Paradise Dam Upstream Fishway Monitoring Program

Final Report

June 2011

for Burnett Water Pty Ltd, contract dated 5 September 2007

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Contents

Contents i

List of Figures ii

List of Tables iii

Glossary iv

Executive summary 1

Introduction 2

Design and function of the upstream fishway 2

Methods 6

Assessment and investigative program results and discussion 17

UA-1 Upstream fish migration at Paradise Dam 17
UA-2 Fish attraction and operational range 26
UA-3 Suitability of fishlift capacity, cycling and entrance conditions 34
UA-4 Fish hopper attraction and fish retention 38
UI-1 Water quality conditions in the fishlift hopper 40
UI-2 Optimum cycle time for each season and flow condition 41
UI-3 Suitability of attraction channel entrance slots 43
UI-4 Occurrence of predation and crowding in the hopper and condition of released fish 45
UI-5 Attraction channel entrance slot conditions 47
UI-6 Suitability of fishlift entrance conditions 49

Conclusion 50

Determine whether the fish passage facilities are effective in achieving the design aims. 50
Establish the constructed design is operating to specification. 51
Provide information that may be of use in the mitigation of the impacts of future water infrastructure developments. 56
Recommendations for the optimisation of operations and/or design over time. 57

Bibliography 59

Appendix A

Appendix B

Appendix C

List of Figures

Figure 1 Paradise Dam outlet release channel and fishway approaches (looking downstream). 3
Figure 2 Entrance to the fishlift and attraction flow valve arrangement (looking upstream from within the fishlift approach channel) 4
Figure 3 Fishway entrance and layout of dam infrastructure (looking upstream).. 5
Figure 4 Schematic of the upstream fishlift at the Paradise Dam... 5
Figure 5 The upstream trap set in place within the fishlift approach channel.. 7
Figure 6 The hopper set in attraction phase within the trapping chamber. 8
Figure 7 The hopper being lifted over the dam 8
Figure 8 A fyke net set in position in the river below Paradise Dam 9
Figure 9 Areas boat electrofished to determine zones of fish aggregation. 10
Figure 10 ADV mounted on an adjustable frame for measuring hydraulic conditions within the fishway. 14
Figure 11 Side view of fishlift approach channel and locations of measurement transects 15
Figure 12 Detection of PIT tagged fish at the upstream fishway and flow release volumes at Paradise Dam from September 2009 to April 2010. 22
Figure 13 Detections of PIT tagged fish at the upstream fishway and flow release volumes at Paradise Dam from April to October 2010. 23
Figure 14 Times of detections of PIT tagged fish detected at the upstream fishway during low to medium flow events 25
Figure 15 Times of detections of PIT tagged fish detected at the upstream fishway during high flow events.25
Figure 16 Box and whisker plots demonstrating data distributions of the number of fish identified during different flow release treatments through the Paradise Dam fishlift entrance slot. 27
Figure 17 Flow conditions downstream of the fishway entrance slot during an environmental outlet tower release of 20 cumecs. 28
Figure 18 Flow conditions downstream of the fishway entrance slot entrance during an environmental outlet tower release of 40 cumecs. 29
Figure 19 Flow conditions downstream of the fishway entrance slot during an environmental outlet release of 60 cumecs. 29
Figure 20 Flow conditions in the fishway entrance slot during an environmental outlet release of 240 cumecs and 150mm spillway flow 23rd September 2010. 30
Figure 21 Fishway entrance slot (spillway) with reverse flow during a 170mm spillway flow and environmental outlet release of 40 cumecs 3rd March 2010. 31
Figure 22 Flow conditions at fishlift entrance slot during increased supplementary attraction flow. 32
Figure 23 Quad leaf gate arrangement at the fishlift entrance slot, red outline shows the screen over the gate hoist 33
Figure 24 Downstream fishway outflows during attraction phase in the outlet release channel. 48
Figure 25 Diagram showing proposed hopper cone entrance modifications that will allow the hopper to be lowered further into the hopper chamber…………………………………………………………………….54

List of Tables

Table 1 Sampling regime for assessment of the upstream fishway. 7
Table 2 Abundance of fish species sampled from all methodologies from 2006 to 2010. 17
Table 3 Proportion of the six most abundant species of fish captured downstream of the dam during fishlift sampling and the proportions of the same species captured in the fishlift hopper and in the fishlift approach channel trap. 18
Table 4 Fish detected at the Paradise Dam upstream fishway PIT tag readers and the operational status of the upstream fishway during detections. 21
Table 5 Fish captured during day and night samples in the hopper. 24
Table 6 Hours of operation for the Paradise Dam fishlift from December 2005 to October 2010 during flow releases. 26
Table 7 Number of fish successfully entering the hopper during varying flow velocities through the fishlift entrance slot……………………………………………………………………………………………………….27
Table 8 Density of fish and biomass captured in the hopper during monitoring. 36
Table 9 PIT tagged fish species, number of fish tagged and detections of fish when the quad leaf gate was open or closed and number of fish the successfully utilised the fishlift. 39
Table 10 Detections of PIT tagged fish during 120 and 30 minute fishlift attraction cycle times..................... 41
Table 11 Proportional time of hopper attraction and total cycle time. 42
Table 12 Fish species, number of fish and mean lengths and mean number of consumed fish that were retrieved from 51 blue catfish in a 24 hour fishway sample... 45

Glossary

Environmental release intake tower

the intake tower located in the impoundment adjacent to the dam wall into which water is drawn for environmental flow releases.

