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Clare Weir Fishlock Monitoring

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SunWater

Queensland Government
Department of Primary Industries and Fisheries

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Cover Photograph: View across Clare Weir to the West..

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Glossary

Amphidromus: Fishes which migrate between the sea and freshwater (or vice versa) at some definite stage in the life cycle but not for the purpose of reproduction.

Catadromous: Fishes that spend most of their time in freshwater and migrate to the sea to reproduce.

DPI&F: Department of Primary Industries and Fisheries

Endemic: a species of organism that is confined to a particular geographical region, for example an island or river basin.

Fish Passage: Everything related to movement of fish in the environment.

Fishlock: a fishway consisting of an entrance, a vertical lock and an exit chamber. Fish are attracted into the lock chamber where water levels are raised to the level of the storage and fish can continue upstream movements. A combination of automated values, gates and attraction flows assist in the operation of a fishlock.

Fishway: a construction allowing upstream and/or downstream passage of fish past a man made barrier.

Headwater: the depth of water above or upstream of a water barrier.

Potamodromous: Fishes that make true migrations wholly in freshwater.

Prolarvae: Larvae that are still bearing yolk.

Schools: A group of fish of similar size that is congregating together primarily to avoid predators.

Tailwater: the depth of water below or downstream of a water barrier.

Summary

Clare Weir is a seven metre high structure that is located 50.3km upstream from the estuary on the Burdekin River in North Queensland. Clare Weir was retrofitted with a fishlock, replacing the old ineffective fishway, to provide passage for fish moving upstream. Monitoring of new fishways is essential to ensure that they are functioning effectively and efficiently and that a best practice is in place for operation of the fishway. The fishlock was monitored by the Department of Primary Industries and Fisheries to assess its overall effectiveness. Monitoring utilised traps in the entrance chamber and exit channel of the fishway, with a number of experiments conducted to determine the fishway effectiveness, most suitable attraction time, effects of the exit channel configuration, suitable velocities for small fish and velocity profile of the fishway throughout the lock cycle.

A total of 671 sampling hours were conducted resulting in the trapping of 97,900 fish of 24 different species. It was found that the fishlock was effective at passing many species of fish of various sizes through both the entrance chamber and the exit channel. The length of the exit channel was found to have no detrimental effects on fish passage. Size ranges that were passed by the fishlock ranged from 15mm Agassiz Glassfish to 1000+mm barramundi. There were a number of mass migrations recorded during the sampling, the most notable of which passed ~64,000 empire gudgeons in a six day period with the peak of the migration passing ~33,000 fish in four hours. Bony bream were another species recorded undertaking mass migrations during the sampling period.

It was also concluded from the sampling that the sand dams downstream from Clare Weir were also affecting fish migrations during the sampling. The sand dams have restricted estuary access to catadromous species hence restricting their movement up and downstream. During a flow event that occurred in April more than two thirds of the barramundi captured at Clare Weir were recorded in a four day period. These fish were primarily individuals less than 300mm in size, a typical migration size for that species. This capture indicated that connectivity between Clare Weir and the estuary occurred during the flood event, allowing fish passage from the estuarine nursery areas.

One of the major problems concerning the fishlock is its breakdown record. The fishlock is presently breaking down for unknown reasons. If the problem is not located and fixed then the fishlock will not provide passage during these times greatly reducing its capacity to pass fish effectively.

The results of this monitoring project indicates that the Clare Weir fishlock is capable of providing passage for small fish down to 15mm in size, as well as large fish greater than 1000mm and is also capable of accommodating mass migrations upstream. The Clare Weir fishlock can be expected to provide effective passage past the weir for the majority of fish species of the Burdekin River if the operational recommendations made by DPI&F are implemented.

Introduction

In May 2001 a preconstruction report was prepared by DPI&F for Sunwater regarding the impact of Clare Weir on the fish communities of the Burdekin River (Marsden, 2001). It was concluded in this report that Clare Weir was having a negative impact on the fish communities, specifically migratory fish species, in the Burdekin River. The old fishway, a submerged orifice pool type fishway, could never be effective at passing fish due to the high velocities that occur within the fishway, fully enclosed roof and siltation that occurs after high flows (Marsden, 2001). Construction of a new fishway to provide fish passage was recommended. It was also recommended that the fishway be assessed to determine its effectiveness at passing fish species within the Burdekin River system (Marsden, 2001). Sunwater subsequently constructed a fishlock that was officially opened in 2005.

As part of the post-construction monitoring of the Clare Weir fishlock, Sunwater contracted the Department of Primary Industries & Fisheries, Northern Fish Community and Fishway Monitoring Team, to provide a post-construction monitoring program of the fishlock in order to assess its effectiveness. There are many different factors that influence the effectiveness of a fishlock, these are generally focused around fish behaviour and the way the structure affects that behaviour. Such factors include the entrance configuration (correct placement of fishlock entrance to maximise upstream migration), attraction time (the length of time that an individual fish has to enter the lock chamber) and exit channel configuration (fish effectively navigating their way out of the fishway exit channel).

Monitoring of the new fishway took place in two periods, the first during February to May 2006 and the second during October 2006. A total of 58 sampling days were conducted over this period. Throughout the sampling period a number of experiments were conducted which targeted different aspects of the fishway design and its influences on fish behaviour. These experiments include:

- Attraction time
- Fishlock effectiveness
- Exit channel configuration
- Small fish velocity
- Velocity profiles

Burdekin River

The Burdekin River catchment is the second largest coastal catchment in Queensland, covering an area of 129,860km2. The basin stretches from Alpha in the south, 600km northwards to the Valley of Lagoons, inland from Ingham.

The Burdekin River catchment consists of seven interconnecting rivers (Figure 1). The main channel of the Burdekin River originates in the Great Dividing Range north of the Valley of Lagoons, from where it meanders southwards to Charters Towers, east through Burdekin Falls Dam and then north to Ayr where it enters the Coral Sea in Upstart Bay. A major sub-system of the Burdekin River, the Belyando/Suttor River System, brings water from the south and west into the Burdekin River upstream from Burdekin Falls Dam. The Bowen River brings water from the south-east and enters the Burdekin downstream of the Burdekin Falls Dam. The Cape River and the Campespe River flow from the west and join the Burdekin River above the Burdekin Falls Dam.

The Basalt River and the Clark River flow from the North-west and join with the Burdekin high in the catchment.

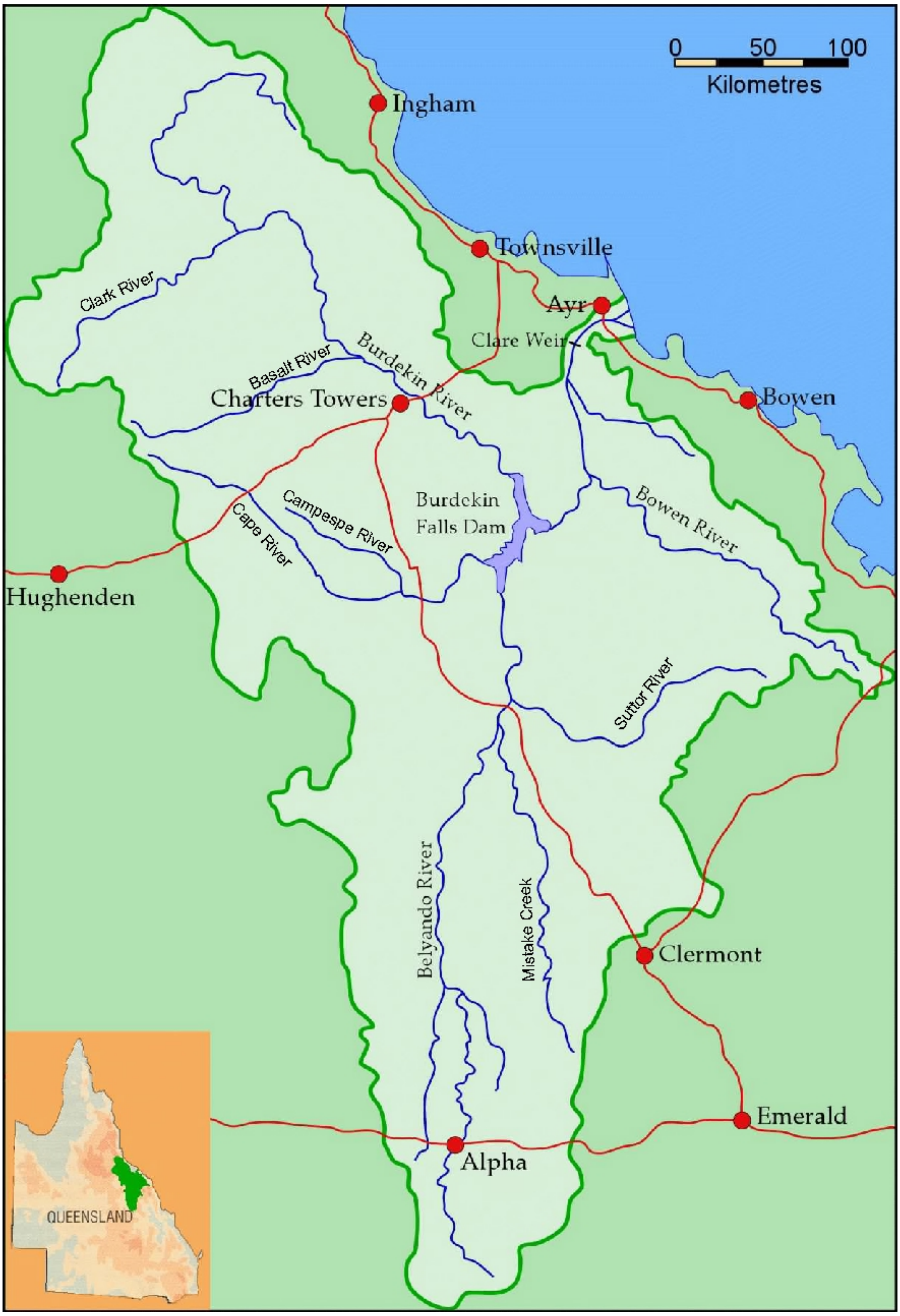


Figure 1. Location of the Burdekin River System in North Central Queensland. The location of Clare Weir can be seen near the mouth of the river system.

The basin is located inland from the coastal escarpment, with the majority of the catchment situated in the Central Highlands. Only a relatively small portion of the catchment is located on the coastal plain, where an extensive flood plain and delta system has formed (Figure 2). The delta of the Burdekin River is the largest on the

Australian east coast and this influences the peak discharge of the Burdekin River, which is the largest in Australia (Tait and Perna, 2001).

The Burdekin River basin generally has a sub-humid tropical savannah climate, with some of the driest conditions in tropical North Queensland (Fleming, 1981). Normally, the coastal areas have between 800 and 1000mm of rain per year, mostly concentrated within the period of the wet season. The upper reaches of the system have greatly reduced rainfall from the coastal areas with less than 700mm received throughout the year (Fleming, 1981).

Throughout the catchment, evaporation rates far exceed annual rainfall and consequently, streams of the Burdekin system have highly variable flows (Fleming, 1981). As an example, in April 1958, the Burdekin River had a peak discharge of 3,096,000Ml/day at Clare Weir; this is the highest recorded flow within this system. Contrasting to this, just seven months later the river ceased to flow. The lower Burdekin River ceases to flow on average once every 2 years, usually in the period from October to November. Other streams in the system have been known to run dry for a number of years.

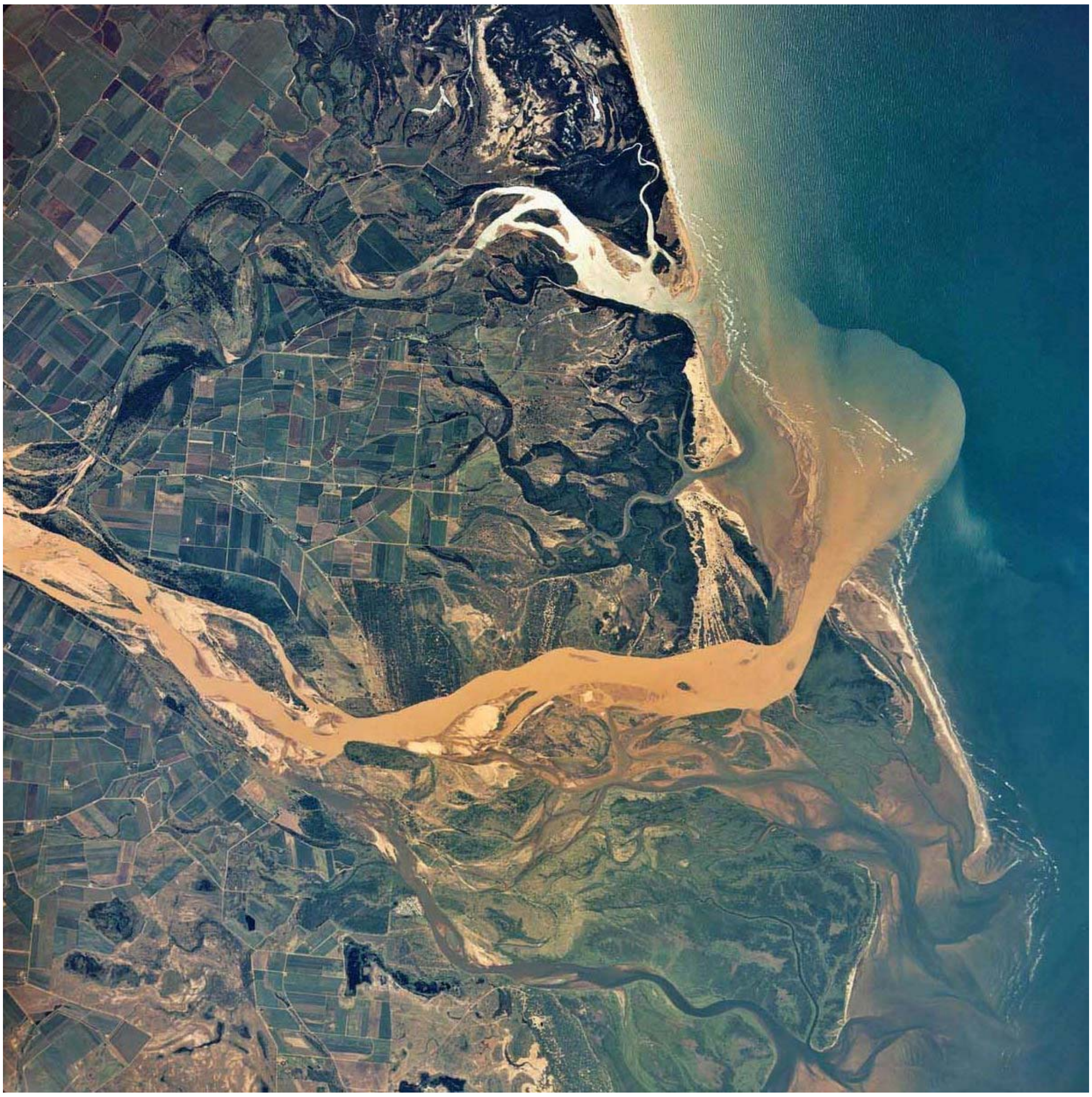


Figure 2: The lower Burdekin River forms an extensive floodplain and delta system.
Source: Geoscape, Department of Natural Resources and Mines, 2005.

Along the main channel of the Burdekin River there are a number of barriers to fish migration. These include weirs, dams and temporary sand dams, all of which form pumping pools for distribution of irrigation water. In the lower Burdekin River sand dams are pushed into place across the riverbed each dry season to impound water for irrigation purposes. With enough flow these structures are washed away by floods during the wet season. However, during periods of low rainfall these sand dams sometime do not experience enough flow to be washed away and hence remain as a barrier. In 2006 these sand dams did not get washed away until the end of the wet season. During the start and middle of the wet season fish species would have been unable to migrate upstream past these sand dams. A number of permanent weirs and dams are also found on the main channel of the Burdekin River, these include:

- The Rocks Weir – a small weir (1.0m) at 40km AMTD, impounding water for irrigation during the dry season (bypassed during the wet season).

- Clare Weir – 7.0m high at 50.3km AMTD, used for irrigation supply.

- Blue Valley Weir – 2-3m high at 118km AMTD, largely redundant to current operations.

- Gorge Weir – 6.0m high at 130km AMTD, impounding water for Burdekin to Moranbah pipeline

- Burdekin Falls Dam – 32m high at 160km AMTD, water supply for downstream irrigation.

- Charters Towers Weir 6.0m high at 470km AMTD, water supply weir for Charters Towers.

The Bowen and Broken Rivers also have a permanent weir and large dam these are

- Bowen River Weir – 5.0m high at 210km AMTD, water supply for Collinsville.

- Eungella Dam – 40m high at 350km AMTD, water supply for downstream irrigation, industrial supply and town water supply

It should be noted that river regulation has also altered flow conditions within the Burdekin River to the probable detriment of migratory fishes. The Burdekin system has become an increasingly regulated system with the installation of numerous barriers between its upper tributary streams and its confluence with the sea to aid the off take of irrigation water, industrial supply and town water. It is regulated to the point where flow is controlled year round apart from large flow events; even during these large flow events water is released to best suit the needs of Sunwater. This regulation causes interruption to fish migration and migration cues. The impact of altering these flows on the diversity and abundance of migratory fishes may be substantial. As noted by Welcomme (1985), reductions in faunal diversity have often been associated with the regulation of floodplain rivers.

