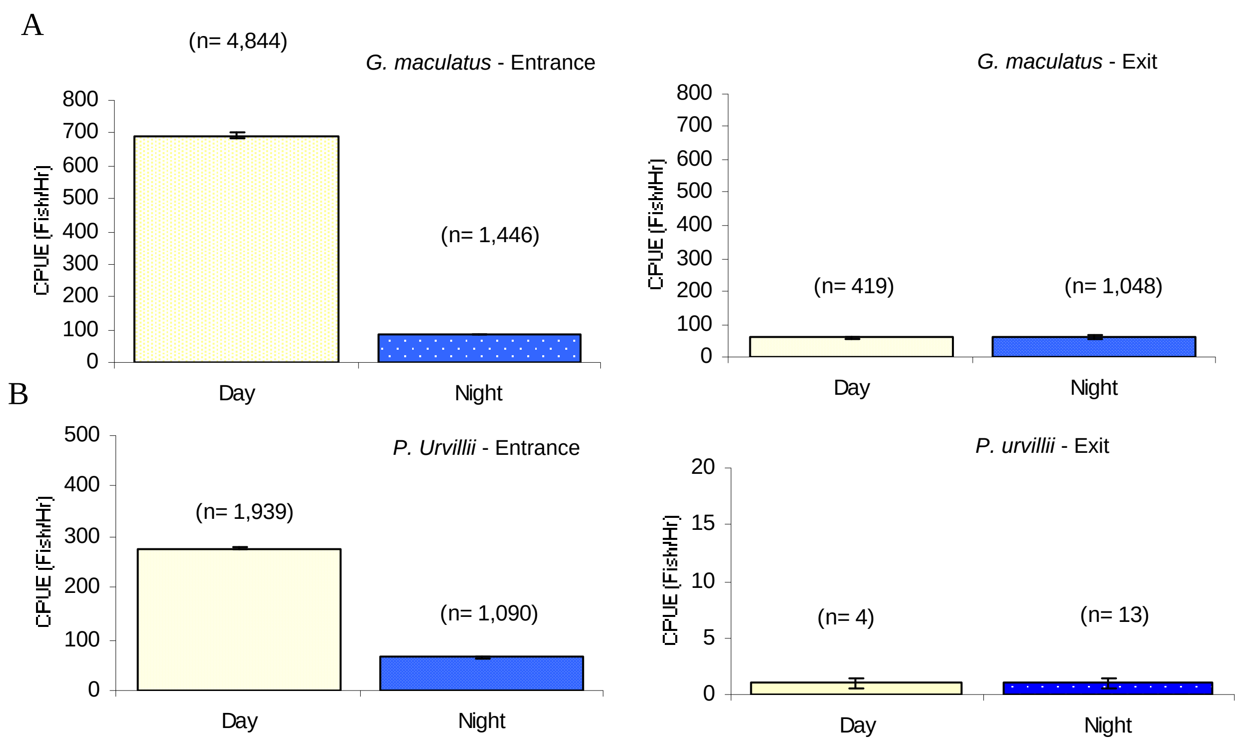


Figure 13. CPUE (Standardised-Fish/Hour +/-SE) from A: *Galaxias maculatus*; and B: *Pseudaphritis urvillii* in both entrance and exit traps comparing daytime and night time catches during the 2008 trial. Error bars indicate standard error around the mean and n+ total number of fish. Note different Y axis scales for B due to low numbers in the exit catch.

4 DISCUSSION

4.1 Utilisation of the Torrens River fishway

Although of short duration (September 25th to October 3rd, 2008), the fishway assessment documented large numbers of diadromous fish migrating from the sea into freshwater via the use of a denil fishway located at the Breakout Creek weir. These consisted of juvenile catadromous and adult anadromous species commonly undertaking upstream migration at this time of year (Bice et al 2007, Jennings et al 2008). Whilst large numbers of young of the year common galaxias and congolli were caught, single individuals of rarer species, namely pouched lamprey and climbing galaxias, also ascended the fishway during the trial period, suggesting that these species may also use the fishway at certain times of the year. These individuals may have immigrated to the Torrens from other catchments, which may indicate that these fish are trying to re-establish populations within the Lower Torrens if immigration rates are substantial and providing appropriate habitats exist and are accessible.