Environmental release outlet

the outlet located at the base of the dam adjacent to the hopper chamber. This outlet contains two hydraulically controlled gate valves from which environmental flow releases of up to 240 cumecs have been made.

Fishlift

a type of fishway that physically carries fish and water in a container over a barrier, usually a dam or high weir.

Fishlift approach channels

two channels lead up to the entrance of the fishlift. One channel originates at the entrance slot from the spillway, whilst the other originates at the entrance slot from the outlet release channel.

Fishlift entrance slot

the 500 mm wide, inclined slot opening located at the upstream extent of the fishlift approach channels. This opening allows fish to enter the fishlift (hopper) within the hopper chamber.

Fishway entrance slot (outlet release channel)

the 500 mm wide, vertical slot opening located at the upstream extent of the outlet release channel. This opening allows fish to enter the fishway from the outlet release channel during flow release from the fishway and/or irrigation valves.

Fishway entrance slot (spillway)

the 500 mm wide, vertical slot opening located adjacent to the spillway apron. This opening allows fish to enter the fishway from the spillway apron below the spillway area during overtopping flow events.

High flow

releases of water made from the environmental release outlet and/or from water overtopping the dam spillway.

Hopper

a component of the fishlift that holds and moves water and fish up and over the barrier.

Hopper chamber attraction flow valves

three valves located on the back wall of the hopper chamber. These provide attraction flows into the hopper chamber and out through the fishlift entrance slot. Water is delivered through three horizontally oriented perforated pipe diffusers at varying heights.

Hopper chamber

the area within the fishway into which the hopper is placed during the attraction phase of the upstream fishway cycle.

Hopper entrance cone

A four-sided meshed panel entrance opening into the hopper. The opening is located at the front of the hopper and tapered to reduce escapement once fish have entered the hopper.

Hopper guide track

the rail track system that guides the hopper up the dam wall during the lifting phase of the upstream fishway cycle.

Hopper hoist

the drum winch that lifts and lowers the hopper to and from the hopper chamber up the dam wall and to and from the impoundment.

Irrigation release intake

the intakes for the irrigation outlets are located within the impoundment, adjacent to the dam wall and entrance to the downstream fishway.

Irrigation release outlets

two irrigation outlets valves located at the upstream extent of the outlet release channel. Each outlet can pass up to 9 cumecs of water into the outlet release channel. Water through one of these outlets can be diverted into a hydroelectric turbine for power production when possible.

Left bank

the bank on the left side of a river when looking downstream.

Low flow

releases of water made from the dam through the fishway valves only.

Main river channel

the original river channel downstream of the Paradise Dam including the bed and banks and water contained within the channel.

Medium flow

releases of water made from the dam through the irrigation outlets. This type of release can also include releases made from the fishway valves.

Outlet release channel

the channel created to deliver water from the dam release valves to the main river channel.

Outlet release weir

the concrete wall located immediately downstream of the irrigation and hydropower outlets. This wall transverses from the right bank abutment across to the adjacent fishway approach channel and forms a barrier to fish.

Quad leaf gate

a mechanically operated gate that opens and closes access through the fishlift entrance slot.

Right bank

the bank on the right side of a river when looking downstream.

Spillway apron

the concrete area directly below the downstream side of the spillway wall that protects the dam wall from erosion.

Supplementary attraction flow valves

two valves located at the upstream extent of the fishlift approach channel. These provide attraction flows directly downstream of the fishlift entrance slot. Water is delivered through two inclined perforated pipe diffusers on either side of the fishlift entrance slot.

Executive summary

At 37 metres high, the Paradise Dam located at 131.2km AMTD on the Burnett River, incorporates the first high lift fish passage facility in Australia. Construction of the dam was completed in November 2005 with the provision of fish passage a requirement under the *Fisheries Act 1994,* Waterway Barrier Works approval. Two fishways were constructed, one, a fishlift, to provide upstream fish passage and another, a fishlock, for downstream fish passage. A condition of the Waterway Barrier Works approval was the implementation of a monitoring program to evaluate the effectiveness of these fishways. This document constitutes the final report detailing the results and recommendations from the upstream fishway monitoring program.