Clare Weir

Clare Weir (Figure 3), completed in 1980, is located on the main channel of the Burdekin River approximately 50.3km from the estuary and is the second (but most significant) permanent weir upstream from the estuary. The weir is a mass concrete structure 5.2m high and 350m wide, which supports 1.8m high hydraulic operated steel gates giving at total height of 7m. The upper deck of the weir also supports a rail system used by the gantry crane that is used to maintain the hydraulic gates. The rail system runs across the weir from the crane storage area at the top of the right-bank to the middle of the left bank.

The total capacity of the storage created by this weir is 15,500 Megalitres (Barry 1997). The size of the weir limits the frequency of drown-out and the weir requires a flow greater than 500,000Ml/day to provide fish passage past the weir. This flow level occurs less than 1.5 percent of the time. On only 100 days in the past 21 years since construction has drown-out allowed for fish passage past the weir.

Figure 3: Clare Weir, focus of the current study. The fishlock is present in the foreground.

Clare Weir Fishlock

Fishlocks are generally used to transport fish over high barriers (8-10m) where other fishways are ineffective, physically too large or prohibitively expensive. A vertical slot fishway was considered for the site, but would have been too long for fish to ascend and difficult to clean. This meant that a vertical slot fishway would be ineffective and that a fishlock was the best suited for the site. An automated fishlock operates by firstly attracting fish into a chamber at tailwater level (lock chamber). The lock chamber is then sealed and flooded to a level corresponding or sufficiently close to the storage level of the dam or weir-pool. Fish are then permitted to exit the chamber via an upstream gate and enter the storage upstream of the barrier to continue their migration. Fish movement during the various phases of the lock cycle are induced by a combination of attraction and release flows which are maintained by hydraulically controlled valves and gates.

The Clare Weir fishlock consists of three distinct sections; the entrance chamber, the lock chamber and the exit channel. The lock is controlled automatically and relies on a Programme Logic Controller (PLC) to control the valve and gate positions as well as the entrance and exit time. Fish are attracted to the flow of water (Attraction Flow) leaving the entrance chamber (approximately 0.6m/s). Once inside the 4.7m high x 2m wide x 4m long entrance chamber the fish must move past the open entrance gate (only open during this phase) into the lock chamber. The lock chamber is 8.5m high x 2m wide x 3m long. After a predetermined time limit (Attraction Time) the entrance gate closes and seals off the fish inside the lock chamber from the entrance chamber. The lock is then filled using the fill valve located next to the fishlock in the valve pit. When filling the lock chamber the water is dispersed using diffusers, which are located at the bottom of the lock chamber on the upstream side. At this time both gates are closed.

Once the water level inside the lock chamber reaches the same level as the water in the exit channel the exit gate is lowered. The fish must then move through the open exit gate and into the exit channel. While the exit gate is open the entrance gate is closed. Once in the exit channel the fish must swim the length of the exit channel in order to reach the main channel upstream. The flow through the exit channel and lock chamber is regulated by the drain valve so that fish are attracted upstream through the exit channel. The exit gate is open for a predetermined amount of time set in the PLC. After the exit time has elapsed the exit gate closes and the lock chamber starts to drain. Draining occurs via the drain valve which is located next to the fishlock in the valve pit. The water enters the drain valve via the pipe bell mouth that is located at the bottom of the lock chamber on the downstream side. At this time both gates are closed. Once the water level in the lock chamber has reached that of the entrance chamber the entrance gate will open allowing fish to move into the lock chamber. The flow through the entire fishlock is regulated by the opening and closing of the three different valves. Table 1 indicates which gates/valves are open at which stage through a complete cycle of the fishlock.

Table 1: Automated operational phases of Clare Weir fishlock

		Phase			
		Attraction	Filling	Exit	Draining
Gate/Valve	Entrance gate	Open	Closed	Closed	Closed
	Attraction valve	Closed	Open (30%)	Closed	Closed
	Drain valve	Open (50%)	Closed	Open (50%)	Open (50%)
	Fill valve	Open (50%)	Open (100%)	Closed	Closed
	Exit gate	Closed	Closed	Open	Closed
	Cycle Time (mins)	Changeable	~ 6 min	~ 4½ min	Changeable

Fishes of the Burdekin River system

There have been a number of comprehensive studies completed on the fish communities of the Burdekin River which have identified forty-two species of fish (Table 2) (Macleay 1883, Midgley 1977, Hogan et al. 1997, Pusey et al. 1998, Marsden 2001). The number of species present is low by world standards (Bishop and Forbes 1991, Pusey et. al. 1998), but is consistent with species richness in other eastern Australian sub-tropical rivers (Pusey et al. 1998). Species found in the Burdekin River include two endemic species: one species of neosilurid catfish (Neosilurus mollespiculum) (Allen and Feinberg 1998) and the small-headed grunter (Scortum parviceps) (Merrick and

Schmida 1984). Barramundi populations in the Burdekin Basin are from one of seven genetically distinct stocks throughout Queensland (Shaklee et al. 1993).

At least 24 known migratory fish species require passage past Clare Weir (Table 2). The size range of these fish varies greatly. Adults of a number of larger fish species found in this system, including bull shark, barramundi, sleepy cod, fork-tailed catfish, striped mullet, oxeye herring, freshwater longtom and long-finned eels, have been recorded migrating in other river systems (Stuart and Berghuis 1997). These species range in size from 35 cm to 200 cm. Small fish in the Burdekin that are known to migrate include olive perchlet, bony bream, rainbowfish and empire gudgeons which can be as small as 10mm when they are migrating, but mostly range from 20-150mm long (Stuart 1999). Juveniles of many species also migrate, with juvenile phases of species such as mullet, barramundi, mangrove jack, sooty grunter, olive perchlets and eels migrating varying distance upstream to access freshwater habitats. These juvenile fish are particularly vulnerable as they have a greatly reduced swimming ability and are unable to negotiate even small barriers.

Table 2 Migration patterns of the freshwater fish of the Burdekin River, Queensland, adapted from Allen 1989, Merrick and Schmida 1984, McDowall 1996, ASFB 1999 and Stuart 1999.

SPECIES	**Seasonal Movements**				**Flows**		
DIADROMOUS	Sum.	Aut.	Win.	Spr.	Low	Mod.	High
long-finned eel *Anguilla reinhardtii* [Anguillidae] ©	✔	✔	✓	✔	✓	✓	✔
South-Pacific eel *Anguilla obscura* [Anguillidae] ©	✔	?	?	✔	✓	✓	✔
bullrout *Notesthes robusta* [Scorpaenidae]	✓		✔	✔	✔	✓	
barramundi *Lates calcarifer* [Centropomidae] ©®	✔	✓	✓	✔	✔	✓	
bull shark *Carcharhinus leucas* [Carcharhinidae] ®	?	?	?	?	?	?	?
mangrove jack *Lutjanus argentimaculatus* [lutjanidae] ®	✓	✓	?	?	✓	?	?
fork-tailed catfish *Arius graeffei* [Ariidae] ®	✔	✔	✔	✔	✔	✔	✔
salmon catfish *Arius leptaspis* [Ariidae] ®	✔	✔	✔	✔	✔	✔	✔
striped mullet *Mugil cephalus* [Mugilidae] ©®	✔	✓	✔	✔	✔	✔	✓
oxeye herring *Megalops cyprinoids* [Megalopidae] ®	✓	✔	✓	✓	✔	✓	?
freshwater longtom *Strongylura kreftii* [Belonidae]	✓	✓		?	✓	✓	?
striped butterfish *Selenotoca multifasciata* [Scatophagidae]	?	?	?	?	?	?	?
dusky flathead *Platycephalus fuscus* [Platycephalidae]	?	?	?	?	?	?	?
threadfin silverbiddy *Gerres filamentosus* [Gerreidae]	?	?	?	?	?	?	?
silverbiddy *Gerres subfasciatus* [Gerreidae]	?	?	?	?	?	?	?
giant herring *Elops hawaiiensis* [Elopidae]	?	?	?	?	?	?	?
snub-nosed garfish *Arrhamphus sclerolepis* [Hemirhamphidae] ®	?	?	?	?	?	?	?
POTAMODROMOUS							
spangled perch *Leiopotherapon unicolour* [Teraponidae]	✔	✓	✓	✔	✔	✔	✔

SPECIES	Seasonal Movements				Flows		
POTAMODROMOUS Cont.	Sum.	Aut.	Win.	Spr.	Low	Mod.	High
sooty grunter *Hephaestus fuliginosus* [Teraponidae] ®	✓	✓	✓	✓	✓	✓	✓
banded grunter *Amniataba percoids* [Teraponidae]	✓		✓	✓	✓	✓	?
small-headed grunter *Scortum parviceps* [Teraponidae]	✓	✓	✓	✓	?	?	✔
golden perch *Macquaria ambigua* [Percichthyidae] ®✈	✔	✓	✓	✔	✔	✔	✓
olive perchlet *Ambassis agassizi* [Chandidae]	✓	✔	✔	✔	✔	✔	
bony herring *Nematalosa erebi* [Clupiedae]	✔	✔	✔	✔	✓	✔	✓
fly-specked hardyhead *Craterocephalus stercusmuscarum Stercusmuscarum* [Atheridae]	✓		✓	✔	✓	✓	
Rendahl's catfish *Porochilus rendahli* [Plotosidae] ®	✔	?	?	✔	?	?	✔
Hyrtl's tandan *Neosilurus hyrtlii* [Plotosidae] ®	✔	?	?	✔	?	?	✔
black catfish *Neosilurus ater* [Plotosidae] ®	✔	?	?	✔	?	?	✔
soft-spined catfish *Neosilurus mollespiculum* [Plotosidae] ®	✔	?	?	✔	?	?	✔
mouth almighty *Glossamia aprion* [Apogonidae]	✓	✓	✓	✓	✓	✓	
Eastern rainbowfish *Melanotaenia splendida splendida* [Melanotaeniidae]	✓	✓	✓	✔	✓	✔	✓
firetail gudgeon *Hypseleotris gallii* [Eleotridae]	✔	?	?	✔	?	?	✔
sleepy cod *Oxyeleotris lineolatus* [Eleotridae] ®	✔	?	?	?	?	✓	?
snakehead gudgeon *Ophieleotris aporos* [Eleotridae]	?	?	?	?	?	?	?
empire gudgeon *Hypseleotris compressa* [Eleotridae]	✔	✔	✔	✔	✔	✔	✔
purple-spotted gudgeon *Mogurnda adspersa* [Eleotridae]	?	?	?	?	?	?	?
Pacific blue-eye *Pseudomugil signifer* [Pseudomugilidae]	?	?	?	?	?	?	?
eel-tail catfish *Tandanus tandanus* [Plotosidae] ®	?	?	?	?	?	?	?
archerfish *Toxotes chatareus* [Toxotidae] ®	✓	?	?	✓	?	✓	?
mosquito fish *Gambusia Holbrooki* [Poeciliidae] ✈	?	?	?	?	?	?	?

© - Commercial Species, ® - Recreational Species, ✈ - Translocated Species

✔ - Large numbers of fish, ✓ - Small numbers of fish, ?- Limited Information

General Sampling Methods

Three locations were sampled in the fishlock using traps. The first was the entrance to the fishlock; the second was the entrance to the exit channel of the fishlock (Exit-Entrance); and the third was the exit of the exit channel (Exit-Exit) (Figure 4 and 5). Two traps were constructed; one for sampling in the entrance chamber (Figure 5) and the second for sampling both the exit-exit and the entrance-exit of the fishlock (Figure

6). All traps were constructed out of aluminium to reduce its overall weight. Both traps incorporated a cone entrance to reduce the level of escapement once the fish had entered the trap (Figure 6). The exit trap was stored up away from flood level when not in use.

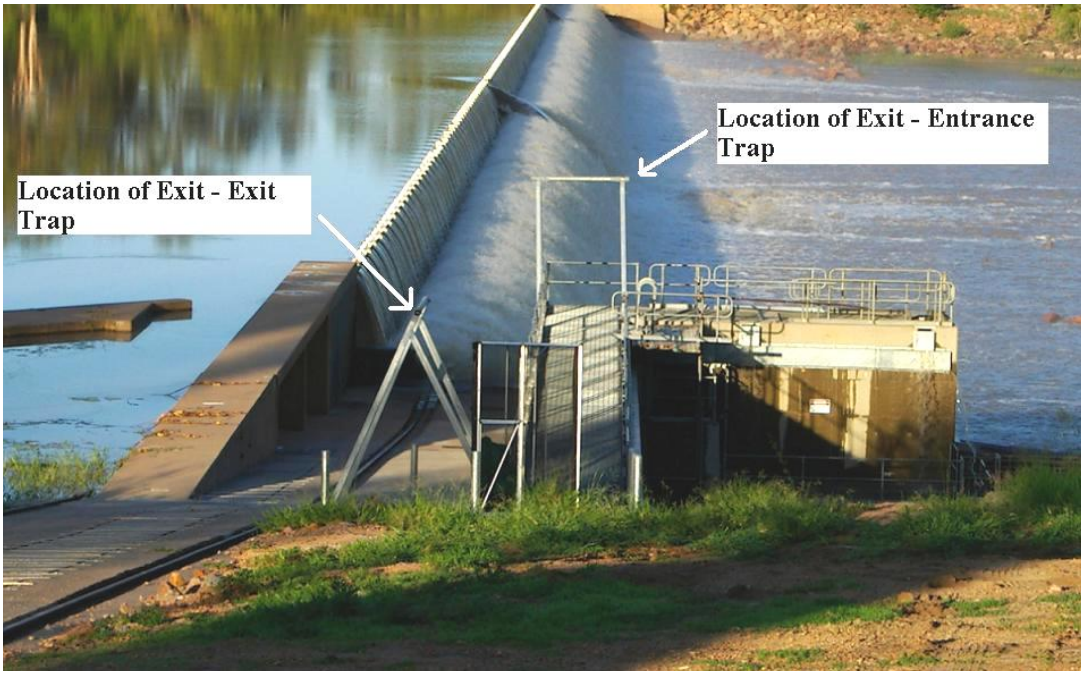


Figure 4: Location of the Exit-Exit and Exit-Entrance traps during sampling.

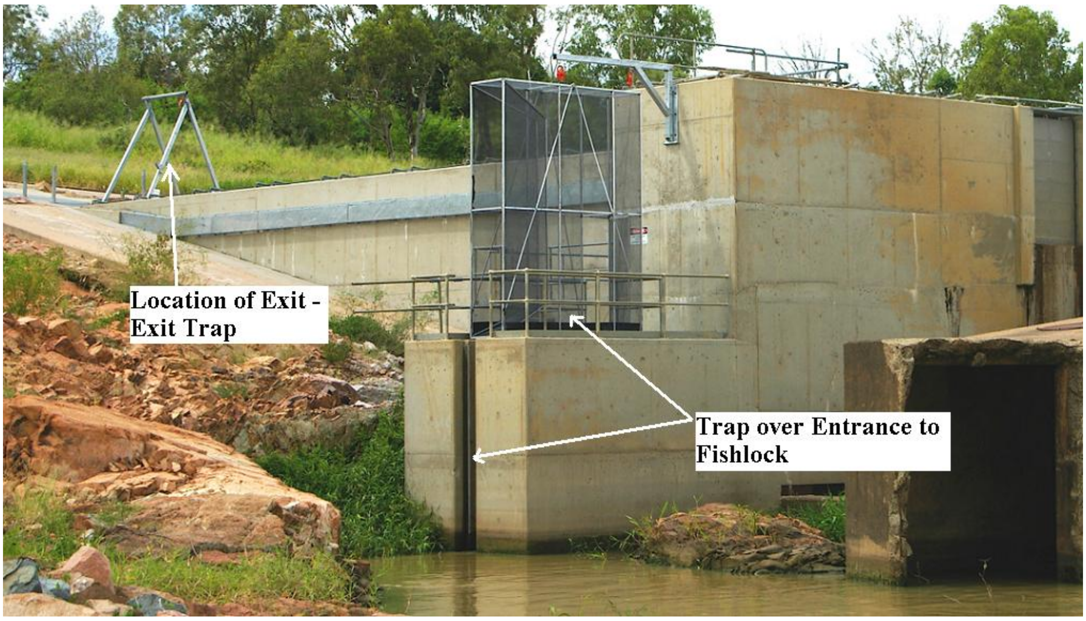


Figure 5: Location of the Exit-Exit trap and the entrance trap.

The exit trap was divided into two sections; with one section allowing for small sized fish (~100mm) to escape predation from large individuals. The two sections were divided by 13mm galvanised chicken mesh. All traps were covered in black aluminium screen (2mm mesh size) in order to capture all sizes of fish. The dimensions for the exit trap were 2.5m high × 2.3m long × 1.48m wide (Diagram 1). The funnel entrance was 0.2m wide. The floor was covered with 2mm HDPE (High Density Poly-Ethlene) to prevent holes forming from fish spines and it also enabled small fish to be collected off the floor with ease.