In addition, the use of the fishway by freshwater species such as flatheaded gudgeons suggest that these populations are able to use the fishway to recolonise into freshwater if they become displaced downstream of the weir under high flows. This pattern also held for goldfish and juvenile carp, both introduced freshwater fish with a current noxious status in Australia. This suggests that although fishways allow for the upstream movement of freshwater species displaced downstream by high flows, fishways of this nature are non-selective in what species can successfully ascend back into freshwater e.g. native or introduced species.

One of the key findings of the assessment was that, whilst estuarine species; yellow-eye and flat-tail mullet, black bream and blue spot goby, were found in the entrance trap in varying abundance, none were found to be successful in ascending the fishway during the 2008 assessment period. For yellow-eye mullet, this was despite large numbers of juvenile fish entering the fishway and being caught at the fishway exit during the 2007 trial.

This pattern is largely consistent with expectations of the fishway design, with the design concept clearly indicating that adult mullet and bream may not utilise the fishway due to its shallow and narrow nature (Mallen-Cooper 2004). It is clear, that the Torrens fishway, whilst providing access for smaller diadromous fish, is far less effective for larger predominantly estuarine fishes. Only the reconstruction of the fishway to accommodate larger bodied fish or the re-angling of Breakout creek to allow a steady decline between Henley Beach Rd and GSV is likely to return free passage for these species to move easily between freshwater and marine habitats.

Additionally, records of blue spot goby and pouched lamprey within the freshwater reaches of the Lower Torrens prior to the construction of the fishway (Hicks & Hammer 2004) suggest that these species may also at times be able to migrate upstream from the sea. This is likely to occur when high tides and storm surges raise sea levels above the weir height as occurred during winter 2008 (Figure 14), although pouched lamprey have also been observed climbing the weir wall at lower water levels (M. Hammer per comm.). The timing of these events however, must coincide with the timing of emigrational cues e.g. winter/spring for most diadromous species mentioned in this report, for this scenario to provide any opportunity for recolonisation of diadromous fishes, and this is not known to have occurred within the Torrens River catchment.

Figure 14. Seawater intrusion under high tidal and storm surge conditions in 2008 forcing Breakout Creek to flow backwards temporarily. This scenario provides opportunity for upstream migration from the sea without reliance on the fishway.

4.2 Fishway Success

Large numbers of fish were able to ascend the fishway successfully; nevertheless many more fish were recorded entering the fishway than exiting it. It is likely that the velocity and/or turbulence created in the fishway may not allow a sufficient boundary layer to develop for passage of small size classes (<24mm TL) of congolli and other diadromous species. This was supported during the 2008 fishway assessment, in that smaller congolli attempted to utilise the fishway in large numbers but only individuals over 30mm were able to successfully ascend. Small fish gathering at the fishway entrance may be highly susceptible to predation, especially with predatory fishes also attracted to the fishway opening. Modifications to the fishway to improve the hydraulic environment may be required to improve passage of very small individuals. Measures such as increasing surface roughness and providing additional low flow areas within the trap may significantly improve the passage of very small individuals. It is recommended that these improvements be considered to maximise the success of very small congolli seeking to move into freshwater habitats from marine nursery habitats.

The fishway appeared to attract fish to the entrance under conditions of declining freshwater flow, suggesting that fish may wait outside the entrance until flow conditions become appropriate. Certainly, large numbers of fish were observed schooling outside the fishway entrance at higher tides, at the point where freshwater flows exited the fishway surface cladding (Figure 15). In general, there are a number of issues that may prevent fish from effectively finding and entering the fishway. In particular, the effectiveness of the attractant flow from the fishway is often decreased by the spillage of water over the weir crest.

It is recommended that a removable lip be designed to increase the weir height during times of fishway operation. By increasing the height of the weir crest (similar to that between the fishway and the weir wall), attractant flows to the fishway entrance will be maximised during the period of peak fishway operation. This extension could be fitted only during the periods when flows are ideal for fishway operation and can subsequently be removed so as not to increase effective weir depth under higher flows. Further studies into the hydraulic performance of the fishway under various flow rates may be required to optimise conditions for fish passage under a variety of flow conditions.

Figure 15. Schooling juvenile common galaxias at the point where freshwater flows exited the fishway roof during higher tidal conditions.