The upstream fishway monitoring program began in July 2005 with data collected until November 2010. The dam did not reach full capacity until March 2010 due to an extended period of drought for the region. During this time monitoring was undertaken during low flow and medium flow releases only. Monitoring during high flows did not occur until March 2010.

The fishway at the Paradise Dam proved to be highly effective at providing upstream passage for the migratory fish community during low and medium flow conditions. Successful fish passage was provided for a wide range of species and size classes. Twenty-nine species of fish were recorded at the dam site and of these 25 species were recorded successfully utilising the upstream fishway. Migratory fish were recorded migrating throughout the year and during all flow conditions. During low to medium flow conditions large numbers of fish successfully used the fishway with over 50,000 fish recorded on a single day. Fish abundance at the fishway increased even with small increases in flow.

The ability of fish to enter into the fishlift (hopper) was dictated by water velocities in and adjacent to the fishlift entrance slot. Lower velocities favoured the entry of small bodied fish species with significantly greater numbers of fish able to move into the fishlift. Longer periods of attraction flows resulted in more fish successfully entering the hopper. Conditions in the hopper appeared to be suitable for the migratory biomass identified utilising the fishway during low to medium flows. Some predation of small fish within the hopper was observed during 24 hour sampling. The recommended fishlift cycle operating regime of 120 minutes improves fish attraction efficiency, prevents crowding and reduces predation opportunity.

The Paradise Dam fishlift was operational for 50% of the time that water was being released from the dam. Non-operational periods were due to mechanical failure of the fishlift system and unsuitable fishway entrance or exit flow conditions that occurred during high flow conditions. For these reasons the fishway was not operated during these times. Entry of fish into the fishway during high flows was compromised by adverse conditions at the fishway entrance slots.

Fish aggregations recorded during high flows, when the fishway was not operating, demonstrate that high flows are a period of peak migration for many species. Larger fish species in particular were most abundant during high flows indicating that the provision of upstream fish passage during high flows is important.

The results of the monitoring program were evaluated against the broad requirements of the Waterway Barrier Works approval issued under the *Fisheries Act 1994*. The design intent of the fishway was that it was to operate over a wide range of headwater and tailwater levels. In practice, operation of the fishway was severely hampered during high flows with operation limited to low and medium flow releases. Fishway entrance conditions were suitable during low to medium flow releases but compromised at high flows. The fishway provided safe passage of most species of fish and a wide variety of size ranges.

Recommendations to improve the efficiency of the fishway during the full range of flow conditions are provided.

Introduction

Paradise Dam, located at 131.2km AMTD on the Burnett River incorporates the first high lift fish passage facility in Australia. As part of requirements under the Waterway Barrier Works approval, and associated fishway directives under the *Fisheries Act 1994*, two fishways were constructed on Paradise Dam, one to provide upstream fish passage and another for downstream fish passage.

A condition of the Waterway Barrier Works approval was the implementation of a monitoring program to evaluate the effectiveness of these fishways. A 'Monitoring Framework' was developed for the Paradise Dam by the Burnett Dam Alliance in consultation with the Queensland Fisheries Services (as they were at the time). The monitoring framework identified that the following objectives were to be addressed:

- Establish the constructed design is operating to specification.
- Determine whether the fish passage facilities are effective in achieving the design aims.
- Provide data for the optimisation of operations and/or design over time.
- Provide information that may be of use in the mitigation of the impacts of future water infrastructure developments.

A number of key questions were established to address the above objectives. These questions are listed in the Upstream Fishlift Assessment and Investigative Program; Table BU5.5.1, in Schedule A of the Accepted Proposal for the Paradise Dam Upstream Fishway Monitoring Program (Appendix A).

The fishway monitoring program incorporated core (assessment) questions consistent with standard fishway assessment methodologies, and non-core (investigative) questions, unique to the Paradise Dam upstream fishway. Whilst both the core assessment questions and the non-core investigative questions were to be undertaken from the outset of the monitoring program, the intent was to complete most of the core assessment components within the first three years of the program. The last two years of the program were to be used primarily to address the non-core investigative monitoring components and to complete any outstanding assessment components.

However, the monitoring program was impacted by a four year delay between the completion of the Paradise Dam in 2005 and the filling and overtopping of the dam in March 2010. As a result, some of the core assessment and non-core investigative components remain outstanding. In addition, the routine operation of the fishlift has been interrupted by an extended commissioning phase due to the low storage levels and unexpected mechanical failures of the fishlift and outlet structures.

This report details the findings of the monitoring program for the Paradise Dam upstream fishway from its commencement in July 2005 up to November 2010. The information presented in this document also draws upon previous annual monitoring reports completed in June 2007, September 2008 and September 2009. Data sourced directly from the above mentioned reports is included within text where required, the three annual reports are provided in Appendix B.