The entrance trap consisted of only one internal section and was covered with chicken wire and fly screen mesh on every side but the top, which was covered with 4mm steel mesh. The trap was covered with chicken wire to prevent barramundi breaching the side walls of the trap. The dimensions for the entry trap were 4m high × 3m long × 0.80m wide (Diagram 2). The funnel entrance was 0.2m wide. The floor was covered with HDPE to prevent holes forming from fish spines and it also enabled small fish to be collected off the floor with ease. The entrance trap was also reinforced with steel mesh at the base of the funnel and for 1m at the bottom of the back side to prevent large barramundi from breaking through the aluminium fly screen and the chicken mesh. The entrance trap required guides (Diagram 2) to be placed on the downstream end, at the top and the bottom so that it could not rotate freely in the entrance chamber. The guides fitted down the slots that are in place for the bulkhead and helped stabilise the trap while lowering and raising it.

Figure 6: The trap used to sample both locations in the exit channel (left). The exit trap in place over the exit-exit sampling position.

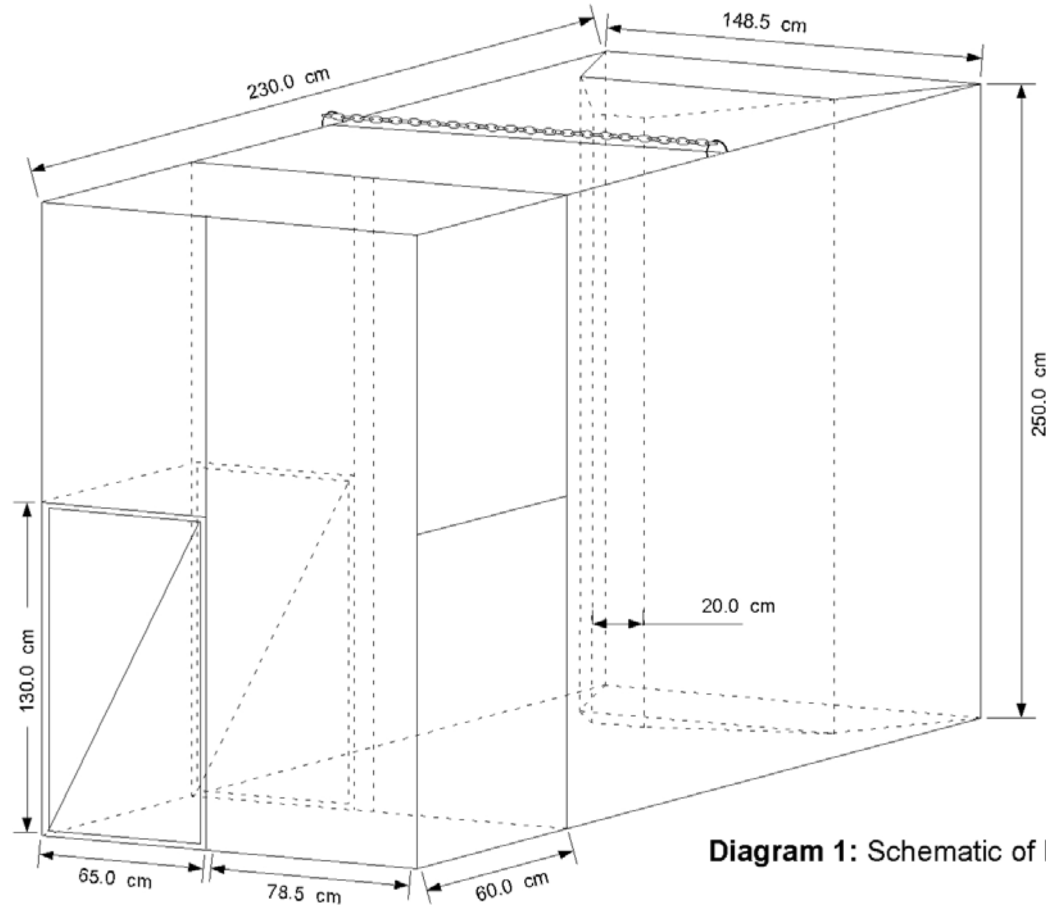


Diagram 1: Schematic of Exit Trap

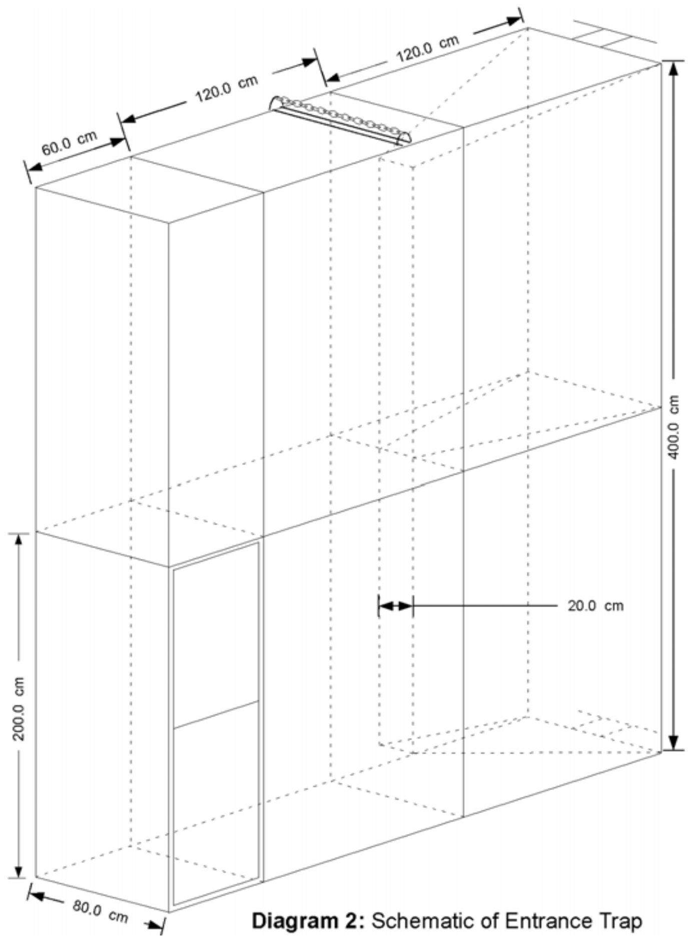


Diagram 2: Schematic of Entrance Trap

Fishlock Effectiveness Sampling

The effectiveness of a fishway can be determined by comparing the species, size distribution and number of individuals that are potentially migrating (fish trapped in the entrance chamber) with the fish that successfully negotiated the fishlock (fish trapped in the fishway exit channel). The purpose of this experiment is to establish if there is a difference between the number of fish sampled in the entrance and the exit of the fishway and therefore gain a measure of the fishlock's effectiveness. There are certain factors that may contribute to individuals not moving through from the entrance chamber to the exit of the exit channel. These factors can include: lack of natural lighting, confined space, noise from the opening and closing of gates and varying levels of vigilance between species. By sampling in the entrance chamber and the exit channel it will be ascertained whether or not some species are having difficulty ascending through the fishlock.

Methods

The fishlock effectiveness experiment was conducted over April, the start of May and a week in October. Each sample consisted of two consecutive 24 hour periods; 24 hours of trapping in the entrance chamber and 24 hours of trapping in the exit channel. After randomly selecting either the entrance or exit of the fishlock, the trap was lowered in the selected position for 24hrs. The trap was raised twice during the 24 hour period. The opposite trap was lowered as soon as possible after raising the first trap. All fish were identified to a species level, counted, measured to the nearest millimetre and released upstream of the fishlock. Fork length was recorded for forked tail species and total length for all other species. When large numbers of any singular species occurred, random sub-samples of 50 fish were measured and the remainder counted. Water quality (including temperature, dissolved oxygen, conductively and pH) was taken everyday while sampling was in progress.

Results

During the fishlock effectiveness experiments 6,729 individuals of 18 species were collected. A mass upstream migration of bony bream and empire gudgeons was witnessed during a two day period (4/4/2006 – 5/4/2006). In this period 4,963 bony bream and 789 empire gudgeons were trapped in either the entrance chamber or the exit channel. This was the largest mass migration of bony bream recorded during Autumn. Compared to the recorded mass migration of empire gudgeons during the 6/2/2006 to the 7/2/2006 and the 2/10/2006 to the 7/10/2006 this movement is relatively small. However, compared to the typical recorded daily movement of this species through the fishlock 789 individuals is relatively large and still regarded as a mass movement of this species.

During the period 9/5/2006 – 12/5/2006 a large number of barramundi attempted to pass through the fishlock. The size classes of the barramundi which passed through the fishlock from the 9th to the 12th of May are represented in Figure 9. As detailed on Figure 9 a majority of the barramundi that where trapped were in the 1+ year size class (86%). This upstream migration of 100 barramundi was sampled approximately 22 days after the onset of a large flow event in the Burdekin River. The time of onset for this migration is not known as sampling did not occur between the 29/4/2006 and the 8/5/2006, a ten day period as the flows were too high for lock operation.

Table 3 shows the total numbers and total sampling time for each the entrance chamber and exit channel. More fish were actually trapped in the exit channel than the entrance chamber. The exit channel also had a higher fish/hour rate than the entrance chamber, indicating that the fishlock is performing effectively and efficiently at passing fish from the entrance of the fishlock to the exit of the exit channel.

Table 3: The number of fish passed during the fishlock effectiveness experiments.

	Total Fish	Total Time	Fish/hour
Entrance	3458	10,300 (min)	20.1436
Exit	4088	9815 (min)	24.99

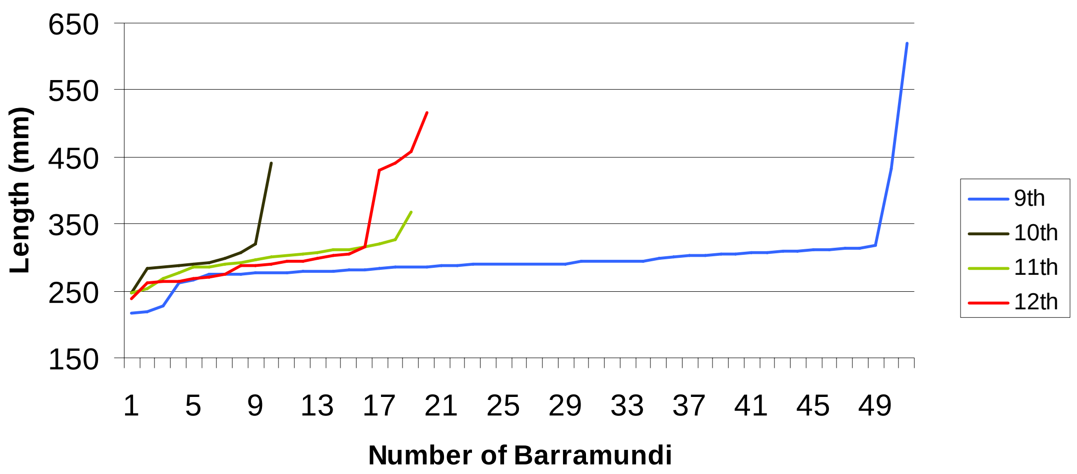
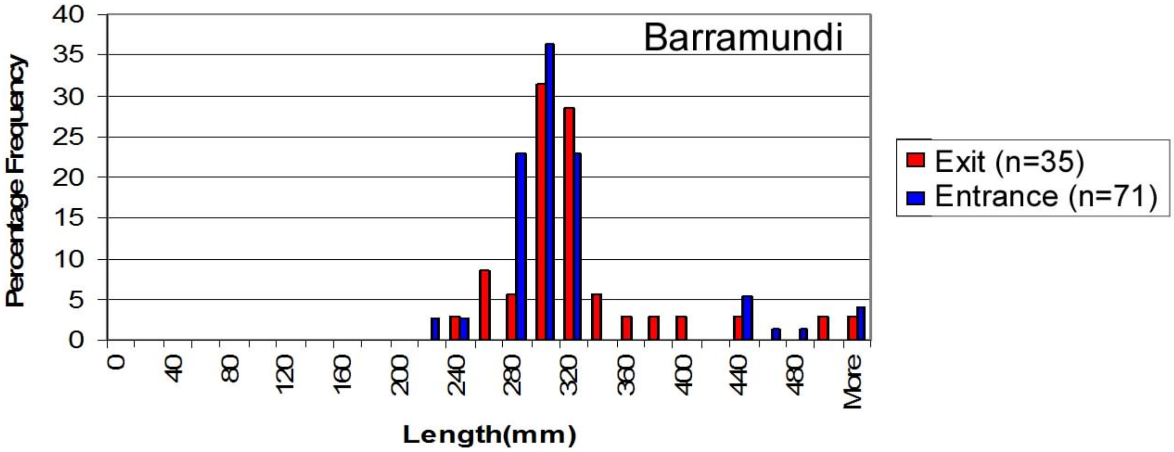
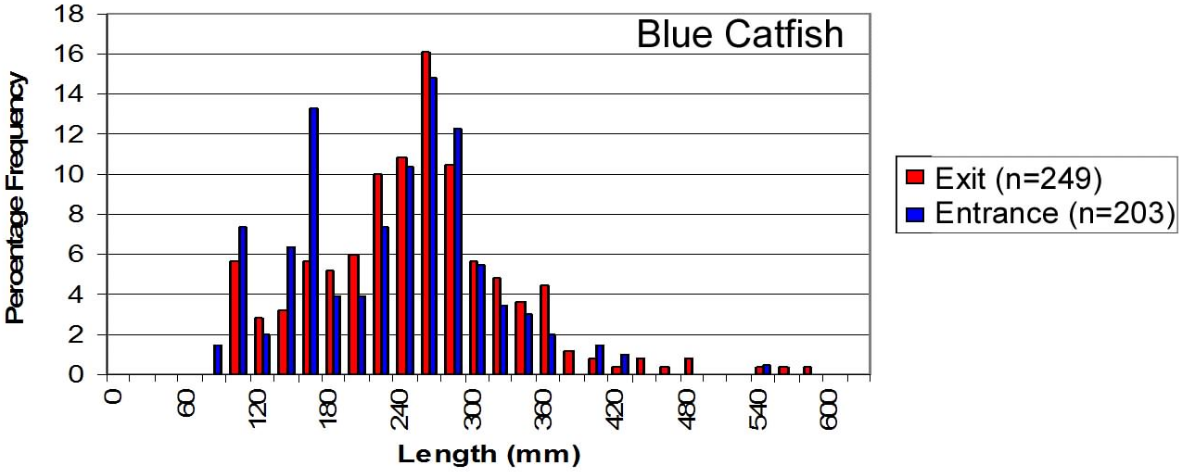


Figure 9: The length and number of barramundi caught from the 9th to the 12th of May

Figure 10 shows the comparative length-frequency histograms for fish sampled in the entrance chamber and the exit channel. These figures present comparative results between fish trapped at in the entrance chamber and fish trapped in the exit channel during the fishlock effectiveness experiments.