Fish had a greater probability of locating the fishway entrance at low water levels, when the primary source of freshwater inflows into the estuary was through the fishway entrance. These conditions were also linked to an increase in salinity stratification below the weir and are therefore ideal for attracting fish into the fishway. This was followed by an increase in the number of fish successfully ascending the fishway, suggesting that the fishway efficiency, in terms of water velocities and turbulence, was optimised when water levels fall below the level of the weir crest. As a result, optimal operation of the fishway is slightly lower than the 200 mm headwater level outlined in the fishway design (Mallen-Cooper 2004).

Fish appeared to ascend the fishway in similar abundances during the day and night although many more fish were entering the fishway during the day than at night. The reason for this is unclear, but may relate to the shelter provided by the entrance structure that could allow refuge from predation by other fish and birds. Under this scenario, entrance catches may not purely represent the intention to migrate into freshwater but may relate more to habitat use. During the night, risk from visual predators is reduced and fish may be less inclined to use the fishway for protection. This raises the possibility that the night time data may represent the proportion of fish entering the fishway with the intention of migrating into freshwater, explaining the more balanced entrance/exit levels during the night. Extended and more detailed assessment however, would need to be undertaken to provide clearer understanding of these patterns.

4.3 Summary

The trial revealed that the Torrens fishway has provided some levels of fish passage to diadromous and freshwater fishes between the sea and the lower River Torrens. Importantly, the fishway is likely to be responsible for the restoration of common galaxias and congolli populations in the lower Torrens. The fishway does not however, provide good passage for a range of estuarine fishes including two mullet species and black bream, which are known to frequently utilise freshwater habitats (McNeil & Hammer 2007). Post-larval congolli (<30 mm) do not seem capable of ascending the fishway, even though they enter the fishway in large numbers.

The fishway appears to function optimally under lower flow conditions where water levels fall below the weir crest, which could be attributed to either increased efficiency of the fishway itself e.g. optimum water velocities and turbulence for fish to successfully ascend the fishway or the ability of fish to successfully locate the entrance of the fishway. This trial provides a very short-term snapshot of the fishway operation and a longer-term assessment is highly recommended to fully assess utilisation of the fishway by different species, and also to ascertain the optimum operational conditions for various fishes to successfully ascend into the freshwater reaches of the lower River Torrens. Additionally, the design of the fishway may need to be reconsidered to improve the passage of smaller bodied fishes seeking upstream migration at the Breakout Creek Weir, in particular congolli, which are attempting to migrate at smaller sizes than the fishway allows.

Finally, the success of the fishway in returning diadromous native fishes to the Breakout Creek and lower River Torrens increases the urgency for restoring fish passage further upstream. Fish passage barriers upstream of Breakout Creek including the large city weir (Hicks and Hammer 2004), should be considered for works to re-establish the passage of native fish from the newly established populations in Breakout Creek. Whilst the current fishway design at the Torrens Mouth has been a successful first step in restoring diadromous fish populations to the River Torrens, further improvements to the fishway's performance and the removal of upstream barriers will allow the full restoration of these populations within one of Adelaide's most important river systems.

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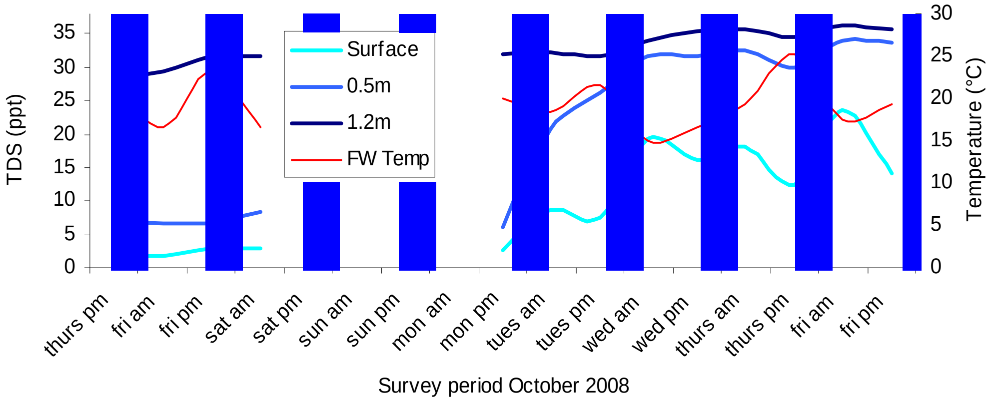
6 APPENDIX 1



Appendix 1. Measured salinity at depths (inferring depth of halocline) and temperature of freshwater outflow during the October 2008 survey period. Shaded banding represents diel cycles.