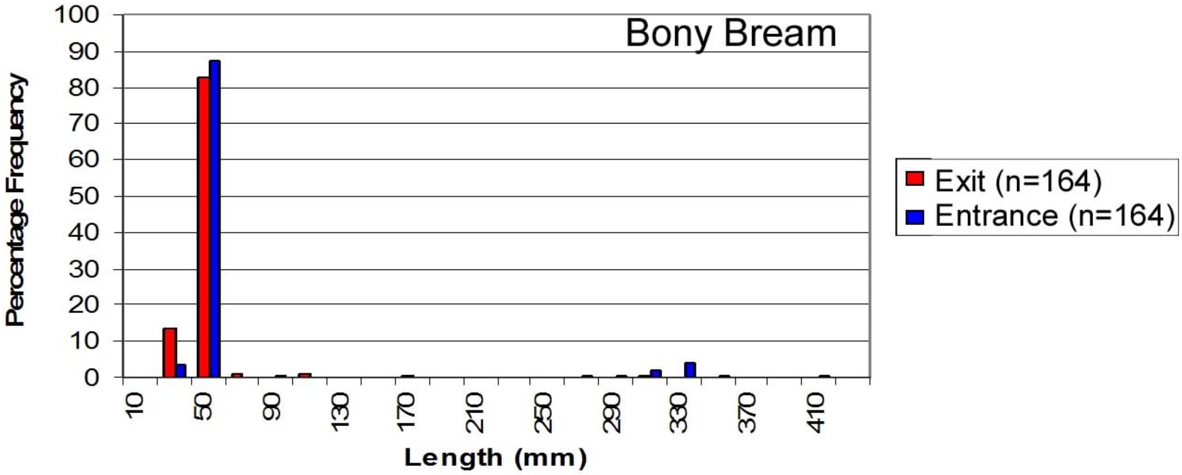


Figure 10a: Comparative length-frequency histograms for fish sampled in the entrance chamber and exit channel of the fishlock at Clare Weir, 2006

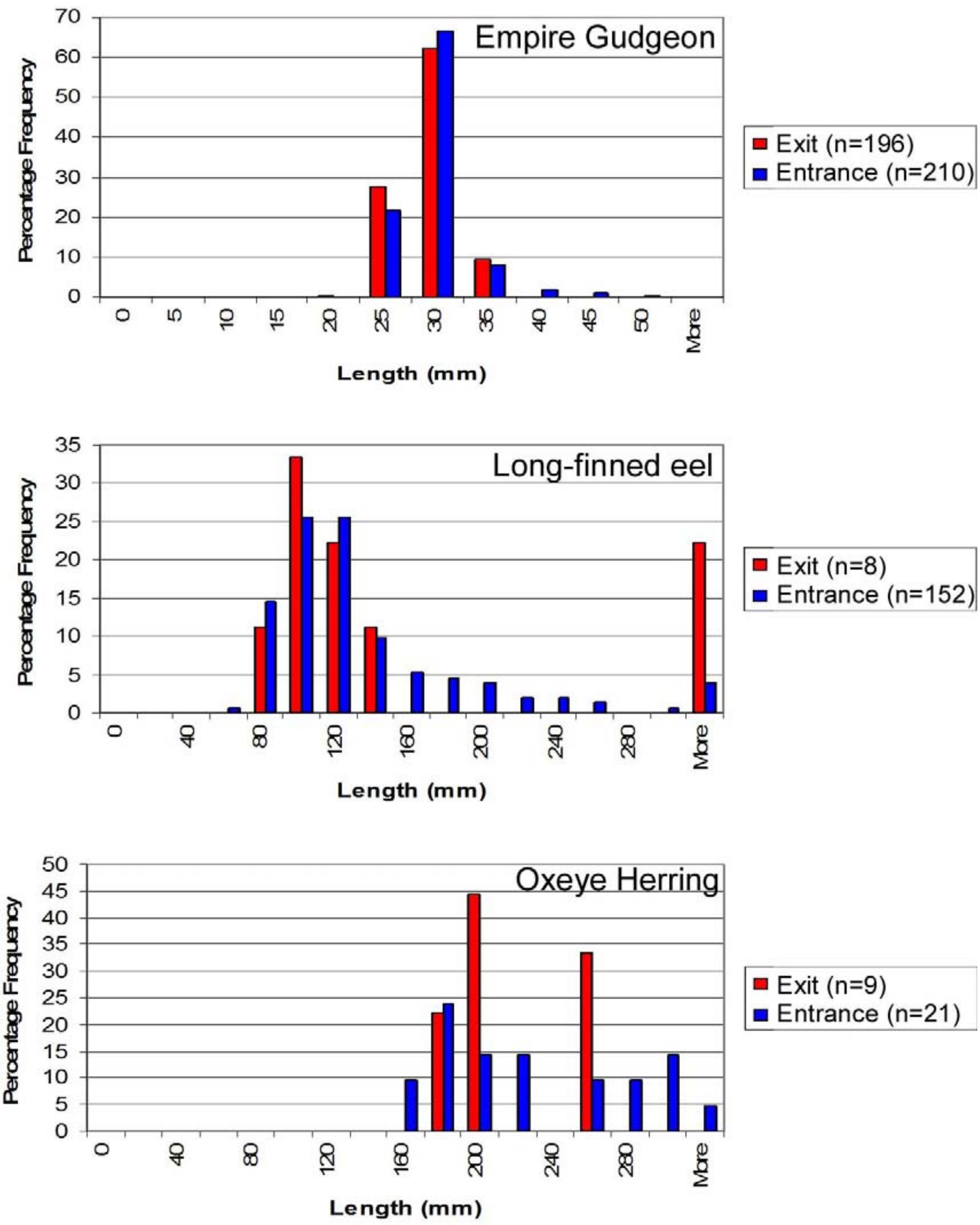


Figure 10b: Comparative length-frequency histograms for fish sampled in the entrance chamber and exit channel of the fishlock at Clare Weir, 2006.

Discussion

Overall performance of the Clare weir fish lock was excellent with few species displaying any detectable issues with ascending through the lock and exiting the fishway. Fish as small as 15mm were detected exiting the fishway, indicating that it is likely that even the smallest species is able to successfully negotiate the lock.

Barramundi

The Burdekin River has numerous sand dams below Clare Weir. During the flow event that occurred over 8/4/2006 – 8/5/2006 (Figure 11) all of these sand dams were inundated with water and enabled fish to move upstream over these barriers. During this time DPI&F witnessed a number of untagged barramundi moving through the fishlock. When the sand dams were inundated with water it would have enabled access for these barramundi to move upstream from the estuary. Most of the sand dams provide some sort of passage either via by-pass channels or only a half blockage of the river. However the sand dam at the freshwater/saltwater interface rarely provides passage as water rarely overflows the dam wall and this sand dam has no by-pass channel. DPI&F, via the ROP (Resource Operations Plan) process, are investigating possibilities of environmental flows past the sand dams in the near future. This flow should provide freshwater to estuarine access for most of year and significantly increase the migratory possibilities for primarily catadromous species.

Figure 11: Clare Weir in flow (approximately 60,000 – 70,000 ML/day). This flow occurred while the fishlock effectiveness experiments were being run.

The more notable feature of Figure 10 is the size ranges of barramundi that were passed. All size ranges successfully passed by both the entrance chamber and the exit channel. There was one 620mm individual captured in the entrance chamber during these experiments however during the exit channel configuration experiments a 1000+mm individual was caught in the exit channel. This signifies that large as well as small individuals can move through the entirety of the fishlock. The one size class that was missing from samples was the juveniles under 200mm in length. Juveniles less than 200mm are not expected to be caught as they prefer to live in/around the estuary and lower floodplain at this stage in their life. More barramundi were caught in the entrance chamber; however a majority of these barramundi were from one movement event that consisted of 51 individuals. More barramundi may have been caught in the entrance trap due to a reluctance to enter the exit-exit trap. After the exit trap was modified with the chicken wire on the outside of the trap DPI&F saw a reduction in the number of barramundi caught in this trap. This being said the entrance trap has chicken wire on the entrance as well and this, to our knowledge, has not stopped barramundi entering this trap.

Blue Catfish

The histogram in Figure 10 shows that similar numbers and lengths were captured in both the exit channel and entrance chamber, indicating that the fishlock is successfully passing all lengths of blue catfish. A few more individuals were captured in the exit channel than the entrance chamber however this is likely to be due to daily variation.

Bony Bream

The histogram indicates that similar lengths and sizes of bony bream were able to effectively pass through the fishlock. Most of the individuals shown came from two samples; there was a mass migration upstream where 4,963 bony bream passed through the entrance chamber (2,190 individuals) and exit channel (2,773 individuals) during a 48 hour period (only 100 individuals per sampling period are shown in Figure 10). A large majority of these 4,963 individuals were of similar length – between 20-50mm. This signifies that the fishlock is not only effective in passing bony bream but also has the capacity to allow mass migrations of bony bream upstream. Nearly 90% of fish passed were between 30 mm and 50 mm in length. However, this is caused by mass migration and reproductive cohorts rather than fishlock ineffectiveness.

In general there were two size classes using the fishlock, the first was the dispersing juveniles, 30-50mm in length, and the second was the large adults, 290-370mm in length. Stuart, 1997, found similar results in the Fitzroy where 95% of individuals that passed through a vertical slot fishway were less than 100mm in length and the remaining 5% were greater than 250mm in length. Juvenile bony bream are moving for dispersal whereas adults are making spawning-associated movement into spawning grounds (Bishop et al, 2001).

Empire Gudgeons

Empire gudgeons passed through the fishlock in similar numbers and size as seen in Figure 10. However, as with the bony bream a large majority of individuals represented in the figure are from a mass movement of empire gudgeons upstream over two different periods. This shows that the fishlock is effective at passing these fish sizes during a mass movement event upstream. There has been no recorded movement of empire gudgeons over 60 mm in length. Empire gudgeons have been suggested to grow to lengths of 140mm however this is in aquaria environments; they are more commonly found to reach an average of ~34mm (Pusey et al, 2004).

Long-finned Eels

It is quite apparent that there were not many individuals caught in the exit channel as the entrance chamber (9 individuals compared to 152 in the entrance chamber). The majority of eels that were captured were caught over the high flow period during the month of April. The long finned eel has a unique ability to find and move through the smallest gap or hole; this may reveal that there may be some escapement from the exit trap. Long finned eels were commonly spotted in the exit trap when it was raised, however by the time they were ready to be collected they had disappeared, they had most likely found a small hole to escape from or escaped out under the door.

This species is considered by many to be catadromous (moving into salt water to breed but lives primarily in freshwater). However, there is an emerging view that this species does not need to move into fresh water to live and that some individuals will spend there entire life in salt water (Pusey, et al 2004). Strontium calcium ratios in otoliths have revealed some individuals are exclusively marine or move between freshwater and saltwater during there life or some enter freshwater as juveniles and return to the sea to breed as adults (Pease et al, 2002). Either way they are accomplished migratory species and have an extraordinary ability to move over a range of barriers in their migrations and would be able to move pass the exit trap if there was a route available. This species was also caught in low numbers during the month of February in the exit channel.

The size of individuals caught in the entrance chamber was generally small (80-150mm) whereas the size recorded in the exit channel was relative large, however many small individuals were seen upon raising the exit trap but were not captured and recorded. The door on the exit trap was located at the upstream side, facing into the flow, whereas the door on the entrance trap was on the side of the flow. The flow around the exit trap door may have provided the elvers with enough flow to locate the small gaps around the door; the flow coming around the entrance trap door would have been greatly reduce due to it position and may have not provided enough flow for the elvers to locate the gaps resulting in their capture.

During the first period of sampling the headwater of the weir and therefore fishlock level was high and as a result this caused leaks out of the hydraulic line coverings (Figure 12) and the access bulkhead of the fishlock. This caused elvers to attempt to migrate, by climbing, up the outside walls of the fishlock; however, they could not get over the top due to inadequate water flow which caused a congregation of elvers in these areas (Figure 13). After reporting the problem to Sunwater the hydraulic line coverings were plugged promptly by Sunwater employees with plywood and this stopped any further flow from attracting elvers into this area. DPI&F recommends that a permanent solution to the problem be found to stop water flowing out of this area when there are high headwater levels. The leakage problem in the access bulkhead was caused by an unsealing bulkhead seal and could not be resolved at the time. DPI&F did not witness the leakage out of the bulkhead as severely again throughout the year so it appears that the bulkhead may have sealed itself in some way hence resolving the problem. However it is possible that it could occur again. DPI&F did not witness leaks from the hydraulic coverings at all after they were fixed. There were several high levels flows that would have caused water to run through these coverings but the work conducted by Sunwater was sufficient to stop the problem from occurring again. This emphasises the need to ensure that any leakages from the fishlock or weir are minimised so that the elvers are not attracted away from the fishlock entrance.

Figure 12: Leakages out the hydraulic line coverings, which caused elvers to climb the ‘wet’ walls to attempt to migrate upstream. The elvers travel was impeded by the coverings sheltering the hydraulics.

Figure 13: Congregation of elvers at the access bulkhead, their process was impeded by dry walls and no flows above this mark.

Some of the elvers that tried to migrate up via the hydraulic coverings ended up being trapped in the pit which holds the fishlock valves. Although there is a one way valve in the bottom of the pit it was not sufficient to allow the elvers to get back to the water. After alerting Sunwater to the problem a slit of concrete was cut to be removed from the pit so that any fish trapped could find access to get back to the river channel. However, at this stage the concrete has only been cut and has not been removed and as such still blocks the passage of fish out of the pit. Water also moves into this area when the tailwater rises which can cause movement problems in relation to trapped fish in this area.

Another problem that DPI&F encountered when sampling during the high headwater was fish entering through the hydraulic coverings in the exit channel, moving through the coverings and falling out onto the top of the entrance chamber. They were then trapped by the kickboards on top of the entrance chamber and could not get to the water, resulting in death. Although fish should not be able to get through the hydraulic coverings anymore the kickboards still pose a threat to fish when the tailwater is high. Larger fish that will not fit through the steel mesh on the floor may get trapped and die. DPI&F recommends that a few gaps of about 200mm to be cut in the kickboards so that any fish that are trapped on top of the entrance chamber have a chance of making it back into the water.

Oxeye Herring (Tarpon)

The oxeye herring that were trapped in both the entrance chamber and exit channel were of similar lengths, however, the number of individuals that passed through differs (this can be seen in figure 10). Berghuis (pers. comm.) suggests that oxeye herring are not likely to 'hang around' the fishlock entrance and may in turn miss the lock cycle. McGill and Marsden, 2000, found a trend that oxeye herring were less likely to move through a fishlock when there was a long cycle time. Individuals that arrive at the lock at the right time would move straight through to the exit whereas if an individual has to wait for long periods it would swim back out of the entrance chamber into the river channel and not move upstream. The influence of tarpon behaviour in relation to its migration is hard to measure via capture methods however new technology has been developed that can help better define behaviour within a fishway. The use of PIT tag and hydro-acoustic techniques (discussed further in section '4.5 Future Sampling in relation to future fishways') would be advantageous in investigating tarpon behavioural patterns more acurately.

Oxeye herring were only witnessed in relatively large numbers after the flow event that started around the 10/4/2006 and once the sand dams had been drowned out (sometime around the 13/4/2006). Pusey et al, 2004, reveals that in other studies where oxeye herring have attempted to ascend fishways they have done so in small numbers. However, in these instances the fish have either been moving through a rock and pool or vertical slot fishway and not a fishlock. In the attraction time experiments (exit channel sampling) only one oxeye herring was trapped and it was trapped on a 30 min attraction length. At this time however, the sand dams were expected to be having a significant detrimental effect on the upstream movement of tarpon. Tarpon would benefit from a faster cycle time as to reduce waiting time in the fishlock entrance and lock chamber and freshwater to estuary access.

Attraction Time Experiments

Attraction time is defined as the period during which the lock chamber entrance gate is open and fish are able to swim from the entrance chamber into the lock chamber. For the duration of the attraction phase the fish are free to swim between the lock chamber and the entrance chamber or return to the river channel. It is not known how long different species will remain inside the lock chamber before retreating back to the river channel or how many fish the lock chamber can accommodate before entry of new arrivals is inhibited. These factors will affect the rate of fish passage. The purpose of this experiment was to determine the most effective attraction time for the fishlock. A fast attraction time (E.g. five minutes) may provide increased fish passage, however, the operational costs associated with such a frequent cycle length would be increased. Operational costs could include maintenance and replacement of hydraulic lines and valves or gate seals. On the other hand a long attraction time (E.g. two hours) would save wear and tear on the hydraulic parts and seals but may provide less effective fish passage. Successful fish passage must be considered with cost effective operation to provide a ‘best compromise’ attraction time.

Methods

The attraction time experiments were conducted in March 2006. An attraction time was randomly selected from 5, 30 or 100 minute time periods and the attraction time was changed on the PLC (Program Logic Controller) to reflect this. The exit trap was placed in the exit-exit channel and left for 24hrs. The trap was raised twice during the 24 hour period and all fish removed from the trap before lowering it back into the water. All fish were identified to a species level, counted, measured to the nearest millimetre and released upstream of the fishlock. Fork length was recorded for forked tail species and total length for all other species. When large numbers of any singular species occurred, random sub-samples of 50 fish per raised trap were measured and the remainder counted. The next attraction time was randomly selected from the remaining two times and the sampling was repeated. The sampling was then repeated for the third and final attraction time. Water quality (including temperature, dissolved oxygen, conductively and pH) was taken everyday while sampling was in progress.

Results

A total of 6165 fish from 19 species were trapped during the attraction time experiments (Table 3) that were run throughout March. Bony Bream accounted for more than 74% of the catch and empire gudgeons accounted for approximately 19% of the catch. The species of fish that were found to be moving upstream in relatively low numbers (i.e. five or less fish) were the sleepy cod, the freshwater longtom, barramundi, black catfish, spotted scat, sooty grunter, spangled perch, mouth almighty, Hyrtl’s tandan and oxeye herring.

Figure 7 shows the average number of fish trapped in the exit channel per hour for each tested attraction flow. Figure 7 also shows the standard error associated with each average. The 5 minute attraction time, although having a higher average has a large standard error. Mass migrations of bony bream and empire gudgeons were occurring at this time. Figure 8 shows the average number of fish trapped in the exit channel per hour for each tested attraction flow with the empire gudgeons and bony bream data omitted. Although the 5 minute attraction flow still is higher, on average it only passes 0.55 fish per hour more that the 30 minute attraction flow.

Table 3: Total numbers of fish that successfully negotiated the fishlock and were trapped in the exit channel during three replicates of the attraction time experiments during March 2006.

Species	5 min	30 min	100 min
Empire Gudgeon (Hypseleotris compressa)	93	666	458
Sleepy Cod (Oxyeleotris lineolata)	0	3	2
Blue Catfish (Arius graeffei)	109	33	48
Bony Bream (Nematalosa erebi)	3861	670	92
Roman Nosed Goby (Awaous acritosus)	7	10	4
Eastern Rainbowfish (Melanotaenia splendida splendida)	4	11	1
Freshwater Longtom (Strongylura krefftii)	0	2	2
Small-headed Grunter (Scortum parviceps)	5	9	8
Agassiz's Glassfish (Ambassis agassizii)	0	1	20
Barramundi (Lates Calcarifer)	1	1	3
Seven-spot Archerfish (Toxotes chatareus)	1	3	2
Black Catfish (Neosilurus ater)	3	0	0
Banded Grunter (Amniataba percoides)	2	11	1
Spotted Scat (Scatophagus argus)	0	1	0
Sooty Grunter (Hephaestus fuliginosus)	1	3	1
Spangled Perch (Leiopotherapon unicolor)	0	3	0
Mouth Almighty (Glossamia aprion)	1	0	2
Hyrtl's Tandan (Neosilurus hyrtlii)	0	2	3
Oxeye Herring (Megalops cyprinoides)	0	1	0
Totals	4088	1430	647

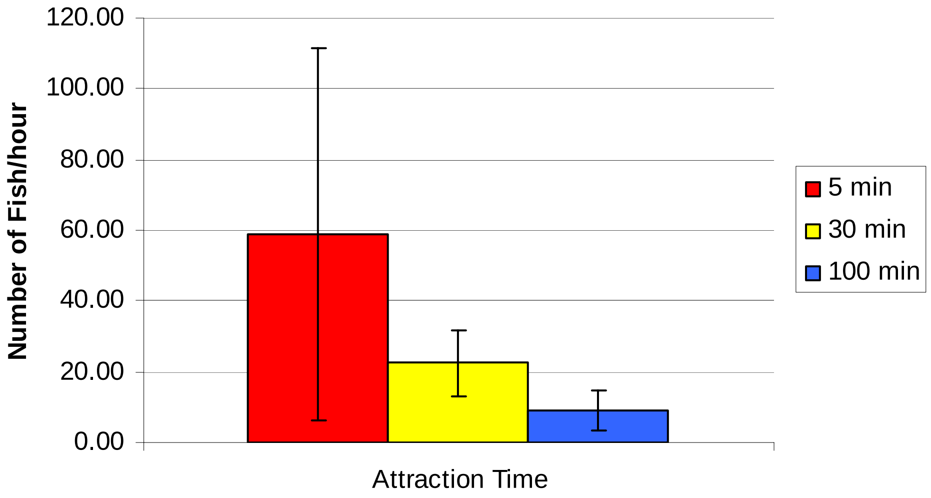


Figure 7: The number of fish/hour for each attraction time

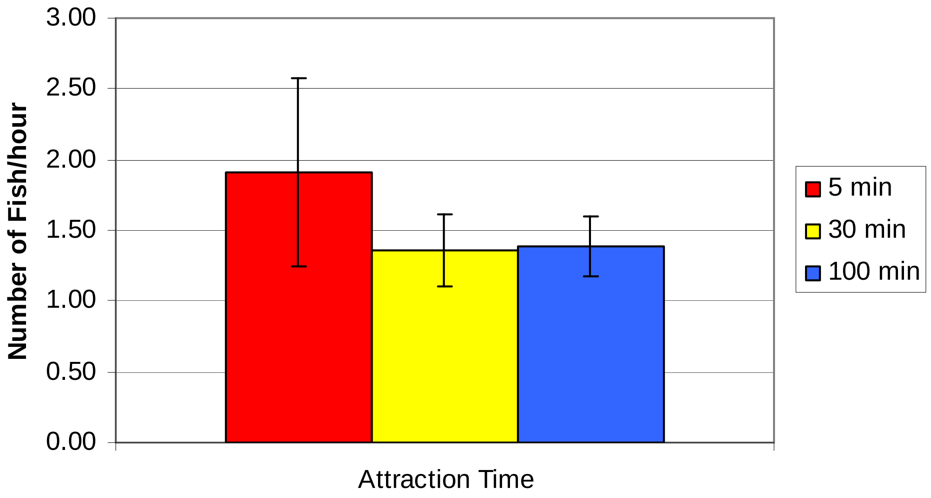


Figure 8: The number of fish/hour for each attraction time (NOTE: empire gudgeons and bony bream have been removed from the data)

Discussion

A notable distinction that occurred during the attraction time experiments is the number of bony bream that were attracted and trapped in the fishlock exit channel. A similar event occurred in the exit configuration experiments (see exit configuration experiment) and is an example of mass migration. Dispersal migration, although not necessarily induced by flooding, would benefit the species as a whole as it allows individuals to access most, if not all, of the available habitat. Bony bream schooling in their juvenile stage (personal observation) are likely to negotiate the fishlock in a large group. Approximately 97% of the individuals trapped were juveniles below 40mm in length indicating that they were the young of the year and were moving up in schools. Aforementioned data from the exit channel configuration indicates that these individuals were spawned in the last breeding period (November – January).

There are some factors to consider when choosing which attraction time is most effective. Although the 100 minute attraction time can pass fish at an effective rate it might have trouble accommodating different fish behaviour. For instance, predation pressure in the entrance chamber may increase as fish will need to wait for long periods of time (up to 99 min) before they can move upstream. The ability of the fishlock to handle mass migrations may be reduced using the 100 minute attraction time. There has been little research into fishlock capacity and their ability to accommodate mass migrations (Stuart and Berghuis, 1997). When the fishlock becomes crowded fish may not enter as they fear predation, feel unsafe or sense that conditions are not suitable for migration. This will reduce the amount of fish that can be passed in a cycle. A better understanding of fish behaviour would help DPI&F ascertain whether or not this is the case and may lead to solutions to crowding in fishlocks.

The mass migration that occurred during these experiments occurred primarily during the 5 and 30 minute attraction time period. Indicating that the 100 minute attraction time may be less effective at accommodating for mass migrations. Using the 5 minute attraction flow would place a lot of wear on the fishlock and would result in more maintenance and a shorter life span of the hydraulics. The life of the fishlock could be lengthened by using a longer attraction time however this must not comprise fish passage.

An attraction time of 30 minutes provides adequate fish passage for numerous species and reduces the level of wear on the fishlock. This attraction time also has the ability to accommodate mass migrations when they occur. It is recommended that fishlock be placed on this attraction length.

Exit Channel Configuration Experiments

The purpose of this experiment was to determine if individuals are completing upstream movement through the fishlock and exiting the fishlock exit channel successfully. The exit channel was made longer than usual and included two turns as the channel needed to go under the railway line (that is used by the crane that manually lifts the weir gates). A long exit channel such as this one could influence a number of factors relating to the movement of individuals exiting the fishlock. Such factors include; the length of time an individual requires to exit the fishlock; if fish are able to navigate their way through the turns and the long exit channel and if small individuals are able to negotiate the long channel with their reduced swimming ability. Small individuals may find it hard to exit the channel as there are no relief/eddy points in the channel for them to rest. Small individuals have no where specifically designed for them to rest, if they cannot swim the whole length in one move they may not be able to use the fishlock to migrate upstream. Small rocks and clumps of sand, pushed downstream into the fishlock by flows, in the exit channel may provide enough relief for small individuals to rest and move through the exit channel. The exit channel was monitored to determine what fish were able to successfully swim the length of the channel.

Methods

After randomly selecting either the exit-entrance or the exit-exit (Figure 4) of the fishlock, the trap was placed in the selected position for 24hrs. The trap was raised twice during the 24 hour period in order to count and measure the fish and prevent overcrowding; raising the trap was done as quick as possible and during the attraction phase to minimise the time that the trap was out of the water. The trap was then placed in the opposite location as soon as possible after the fish had been emptied out of the trap. All fish from each trap were counted and measured. All fish were identified to a species level, counted, measured to the nearest millimetre and released upstream of the fishlock. Fork length was recorded for forked tail species and total length for all other species. When large numbers of any singular species occurred, random sub-samples of 50 fish were measured and the remainder counted. Water quality (including temperature, dissolved oxygen, conductively and pH) was taken everyday while sampling was in progress

Results

During these experiments 19 species were identified and 19,672 individuals were trapped and counted.

Blue catfish were present in relatively large numbers during each sample. In Figure 14 the percentage frequency for catfish moving through the exit channel is shown. The figure shows that during the exit channel configuration experiments most lengths of catfish were able to pass through the whole entirety of the exit channel. Some size classes were trapped more often in the trap located in the end of exit channel (exit-exit – Figure 4) than in the start of the exit channel (exit-entrance – Figure 4), these tended to be larger fish.

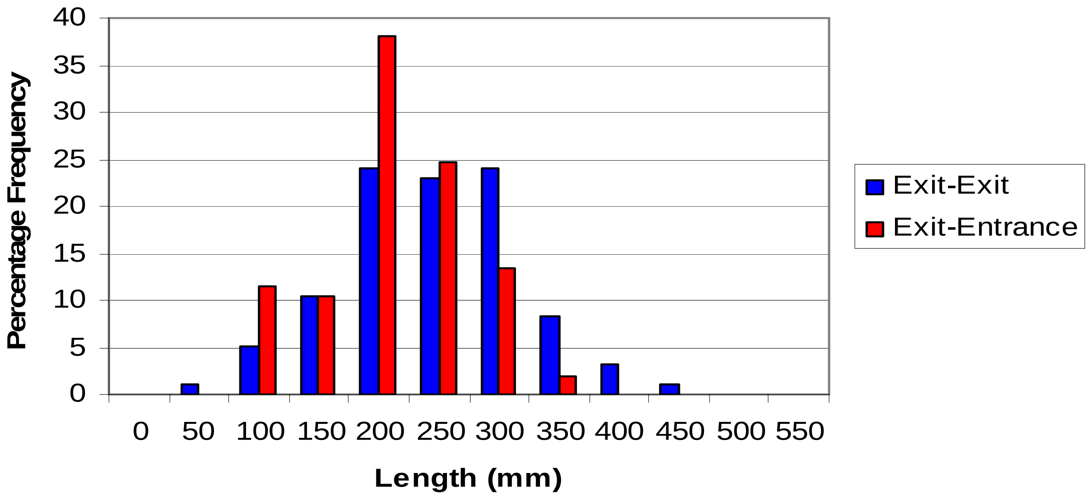


Figure 14: Percentage frequency for blue catfish moving through the fishlock exit channel (Exit-exit n=96 and Exit-entrance n=105).

One of the notable observations during these experiments was the mass migration of empire gudgeons, Hypseleotris compressa. The majority of the sampled migration occurred over a 24 hour period; however it must be noted that the previous days were not sampled due to high flows and there could have been a higher peak in migration on those days. There were 12,446 individuals trapped on the 6/2/06 and 3,192 on the 7/2/06. Sampling did occur on the 3/2/06 however, the number of empire gudgeons trapped was only 170. This indicates that the mass migration could have occurred between 3/2/2006 and the 7/2/2006 a five day period.

Over the space of 15 days the average size of the empire gudgeons measured (first 50 individuals were measured for each trap raised) increased (Figure 15).

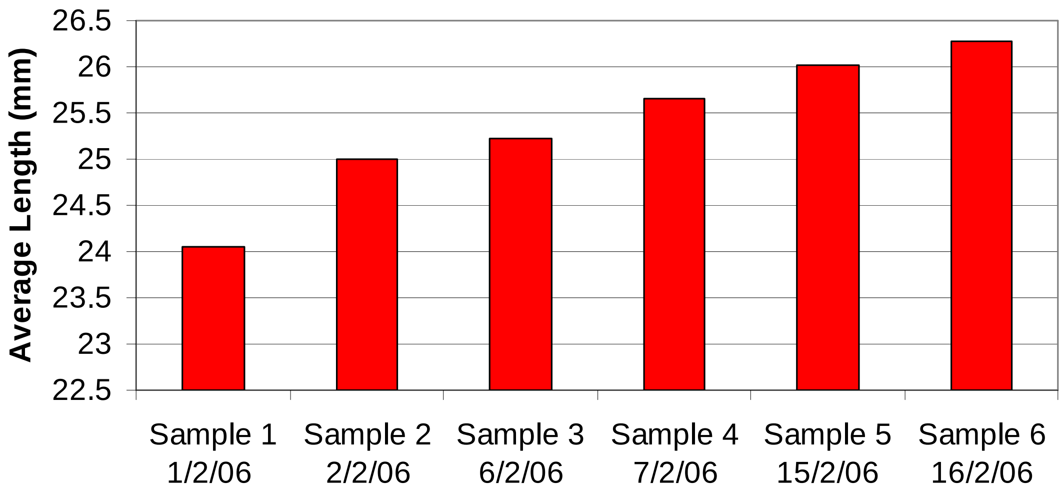


Figure 15: The average length of empire gudgeons moving through the fishlock from the 1/2/06 to the 16/2/06.

Discussion

In general the exit channel configuration did not appear to affect fish moving through the fishway, with no decernable difference between samples at the exit-exit and exit-entrance sampling locations. Many small fish were encountered during this experiment and they were able to successfully ascend through the exit channel.

Blue catfish were moving through the fishlock in large numbers and in a variety of sizes. Blue catfish are a mouth brooding species and some of the smaller individuals may have been travelling in the mouths of their fathers. However, no individuals were witnessed to have young in their mouth at the time of measuring.

Pusey, unpublished, in a report concerning the Burdekin River stated that it is unlikely that empire gudgeons would be able to negotiate fishways. However this is not the case recorded here. The smallest empire gudgeon that was recorded in the exit channel of the fishlock was 17mm in total length. Pusey et al, 2004, later stated that in general smaller empire gudgeons apparently have difficulty ascending fishways, however this statement was focused on studies which involved vertical slot fishways and not a fishlock design such as the one located on the Clare Weir. It is clear from these experiments that juvenile empire gudgeons (<17mm) are able to ascend the Clare Weir fishlock effectively and in great numbers.

Cotterell, 1998, stated that empire gudgeons undertake mass migrations from flooded mangrove areas. During sampling the main sand dam in the lower Burdekin River was still in place and would have restricted access from the estuary, however, some of the smaller sand dams may have been broken or bypassed enabling larger connectively access to the fishlock. Individuals that were migrating upstream most likely would have come from riverine habitats downstream of the weir as there was no estuary access. As can be seen on Figure 22 (figure located in '3.1 General Results') these mass migrations are most likely related to local rainfall event. There is no previous data to equate the movement of empire gudgeons to rainfall or flow. They are generally thought to migrate during rises in discharge however in this instance they appear to be more closely associated to rainfall. In any event rainfall and discharge are typically closely related. Each rainfall event that was sampled had a corresponding mass migration of empire gudgeons. The rain event on the 9/1/2006 was not sampled and the one occurring on the 9/4/2006 was followed by a large flow event down the Burdekin River that could have made upstream movement of small fish difficult. The rainfall event on the 9/4/2006 was sampled some 10 days later however there was a large flow event at the time which may have reduced the ability of empire gudgeons to migrate upstream, hence no mass migration was recorded.

For the mass spawning event that occurred between the 1/2/2006 and the 16/2/2006 the empire gudgeons may have originated from a single mass spawning event as their size increases compared to time (Figure 15). Empire gudgeons spawn more than once in a season (Auty, 1978) and this corresponds with what was seen in later experiments; the length of individuals moving upstream over the entire sampling period stayed around the same (20-30mm) indicating continual recruitment. The very small increases in size of empire gudgeons seen in figure 15 may show growth among the cohort over time. Mass migrations are an important event as they move large numbers of fish upstream in a short amount of time and allow the fish to confuse predators with large numbers. With mass migrations in mind, it is essential that the fishlock is operational at these times; if these fish are trapped below the weir they could face high predation levels and numbers could be greatly reduced.

It has been suggested that the empire gudgeon prolarvae are probably washed downstream (Hansen, 1986). Very large numbers of juveniles and adults have been found immediately downstream of tidal barrages and dams in lowland rivers (Pusey et al, 2004). The eggs are demersal and are attached to rocks and weeds (Merrick and Schmida, 1984; Hansen, 1986) and as such are unable to be washed downstream. The prolarvae are poorly developed and lack rayed fins (Merrick and Schmida, 1984) resulting in reduced swimming ability. The growth rate of this species is typically 60-

70mm after one year (Pusey et al, 2004) indicating that these fish are young that were spawned early in the 2005/2006 wet season. The female empire gudgeon is capable of spawning repeatedly through the breeding season and is able to spawn at least 20 times (Auty, 1978). These spawnings can occur between 36-78 hours apart during the onset of the breeding season but later in the season they occur around one week apart (Auty, 1978).

Pusey et al, 2004, summarised three types of movement involved in the empire gudgeons life cycle; 1) the likely passive downstream movement of larvae to estuarine and lowland river habitats (generally caused by flows); 2) mass upstream migration by juveniles; 3) upstream migration by adults for reproduction, dispersal or colonisation. The fishlock has been able to demonstrate the first two of these movements; however the adult's migration is yet to be witnessed. Movements involved in reproduction however would not be expected to be seen until the end of spring/beginning of summer.

Bony Bream, Nematalosa erebi, were captured moving upstream in large numbers at around the same time as the empire gudgeons. Due to the sampling periods DPI&F are unable to specify whether this was the start, middle or end of this movement event. However, as mentioned with the empire gudgeons the migration would have occurred between the 3/2/2006 and the 7/2/2006. Bony bream spawn in the late spring early summer before the wet season has started however northern populations have a protracted spawning season which can last year round (Merrick and Schmida, 1984; Puckridge and Walker, 1990; Pusey et al, 2000). Bony bream grow to about 70mm in their first year (Puckridge, 1992), indicating that the majority of the individuals trapped were spawned this breeding season (2005/2006).

Movement biology of bony bream is limited with most of the information and data being sourced from fishway studies. The eggs of bony bream are demersal in their initial stage but as they have been caught in plankton trawls on the surface they have been suggested to have a pelagic phase (Puckridge and Walker, 1990). During this pelagic phase eggs would be susceptible to passive movement over the weir. The bony bream are migrating upstream in large numbers to disperse to new habitats. Dispersal migration occurs to recolonise areas within the river system. This dispersion migration allows this species to occupy vast areas of habitat, some of which are permanent and some which are not depending on climate conditions at the time. The wide dispersal behaviour seen in this species ensures that some populations will survive no matter what the conditions are throughout the year.

Barramundi movement during the exit channel configuration experiments was limited; however the most notable observation was that a large majority of the trapped individuals were tagged. This indicated to DPI&F that there may not be a large recruitment of 'natural' barramundi moving upstream of Clare Weir. Out of 34 barramundi caught only 12 were not tagged (~35% 'natural' fish). The assumption can not be made that these 12 individuals were naturally bred as not all stocked fish are tagged when released. The percentage of 'natural' fish may be lower than 35%. In any case, it is of concern to DPI&F at the low percentage of naturally recruited fish sampled in this part of the Burdekin catchment. The primarily reason for the low capture of natural barramundi is the restricted access to the estuary. Without direct access to the estuary juvenile barramundi cannot migrate upstream into the freshwater environments.

Entrance Velocity Effects on Small Fish

The purpose of this experiment was to determine the preference of small fish in reference to water velocity exiting the entrance to the fishlock. Due to small fish having less developed features compared with adults and in general a lesser swimming ability they may have different requirements for passage through the fishlock. By increasing the flow out of the entrance chamber the resulting attraction flow downstream is increased and may attract more large and small fish to the fishlock. If these smaller fish are able to negotiate high water velocities then, as a result of an increased attraction flow, more fish may be able to pass through the fishlock.

Methods

The small fish experiments were run over 2/10/2006 – 7/10/2006. The fishlock was placed in the park position and set with the downstream gate open (attraction phase). The fill valve was used to control the flow of water out of the entrance chamber. Three velocities were tested; low (~0.15m/s), medium (~0.35m/s) and high (~1.0m/s). One of the three velocities was randomly selected; the fill valve was adjusted to reflect this velocity. The velocity was measured between the entrance walls to the entrance chamber (Figure 16). The trap was placed in the entrance chamber for four hours. After the four hour period the trap was raised in order to count and measure the fish. All fish under 80mm were identified to a species level, counted, measured to the nearest millimetre and released upstream of the fishlock. Fork length was recorded for forked tail species and total length for all other species. When large numbers of any singular species occurred, random sub-samples of 50 fish were measured and the remainder counted.

Figure 16: The entrance walls of the entrance chamber. This is where the velocity measurements where obtained.

Results

The smallest fish that moved through the entrance chamber was 20mm, 22mm and 23mm in flows of low, medium and fast respectively. The average and maximum velocity values are shown in table 4. The species and number of individuals that passed into the entrance chamber are shown in table 5.

Table 4: The velocity for each high, medium and low.

Flow type	Average Velocity	Maximum Velocity
High High	1.01 1.01	1.2 1.1
Medium Medium	0.34 0.36	0.5 0.6
Low Low	0.12 0.14	0.3 0.3

Table 5: Species and number of individuals moving through the fishway at the different flows.

Species	High	Medium	Low
Empire Gudgeon (Hypseleotris compressa)	17,158	38,373	8,472
Bony Bream (Nematalosa erebi)	0	285	222
Fly-specked Hardyhead (Craterocephalus stercusmuscarum stercusmuscarum)	0	1	0
Agassiz's Glassfish (Ambassis agassizii)	1	0	2
Eastern Rainbowfish (Melanotaenia splendida splendida)	0	1	0
Long-finned Eel (Anguilla reinhardtii)	0	1	1
Roman Nosed Goby (Awaous acritosus)	0	0	1
Total	17,159	38,661	8,698

The different velocities moving out of the fishlock entrance created different hydrological conditions. The high velocity created very turbulent water both outside the entrance to the fishlock and in the entrance to the fishlock (Figure 18). As can be seen in the figures the high velocity created upwelling and eddies outside the fishlock entrance. This increased the total attraction flow for fish trying to find the entrance to the fishlock. The medium velocity created medium turbulence (Figure 19) but also a reduced attraction flow downstream. The low flow created minimal turbulence (Figure 20) and had a much reduced attraction flow. There was no turbulence that could be easily seen from the top of the water and the flow out of the fishlock entrance was nearly non-existent.

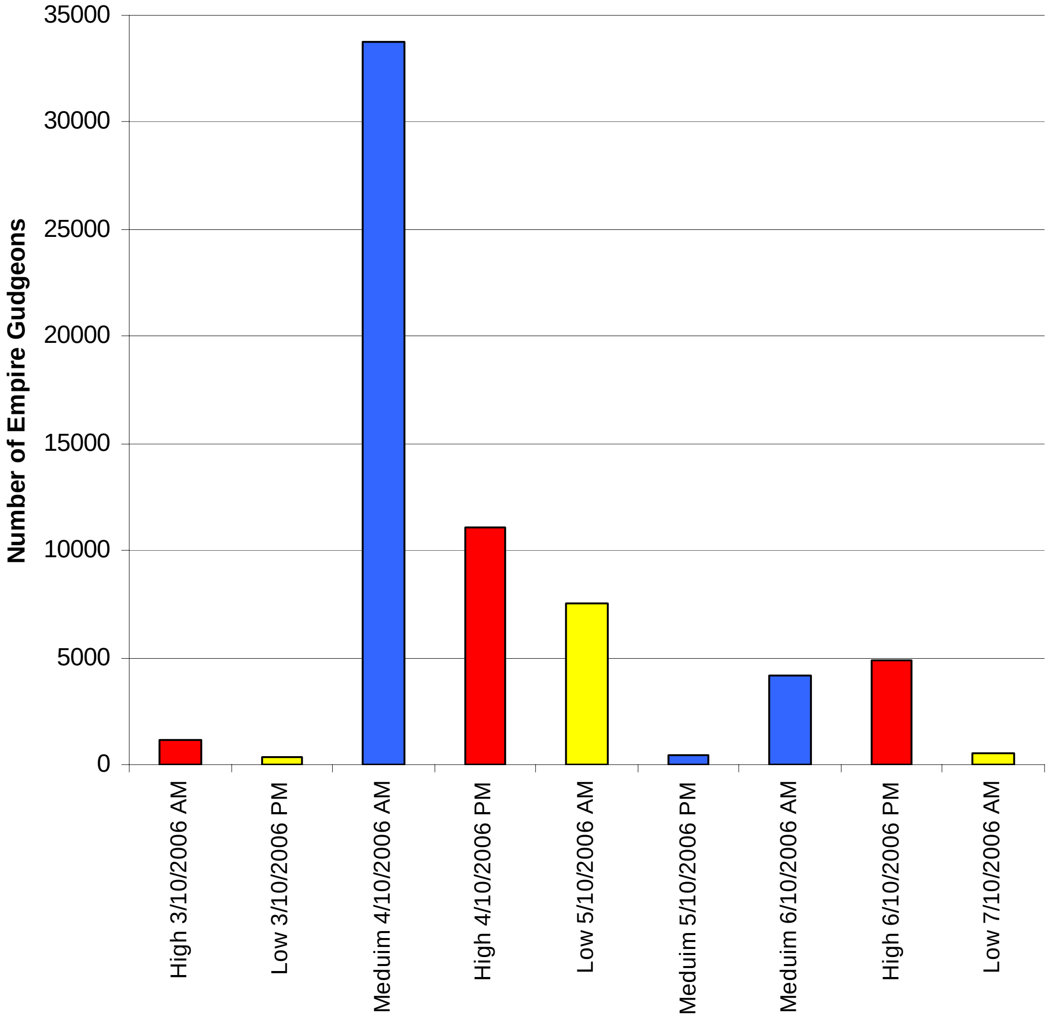


Figure 17: Number of empire gudgeons moving through the fishlock during the small fish velocity experiments at low, medium and high flow.

Figure 18: Turbulence created by the high flows around the fishlock entrance.

Figure 19: Turbulence created by the medium flows around the fishlock entrance.

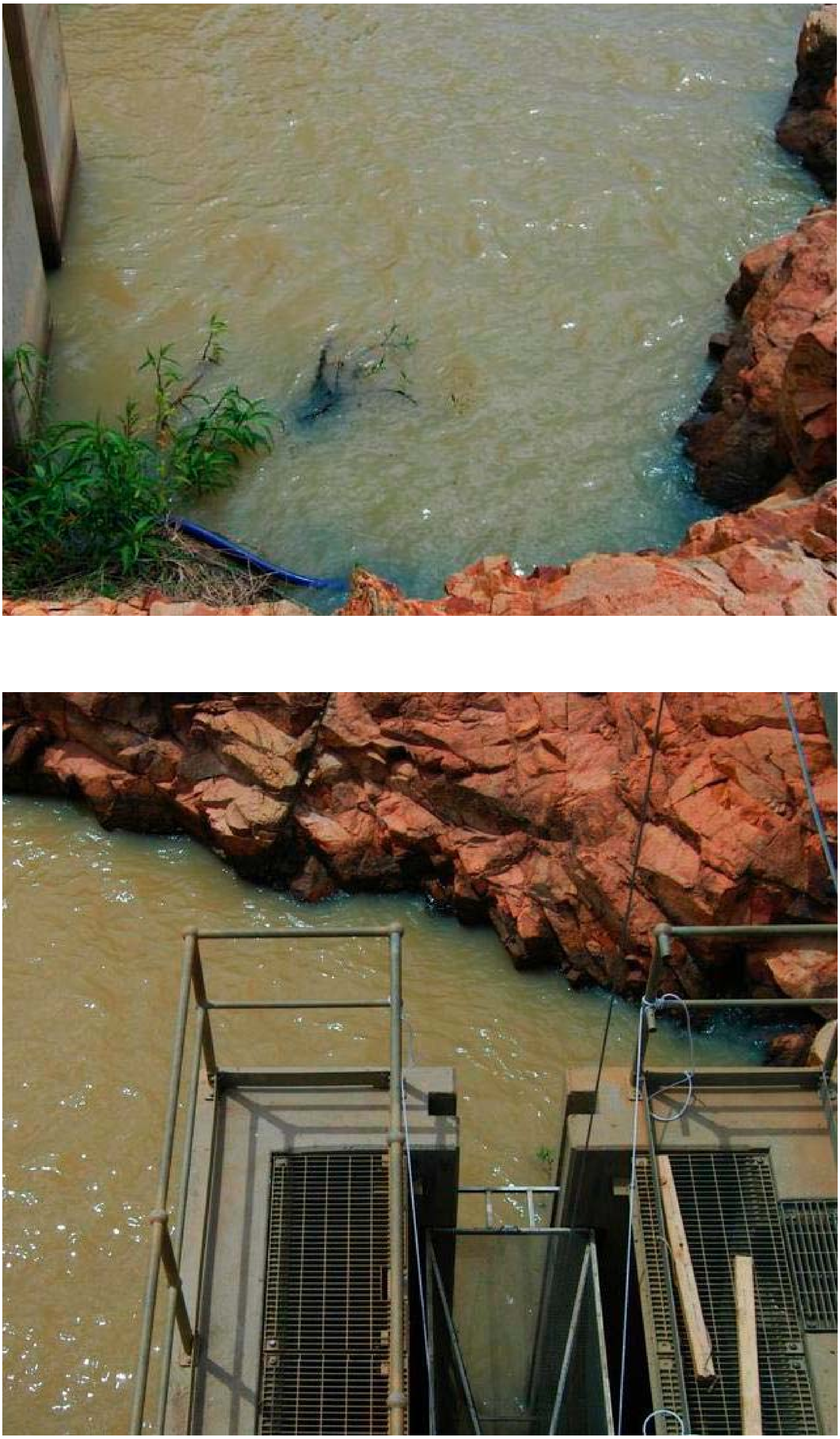


Figure 20: Turbulence created by the low flows around the fishlock entrance.

Discussion

The capture of small fish in fishlocks has not been experimented on previously. The smallest mesh size that has previously been used was 12mm on the fishlock at Eden Bann (Stuart and Berghuis, 1997), Dumbleton Weir (McGill and Marsden, 2000) and Walla Weir (Berghuis et al, 2000). This sized mesh would trap fish larger than approximately 80mm depending on species morphology. The study conducted at Clare Weir has provided particularly significant results in regards to small fish and their passage through fishlocks. The study has shown that small fish down to 15mm in size have successfully moved up the fishlock and out of the exit channel. It has also shown that small fish use the fishlock to move upstream in extremely large numbers in short periods of time. It has shown that small fish may even be the primary user of fishlocks such as the one located at Clare Weir.

During the small fish velocity experiment over 64,000 fish passed through the fishlock. Large amounts of individuals were recorded at all three velocity levels indicating that some species are capable of negotiating flows up to 1.0m/s. However at this high velocity no bony bream were recorded. This indicates that flows of 0.6m/s or more are not suitable for the passage of bony bream.

The small fish velocity experiments were dominated by one species of fish, the empire gudgeon, in mass numbers. This movement was most definitely a mass migration. This was the largest mass migration seen while sampling at Clare Weir. During the five days of sampling more than 64,000 empire gudgeons passed through the entrance chamber (Figure 17). This is a very significant result for many reasons.

Small fish such as the empire gudgeon are the food source for many of the predatory species such as barramundi and without this food source barramundi may not be able to find enough prey to survive in large numbers. Due to the recent construction of the Clare Weir fishlock, habitat connectivity has been restored for this part of the Burdekin River. This mass migration demonstrates the importance of the Clare Weir Fishlock in the restoration of fish population in this region, specific upstream of Clare Weir.

A whole of ecosystem approach to fish populations is needed when considering the health of a water body. The larger, more dominant species such as barramundi will occupy a habitat according to a number of different factors. Water quality, prey abundance and access are all factors that would determine the number of predatory species in a water body. Prey abundance is a crucial factor as without food these predatory fish would not be able to stay in a water body for a long period of time. The movement of small fish is very significant in freshwater systems and the significance of these mass migrations can not go unheeded. The monitoring at Clare Weir is the first time small fish have been targeted in a fishlock, all previous monitoring has only focused on the larger species of fish.

Smaller fish are migrating on the small flows that occur early in the wet season. Small fish may not be able to negotiate the turbulence of larger flows. Larger fish may leave their upstream migration to large flows as this will enable them to access other habitats not normally accessible from the river channel. Although they were not recorded in this experiment less than ten fish over 80mm in length were caught during this five day period. This emphasises the importance of an operational fishlock for the entire year.

Lock Cycle Velocity Variations

The purpose of the velocity profiles is to determine if there are any areas within the fishlock that fish may find specifically difficult to navigate due to fast flows. This profile will give DPI&F and Sunwater a better understanding of the flow regime that exists at different stages in the fishlock cycle and what area within the fishlock that may need improvement. It will also show if the attraction flow is to fast or too slow for fish passage. There needs to be enough flow to attract all sizes of fish to the fishlock yet be slow enough for all those fish to move upstream through the fishlock.

Methods

The cycle times were changed on the PLC to reflect five minute attraction and exit times. Due to the capabilities of the probe only average and maximum velocities were recorded. The velocity probe was inserted into the entrance of the entrance chamber. The probe was placed in the middle of the water column and in the centre of the entrance to the entrance chamber and left for ten seconds at which the average was taken and recorded. Averages were taken throughout this stage in the cycle. At this time the maximum velocity for the stage in the cycle was recorded. The probe was left in this position for an entire cycle. The probe was then moved to the exit channel for the next cycle and the above procedure repeated.

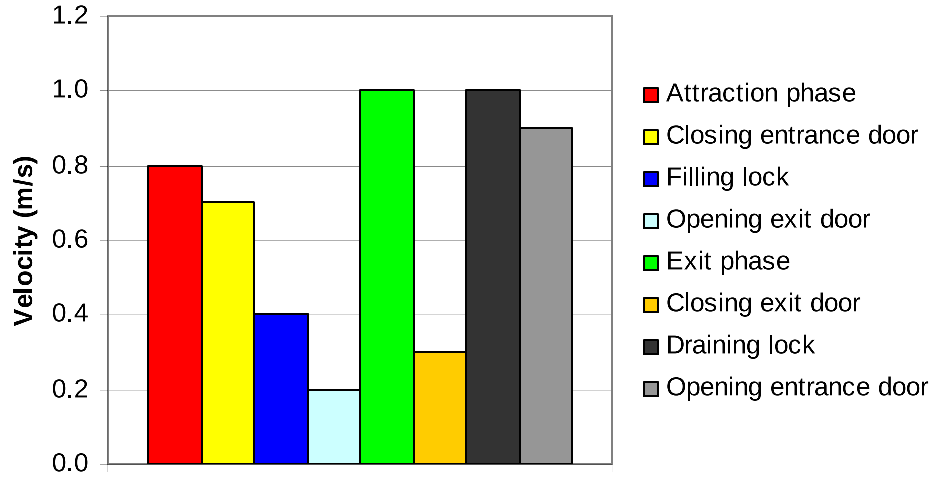
Results

Table 6: Velocity profiles (metres/second) for the exit channel

	Avg 1	Avg 2	Avg 3	Avg 4	Avg 5	Avg 6	Avg 7	Avg 8	Avg 9	Avg. 10	Max
Attraction phase	0.16	0.15	0.18	0.15	0.16	0.16	0.17	0.15	0.15	0.12	0.2
Closing entrance door	0.17	0.19									0.2
Filling lock	0.18	0.16	0.33	0.11							0.4
Opening exit door	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.1
Exit phase	0.33	0.07	0.17	0.40	0.35	0.21	0.26	0.23	0.28	0.18	0.4
Closing exit door	0.10	0.10	0.00	0.08							0.1
Draining lock	0.00	0.00	0.00	0.00	0.00	0.00	0.00				0.0
Opening entrance door	0.22	0.21	0.13								0.2

Table 7: Velocity profiles (metres/second) for the entrance to the entrance chamber

	Avg 1	Avg 2	Avg 3	Avg 4	Avg 5	Avg 6	Avg 7	Avg 8	Avg 9	Avg. 10	Max
Attraction phase	0.5	0.5	0.48	0.52	0.52	0.52	0.46	0.62	0.66	0.61	0.8
Closing entrance door	0.55	0.58	0.61	0.39							0.7
Filling lock	0.17	0.1	0.15	0.18							0.4
Opening exit door	0.12	0.11	0.11	0.12	0.16	0.18					0.2
Exit phase	0.47	0.86	0.85	0.83	0.84	0.84	0.85	0.84	0.84	0.84	1.0
Closing exit door	0.16	0.09	0.11	0.15	0.12	0.11	0.21				0.3
Draining lock	0.38	0.79	0.71	0.63	0.47	0.37	0.16				1.0
Opening entrance door	0.72	0.49	0.58								0.9



b)

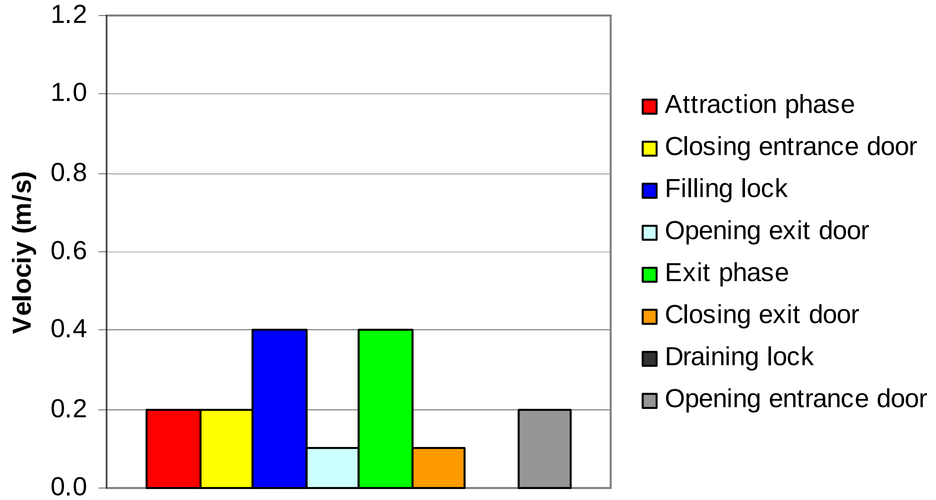


Figure 21: Maximum velocities for both the exit channel (a) and the entrance to the entrance channel (b).

The maximum velocity that was recorded was over 1.0 m/s in the entrance to the entrance chamber. This velocity occurred during the exit phase and the draining phase. In general the velocities coming out of the entrance chamber were more than twice that of the exit channel. This is expected as the cross-sectional area in which water can flow through is much larger in the exit channel.

Discussion

One of the most notable velocities was in the exit channel during the opening of the exit door and during the draining of the fishlock. These velocities were basically zero (0-0.01m/s). This is of concern, especially during the draining of the fishlock as fish may still be exiting the exit channel during this time. If the water stops moving the fish could become confused/scared and swim back towards the exit gate. However, as the velocity down at the entrance to the entrance chamber is at approximately 1.00m/s there is limited options to increase flow in this area. There are two options available to help solve this problem. The first involves reducing the amount of drain valve (to say 25% rather than the current 50%) that is open and also opening the attraction valve (to

25%). This would keep the velocities exiting the entrance chamber near the current levels but would also move water through the exit channel. The second option would be to simply open the attraction valve to 25% and in turn increase the velocity out of the entrance chamber.

Throughout a cycle there are opportunities for fish with a reduced swimming ability to enter the entrance chamber and lock chamber due to the varied velocities. DPI&F did wish to conduct a velocity profile of the lock entrance however due to the grills in place over the entrance chamber we could not gain access to do this. However, as the lock entrance is slightly larger in cross-sectional area than the entrance chamber entrance it would have slightly less velocities.

Overall Sampling Results

Total number of fish

Over all experiments conducted to date 97,900 fish (Table 8) have been recorded to have passed either into the fishlock entrance chamber or into the exit channel of 24 different species. A total of 40,260 sampling minutes (671hrs) have been conducted. This equates to 2.432 fish per minute attempting to move through the fishlock, or 145.9 fish per hour. Assuming that upstream migration remains constant throughout the year this would equate to 1,278,098 fish per year moving upstream of Clare Weir via the fishlock. The number of fish that successfully moved through the exit of the exit channel was 29,925. This equates to 1.07 fish per minute or 64.27 fish per hour.

Table 8: Number of species caught during sampling to date. Note: the number of sampling hours for the entrance chamber is 205 hours 25 minutes and 465 hours 35 minutes for the exit channel.

Species	Entrance Chamber	Exit Channel	Total
Catadromous			
Barramundi (Lates Calcarifer)	71	74	145
Long-finned eel (Anguilla reinhardtii)	173	42	215
Amphidromus			
Blue Catfish (Arius graeffei)	249	1,178	1,427
Oxeye Herring (Megalops cyprinoides)	21	10	31
Sea Mullet (Mugil cephalus)	0	1	1
Spotted Scat? (Scatophagus argus)	0	1	1
Potamodromous			
Agassiz's Glassfish (Ambassis agassizii)	3	42	45
Banded Grunter (Amniataba percoides)	0	83	83

Black Catfish (Neosilurus ater)	4	14	18
Bony herring (Nematalosa erebi)	2,761	9,962	12,723
Eastern Rainbowfish (Melanotaenia splendida splendida)	6	71	77
Empire Gudgeon (Hypseleotris compressa)	64,667	18,307	82,974
Fly-specked Hardyhead (Craterocephalus stercusmuscarum stercusmuscarum)	3	6	9
Freshwater Longtom (Strongylura krefftii)	0	12	12
Hyrtl's Tandan (Neosilurus hyrtlii)	3	16	19
Mosquito Fish (Gambusia affinis)	4	1	5
Mouth Almighty (Glossamia aprion)	1	5	6
Roman-nosed Goby (Awaous acritosus)	3	31	34
Seven-spot Archerfish (Toxotes chatareus)	0	16	16
Sleepy cod (Oxyeleotris lineolata)	5	9	14
Small-headed Grunter (Scortum parviceps)	0	24	24
Snub-nosed Gar? (Arrhamphus sclerolepis)	0	2	2
Spangled Perch (Leiopotherapon unicolor)	0	4	4
Sooty Grunter (Hephaestus fuliginosus)	1	14	15
Totals	67,975	29,925	97,900

Environmental Factors

Table 9 shows the environmental factors at Clare Weir over the sampling periods. Most notable is the range in temperature and dissolved oxygen. The temperature was taken over February - June so both summer and winter temperatures were included. The dissolved oxygen in the tailwater was dependant on the flow over the weir, out the outlet works and out of the fishlock.

Table 9: Environmental factors recorded at Clare Weir over the sampling periods.

	Temperature ºC		pH		Dissolved oxygen mgL-1		Conductivity	
	Min	Max	Min	Max	Min	Max	Min	Max
Weirpool	24.83	32.25	7.37	8.26	6.34	9.59	118	206
Tailwater	24.83	32.14	7.54	8.12	7.43	10.57	118	207

Rainfall events Vs empire gudgeons mass migrations

Figure 22 shows the relationship between rainfall events and mass migrations of empire gudgeons. The first recorded mass migration (6/2/2006) occurred approximately 10 days after the onset of a large flow, caused by a large local rainfall event. The second mass migration (15/3/2006) was recorded around 8 days after a medium local rainfall event. The third mass migration was recorded approximately 9 days after a medium local rainfall event. As can be seen in Figure 22 each rainfall event had a corresponding mass migration of empire gudgeons, which occurs approximately 8-10 days later. There were other rainfall events during this period however not all of them were sampled. During the small fish experiments there was a mass migration between 2/10/2006 – 7/10/2006. The peak during this mass migration was on the 4/10/2006 in the morning where ~33,000 empire gudgeons were trapped. There was no rainfall directly preceding this mass migration event however there was a slight increase in flow (from about 650ML/day to 1,100ML/day) between the 21/9/2006 and the 29/9/2006 (7-14 days before the migration). Empire gudgeons may be responding to the slight rise in river levels rather that the fall of rain but it appears that the rain has an effect on the spawning behaviour and timing.

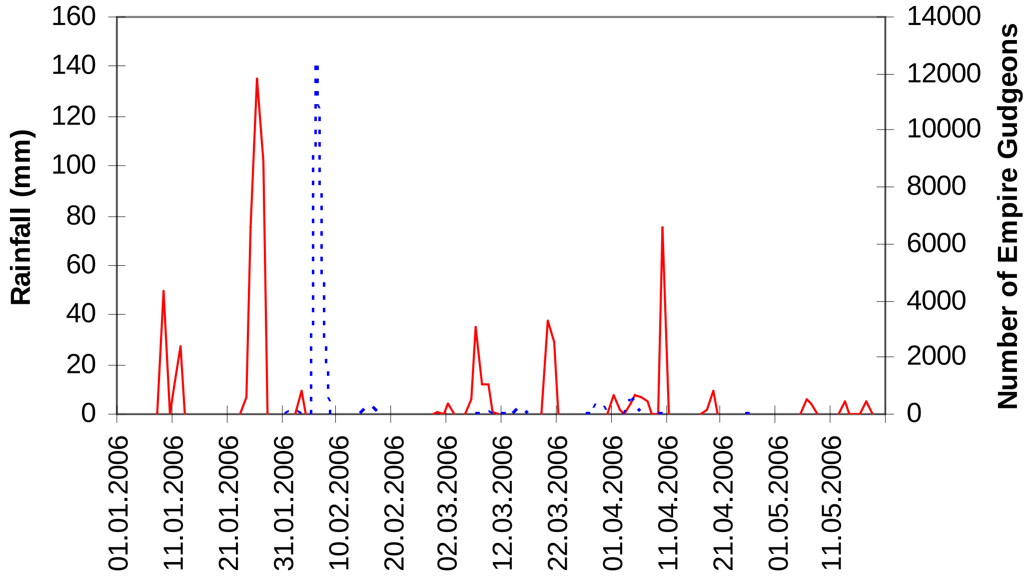


Figure 22: Rainfall (red-solid line) for the township of Clare and number of empire gudgeons (blue – dotted line) for the period 1/1/2006 – 30/6/2006.

Shrimp and prawn migrations

There were a number of shrimp species that were caught in both the entrance chamber and the exit channel. These shrimp are presumed to be moving upstream. They were also witnessed climbing up the weir wall however due to its design they were unable to successfully reach the top. Clare Weir is now providing passage for these shrimp species upstream. As these species are important food for many species their movement upstream will help populations upstream recover and also remove the large food source directly below the weir. Although no experiments or data was carried on these species it is clear to DPI&F that they were migrating upstream and not just moving within the fishlock itself. When this species was witnessed moving up the weir wall they did so in the hundreds for extended periods of time. Two different shrimp species have been identified as moving through the fishlock. One belongs to the Family Atyidae and is most likely Atya spp. The other belongs to the Family Palaemonidae and is a Macrobrachium spp.

Discussion

Success of the fishway

The fishlock is providing passage for a number of fish species in a range of sizes. Twenty-four species of fish were trapped during the five experiments, ranging in size from 14mm to 1000+mm. Pusey et al, 1998, recorded 21 species of fish at a site above Clare Weir and below the conjunction of the Bowen River and Burdekin River. Electrofishing directly below Clare Weir by Marsden and McGill, 2001, recorded 14 species. Hogan et al, 1997, lists 27 species that were caught downstream of Clare Weir and in two lower creeks in the Burdekin River. Of the twenty-four species caught in these experiments two had not been caught in the three studies mentioned above. These species were the roman nosed goby, Awaous acritosus and the spotted scat, Scatophagus argus.

Endemic species

The small-headed grunter which is endemic to the Burdekin River catchment was found moving upstream through the fishlock. This species has a known distribution above the Burdekin Falls Dam however has only been found in small numbers below this point. Hogan et al, 1997, did not record this species at Clare Weir however he did record this species to be present throughout the Bowen River drainage specifically in the mid reaches and below the Collinsville Weir (Hogan et al, 2000). Individuals 33-69mm in length were caught in the sampling of Clare Weir indicating that these juveniles may have been washed downstream during a flow event. There is limited information regarding the reproductive biology of the small headed grunter; Merrick and Schmida, 1984, indicated that the eggs are pelagic and hatch after 36 hours. This is concurrent with the view that the individuals caught in these experiments were washed downstream during periods of flow. The Clare Weir fishlock is now providing passage upstream for this endemic species.

Barramundi tag data

Tag data from the barramundi that were caught indicate that all fish were stocked into the Clare Weir. They all came from two stocking events one on the 12/3/2006 and the other on the 26/11/2005. The recorded release location for these stocked fish was about 7km upstream of the weir. However due to the method of stocking the fish were released throughout the weir pool. These fish have moved over the weir and were returning upstream; they were most likely washed down during flow events or they moved downstream using the fishlock (however no evidence of this has been recorded at Clare Weir). Localised movement, as seen by these fish, is expected by individuals of this size.

Trap Performance

The traps that were made by DPI&F are performing well under the sampling conditions. Some modifications had to be made to the exit trap early in February as the walls of the exit channel are not square. This resulted in the need to shorten the width of the trap at the bottom so that it would fit into the channel. Over the course of sampling the trap did require some maintenance in regards to small holes in the fly-screen mesh made from fish spines, specifically from blue catfish, however they were easily fixed with silicon like glue. The other problem that we faced with the exit trap was algae and debris kept getting caught in the fine fly-screen mesh. As a result the corner welds broke and the trap had to be reinforced and a screen was made to trap the algae and debris before it entered the exit channel (Figure 23). This problem did not occur for the entrance trap as the water hydrology is significantly different; however the screen was still used to stop any debris. The trap used in the entrance chamber held up a lot better because of its larger surface area.

Figure 23: The screen that was made up to stop debris and algae getting caught in the traps and the screen in place at the exit of the exit channel.

Due to the position and size of the entrance chamber manoeuvring it into position requires at least 5 people. Once the trap is in place it is quiet easly raised and lowered using the frame made by Sunwater. The exit trap was stored up away from flood level when not in use. The entrance trap stayed in position on top of the entrance chamber (Figure 5) when not in use. The entrance trap was removed off the weir above flood level when there was an indication that there might be a sizable flow that could flood the weir or significantly raise the tailwater.

Barramundi were noticed ramming the trap walls when the trap was being lifted. With enough force barramundi have succeeded to break through the aluminium fly mesh and the chicken wire used in the exit and entrance trap. One individual even managed to break through the chicken wire and fly-screen mesh in the entrance trap while another broke through the exit trap. In an attempt to stop escapees the entrance trap was also reinforced with steel mesh on the bottom of the funnel and lower rear to stop barramundi ramming through the mesh and out of the trap. This has so far proved successful and is the only material that the barramundi did not break through.

Small gaps between the door and the frame may have lead to a small amount of small fish and elvers escaping. Although every effort was made to reduce the size of the gap a perfectly sealed door was unattainable. As fish were able to move back out of the trap the same way they got in raising the trap more regularly would have most likely seen slightly more fish captured. However, by raising the trap you can effectively miss capturing fish that are still travelling through the exit channel. If a large amount of fish have been captured or they are difficult to handle (blue catfish) it may take some time to get the trap back into the water. If this happens you run the risk of missing other parts of the cycle such as the exiting of the lock.

The traps caught over 24 species of fish over the sampling period however there are some species that might be expected to be passing through the fishlock that were not caught. Some of these species include sharks, mullet, rays and mangrove jack. Angling saw the capture of sharks directly below the weir however they were not witnesses moving through the fishway. The biology and swimming behaviour of sharks might account for their absence. Sharks have rigid pectoral fins that protrude laterally making their width in excess of 200mm (the width of entrance to the trap) and are therefore unable to enter the trap. Sharks also have a continuous swimming motion and would not be likely to wait in the lock chamber for the cycle to change.

Marsden and McGill, 2001, recorded only 19 striped mullet in sampling of the lower Burdekin River and these individuals were collected from only two out of seven sites. This indicates a low population of mullet within the freshwater reaches of the Burdekin River. The absence of this species in this study is most likely related to their low abundance in the Burdekin River. In the Marsden and McGill, 2001, two mangrove jacks were caught below Clare Weir while none were captured above the weir. The absence of this species in this study is most likely related to their low abundance in the Burdekin River than anything else. Possible reasons for their low abundance are the reduction in habitat connectivity, caused by sand dams, and loss of coastal swamp habitat.

Fishlock breakdowns

Over the last six months there have been numerous operational problems with the fishlock that affected sampling. The fishlock was not in operation for approximately 23 days over the period 1/2/2006 to the 1/6/2006. This equated to more than 3 weeks that DPI&F were unable to sample at Clare Weir. Some of these problems also occurred while experiments were being conducted resulting in the need to repeat these experiments and causing more lost sampling days.

Position of Flow

The position of any flows that are caused by lowered gates of the weir is very important in attracting fish to the attraction channel. On two occasions DPI&F turned up at the weir and lowered gates were incorrectly positioned to provide ‘best practice’ operational procedures. Figures 24a, 24b and 24c show how different release points can effect water movement down the river. Figure 24a has one main release point in the middle of the river causing fish attraction away from the fishlock. Figure 24b has two main release points, one in the middle of the river and the second over towards the fishlock. This will attract fish to both the centre of the river and the fishlock. Figure 24c shows the best practice directional release flow, with the one main flow originating from near the fishlock. The flow in the picture is creating quite a lot of turbulence as a result of the first gate of the weir being open. This can make it difficult for some species to negotiate the turbulent water and locate the fishlock. In a meeting between DPI&F and Sunwater it was agreed that gate 3 would be opened first if water was to be released followed by 4, 5 then 6, 7 and 8 as a group but it appears that this is not being carried out.

Figure 24a: The flow moving directly downstream attracts fish to the centre of the river. There is also a small flow created by the outlet works.

Figure 24b: The flow moving downstream attracts fish to the centre of the river and not to the eastern side where the fishlock is located.

Figure 24c: The flow is moving towards the western bank.

Figure 25: Area a) shows the zone where water is pushed up against the rock shore and area b) shows the turbulence in the fishway channel created by the water flowing over the old fishway.

If the first two gates are open it causes the turbulent water to push up against the rock shore line creating high velocities and very turbulent water (area a and b in Figure 25). The water also runs over the old fishway creating more turbulence in the fishway channel (area b in Figure 25). DPI&F were sampling at Clare Weir while flows in figure

24b and 24c were present. Halfway through sampling the release points were swapped between figures 24b to 24c. Once the flow was directed away from the middle of the river this saw an increase in the number of species present moving through the fishway.

When the outlet works are open and releasing more than 1200ML/day the outlet works release pushes the water to the west and can create reverse flow into the fishlock channel (Figure 26). The large amount of water being pushed up onto the rocks from the outlet works and the corresponding eddy that forms causes a reverse flow in the entrance channel restricting passage to the fishlock. When the water flows upstream (reverse flow) the fish will continue to swim against the current and therefore be swimming/directed downstream and not towards the fishlock. If the outlet works are going to be operated for long periods at this high release rate something should be constructed to stop the reverse flow from occurring.

Figure 26: The arrows indicate the direction of flow when the outlet works are creating a reverse flow in the entrance channel.

<u>Problems with Sampling</u>

During February and the beginning of March there were no problems with the quality of water flowing through the fishlock. During the end of March algae started to appear in the water column flowing through the fishlock. Due to the fine fly screen mesh that was being used on the trap the algae was getting caught and restricting the flow of water through the trap. This caused pressure to build up on certain areas of the trap and consequently the fly screen mesh ripped at some points. A fly screen mesh screen was made and placed in the upstream end of the fishlock to capture some of the algae before it reached the trap. One of the problems that arose specifically after the large flow event during April-May was the amount of debris moving downstream and through the fishway (Figure 27). There was still some algae present in the water at this time however the primary problem was the debris. The debris did not cause operational problems for the fishlock but rather sampling difficulties. The screen had to be cleaned regularly to ensure that the flow of water was not impeded and that debris was not causing problems with the trap.

Figure 27: Large amounts of debris accumulated at the exit to the exit channel of the fishlock.

The effectiveness of the fishlock to attract fish to the entrance was to be examined. Electrofishing in conjunction with trapping was to be used in order to test the success of fish locating the entrance chamber. At the time that this experiment was scheduled there was a gate down right next to the fishlock that made it unsafe to conduct electrofishing operations directly below the fishlock. Due to the requirement of a low turbulence below the fishlock a suitable time for electrofishing could not be found. The release of outlet works over 1000M/L a day causes too much turbulence below the fishlock hence making it unsafe for electrofishing operations. During the winter months where was less flow and reduced outlet works releases meant it was not suitable to conduct this type of experiment. Due to the colder weather during winter the propensity of fish to migrate is greatly reduced hence they would not be actively trying to locate the fishway entrance. This would skew the results as fish that appear to not to be able to locate the fishlock are simply living below the weir.

Although it was not possible to ascertain whether or not fish were effectively finding the entrance chamber it is clear from the results of the project that a large majority of individuals have been successful in locating the entrance. There has been very large mass migrations of small fish (<33,000 in four hours), fish of all sizes (ranging from 15mm to 1000mm) and 24 different species.

Future Sampling in relation to future fishways

During the sampling of Clare Weir there were several obstructions that led to delays in sampling and increased hardship. More thought about sampling process and methods in the design phase of the fishlock/fishway may have been able to dismiss many of these obstructions.

The grates that cover the exit channel are very heavy and posed a challenge for their removal and replacement upon using the exit trap. During initial design phases grates that cover this area that are specifically lighter in weight could be included. Another problem that DPI&F encountered was the installation of the entrance trap. Due to the size of the entrance trap and the location of the entrance chamber numerous people were required to be on site in order to position the entrance trap on top of the entrance chamber. This involved several (three or more) Sunwater staff coming out to Clare Weir in order to assist DPI&F. This restricted the flexibility of our sampling. If the trap was not in location DPI&F needed to wait for suitable timing with Sunwater to arrange for the movement of the trap.

A relatively new technology that DPI&F are interested in implementing on a fishlock/fishway is PIT tags (Passive Integrated Transponder tags). These effectively ‘count’ previously tagged fish as they move near/past the monitoring box. In order to use this technology a power supply and monitoring box needs to be located close to the fishlock/fishway itself. It would be cost effective to install/fit these features during construction. This would allow long term unmanned use of this monitoring technique. In the case of Clare Weir there was no power supply close enough to the fishlock to run a monitoring box for long periods of time. There was also no security for a monitoring box when DPI&F or Sunwater employees are not on location. If prior thought had been given to the requirements of PIT tagging technology these requirements could have been fitted in the construction phase. The monitoring box could have been housed in the hut out of the weather and it would have been secure from thieves and vandals.

Using PIT tags requires fish of 100mm or greater in size to be caught and tagged with a transponder. Capture of these fish can be by trapping or electrofishing. It can be time consuming to capture and tag a large amount of fish however once the tag is inserted data will be continued to be recorded for the life of transponder (life of transponder varies depending on species but they have the capacity to last the life of the fish as they have no battery).

Another technology that could be of great use in the near future is hydro-acoustics. This involves the use an echo sounding system that detects and records the return signals of transmitted pulses of ultrasound waves (Berghuis and Matveev, 2004). The final result of different processed signals is an echogram, from this echogram information relating to the target object, a fish, can be acquired. This technology has been widely used within the deep-water marine environment for many years. It has been used overseas to assess fish abundance, size, distribution and behaviour at man-made structures. When using the spilt beam technology, information on fish size, direction of travel, position within the water column and swimming speed can be obtained. This data would be vital in understanding fish behaviour in and around fishlocks/fishways in an unobtrusive, no capture method. By utilising this type of technology sample size can be dramatically increased along with the reliability of abundance estimates.

Improving Future fish numbers

Fish communities in the Burdekin River face not only detrimental effects due to barriers such as Clare Weir and various sand dams but also degraded habitat. The cascading effects of habitat degradation can inhibit fish populations, life cycles and sufficiently effect recruitment into the population. Due to the degraded floodplain habitat species that would be using the fishlock would need to utilise the main river channel. Rainbowfish dominate fish populations in the Burdekin River (Pusey et al, 1998) but not many were sampled using Clare Weir fishlock despite its generalist approach to habitat preference. Whether this is due to habitat differences, a lack of recruitment or this species not wanting to use the fishway is unknown.

Archer fish were not sampled by Tait and Perna, 2001, in any of the sites on the Burdekin River floodplains. They hypothesised that this was due to the loss of riparian habitat (and hence a reduction in prey abundance) and low oxygen sensitivity. Numerous juvenile seven-spotted archer fish were witnessed directly below Clare Weir (personal observations). The high levels of dissolved oxygen and sufficient overhanging vegetation downstream of Clare Weir and in the weir pool itself provide good habitat for this species. Several individuals were also sampled moving upstream through the fishlock. Bishop et al, 2001, sampled the majority of juveniles in lowland shallow backflow billabongs and it appears in the case of the archer fish its nil existence on floodplains is due to the hypothesis given by Tait and Perna, 2001.

The number of barramundi moving upstream was small compared to other similar studies (McGill and Marsden, 2000; Stuart, 1997). The reasons for this are unknown but are likely to be due to a number of different factors. Barriers, both physical and chemical, recruitment, poor quality floodplain habitat, flow and predation (including commercial and recreational fishing) can all effect the barramundi population. Floodplain habitats provide juvenile barramundi with a food source and shelter and provide a good area to "grow-out". When this type of habitat is degraded juvenile barramundi will need to find suitable grow-out habitat elsewhere. Improvement in the quality of floodplain habitat will help increase the barramundi populations and the populations of other species.

The sand dams that are located downstream of Clare Weir pose a threat to the future fish stocks of the Burdekin River. They restrict access for many species upstream and downstream. By reducing access to individuals it reduces their ability to find new habitats for reproduction and growth thus reducing overall numbers. Tait and Perna, 2001, suggest the selective removal of these structures to allow the pre-existing hydrology to be reinstated. The upstream movement of some catadromous species was noticed once the sand dams were broken by a large flow during April. Whether or not the increase in fish numbers of certain catadromous species was due solely to flow or both the estuary to weir connectively and the flow is uncertain. However, other smaller flows that were sampled did not see the same movement patterns of these fish species. Some sand dams may have been broken over these small flows however there was insufficient flow to break the main sand dam and as such there was not estuary to weir connectively.

Recommendations

General

Reporting and fixing of any leakages that may be present on the weir or fishlock to ensure that elvers find the fishlock entrance.

Ensure quick response to fishlock operational problems to ensure the continued passage of fish upstream.

To improve fish populations in the Burdekin River system money should be allocated to start improving areas that requires habitat rehabilitation, particularly the lower floodplain habitats around Ayr. Improved habitats will support larger populations and hence larger movement upstream.

Fish passage around the sand dams needs to be improved in order to facilitate the movement of species up and downstream.

The fishlock needs to be operational year round with no lengthy delays in maintenance or repairs. This will enable the most effective passage and restoration of fish migration between the Burdekin Falls Dam and the estuary.

Month by Month Operation guide for Clare Weir Fishlock

January, February and March

During this time of year the wet season should be underway and flows downstream should become more frequent. Many fish species are cued to migrate up or downstream on flow events and consequently there are many fish attempting to move through the fishlock. During these months the cycle time should be changed to reflect a shorter cycle time to accommodate the large number of fish using the lock. DPI&F recommends a 15 minute attraction time coupled with a 10 minutes exit time. This will effectively bring the cycle time down from approximately 60 minutes to approximately 40 minutes. The fill and drain valve should be set on 50%. If a large flood disables the lock, every effort should be made to get the lock operational again in as short a period as possible as the tail-end of flow events at this time of year is recognised as period of peak migration.

April and May

April and May fall in autumn when the weather starts to cool down and the fish start to move less frequently as seen by the data in April 2006. There was a small spike in movement during late April and early May however this was due to the large flow event that occurred late in the wet season. As yearly weather patterns are becoming more unpredictable, this time the year can potentially pass a large number of species and individuals given the right conditions. Therefore the cycle time still needs to remain short in order to pass fish at an acceptable rate. DPI&F recommends changing the attraction time to 30 minutes and the exit time to 15 minutes. The fill and drain valve should be set on 50%.

June, July and August

During the winter months the water cools down and the propensity of fish to move upstream weakens. Some fish will still be moving up and downstream however these are likely to be locally focused movements rather than long distance migrations. DPI&F therefore recommends that the cycle time be lengthened primarily in order to conserve the wear and tear on parts and reduce maintenance levels during these months. Based on the attraction time data DPI&F recommends a 90 minute attraction time and a 30 minute exit time. DPI&F recommends that any maintenance requiring the fishlock to be shutdown to be conducted during this period as this is the time a shutdown would have least effect on fish passage. The fill and drain valve should be set on 50%.

September

September is a month where depending on the weather conditions fish will start to become more active and increasingly start to utilise the fishlock as the weather is starting to warm up. The fishlock cycles therefore need to be reduced. The attraction time should be set at 30 minutes and the exit time at 15 minutes. Although during this time there might not be many large fish moving through the fishway the small fish species will be increasingly migrating upstream and will utilise the fishlock the most during these times. The fill and drain valve should be set on 50%.

October

This month saw the movement of primarily small fish. Some species were mass migrating upstream in extremely large numbers. Operation of the fishlock should be skewed towards the upstream movement of small fish. With varied velocities in the entrance to the entrance chamber throughout a whole cycle small fish of varied swimming ability should have the chance to enter into the lock at some stage. The attraction velocity should be increased to approximately 60% of full open fill valve from 50%. This will cause a greater attraction flow for the small fish but will not limit the passage of small fish with a limited swimming ability such as bony bream (see small fish velocity experiment). It will also help distinguish the fishlock attraction flow from the outlet works flow (which is generally increasing in flow volume this time of year). The cycle time should also be decreased to 15 minutes attraction time and 10 minutes exit time. This will prevent small fish from overexerting themselves trying to stay within the lock chamber and facilitate a reduced stress level on the fish moving upstream.

November

November is a month that is dominated by movement of barramundi downstream. The cycle time of the lock needs to address this issue. The main problem faced by downstream movement of barramundi is finding the downstream flow created around the exit channel. It is therefore recommended that the attraction intensity be increased along with the drain valve during the exit time. These valves should be changed from there present valve of 50% to 75%. The cycle time should also be changed so that the barramundi have more time to find the exit channel (effectively trying to use the exit channel to attract the large barramundi). The cycle times should be changed to reflect a 15 minutes attraction time and a 30 minute exit time.

December

During this month the wet season may have started and the focus of the fishlocks operation should be on fish movement upstream, specifically the first flow for the year. The first flow of the wet season provides the first opportunity for many fish species to move upstream. As such it is important that the fishlock is operational and in good working order. The valves should be changed to their original levels of: fill valve – 50% and drain valve – 50%. The cycle time should be set at 20 minutes attraction time and 10 minutes exit time to allow any upstream migrations ample time to find the entrance to the fishlock while limiting the exit time for a faster cycle time.

Future studies

Although this study has proven the fishlock's worth and effectiveness there are many more details about the movement of fish that are not known. There has been little research conducted on the behaviour of fish in fishlocks and their reactions to changes in velocity throughout a cycle. The velocities in the Clare Weir fishlock vary through each stage in the cycle. A study conducted into the behaviour of different fish species would be recommended in order to establish whether or not the current settings are most appropriate for fish passage in regards to behaviour. New technology such as PIT tags and hydro-acoustics would be best suited to establish the behavioural characteristics of different fish species.

A study for the long term improvement of fish populations should be undertaken. This work should build on a previous study conducted by Marsden and McGill, 2001, that sampled a variety of sites below, around and above Clare Weir and focused on the long term effectiveness that the fishlock has had on fish populations in the Burdekin River. The effect that the fishlock has had on the fish populations in the Burdekin River will not be seen in the short term but rather the long term. This needs to be considered when such a study is undertaken. It may take several years before a significant difference in fish populations and communities can be seen.

Conclusions

The fishlock is having a positive impact on the fish communities within the Burdekin River. It has provided habitat connectivity from the Bowen River, Burdekin River Junction to the estuary (provided that the sand dams are not in place or passable).

The fishlock is operating well and is passing a wide variety of species with different behaviours and morphologies.

The exit channel, despite its length and turns, provides effective passage for fish.

The fishlock is able to cope with mass migrations and large numbers of individuals migrating upstream.

The fishlock is capable of passing a variety of sized fish and has provided passage for small to large fish.

The fishlock is attracting large numbers of fish despite relatively small attraction flows compared to river flows.

The sand dams are having a detrimental effect on the fish passage of primarily catadromous species by restricting access to/from the estuary.

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