Design and function of the upstream fishway

The fishlift, the first of its kind in Australia, provides passage for upstream migrating fish at Paradise Dam. Fish attempting to migrate upstream at the dam, must first enter the outlet release channel on the right bank of the river (Figure 1). After fish move up this channel attraction flows from the fishway direct them towards the entrance to the fishlift approach channel. Access is provided through a 500 mm wide vertical slot, spanning the depth of the channel, located adjacent to the outlet release weir (Figure 3). The fishway entrance slot concentrates flows and aims to improve fish attraction to the fishlift approach channel. Fish can then move up this channel and are attracted to the fishlift entrance slot by water released through diffusers located in the hopper chamber (hopper chamber attraction flow valves) (Figure 2). When the dam is overtopping, a secondary approach channel adjacent to the spillway (fishlift approach channel) can be used by fish to enter the fishway (Figure 1). A dedicated fishlock fishway was constructed to provide passage for downstream moving fish. A separate monitoring program and associated reports were implemented for the downstream fishway.

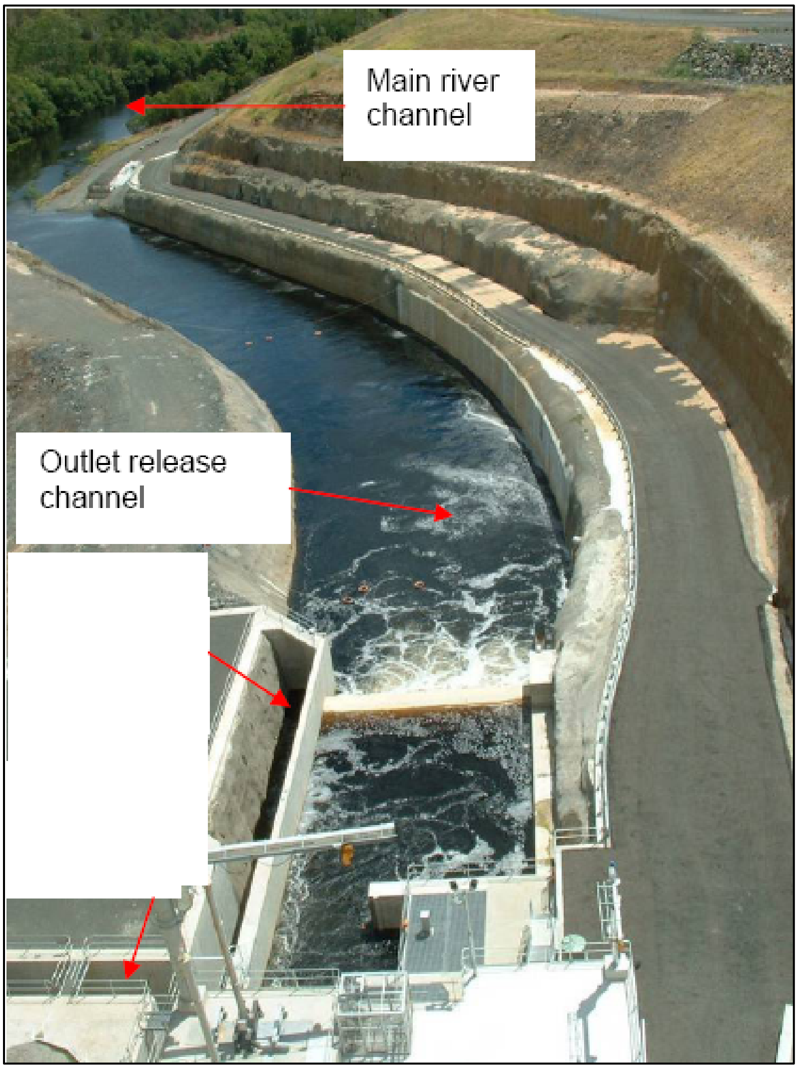

Figure 1 Paradise Dam outlet release channel and fishway approaches (looking downstream).

During the operation cycle of the hopper, fish are retained within the hopper chamber by the hopper entrance cone (Figure 6). The quad leaf gate then closes and the submerged fish hopper, containing water and fish, is hoisted up and over the dam wall and lowered into the impoundment (see schematic Figure 4). Upon entering the water in the impoundment, an actuator on the hopper is triggered automatically and a trapdoor in the hopper base opens and fish are released on the upstream side of the dam wall. The hopper is lifted out of the water and lowered for a second time to ensure that all fish have exited the hopper. The empty hopper is then hoisted back over the dam wall to re-commence the cycle.

Various facets of the operation of the fishway can be altered to suite conditions for passage for upstream migrating fish. For example, when the quad leaf gate is open, attraction flow is released from three horizontally orientated diffusers (hopper chamber attraction flow valves) on the back wall of the chamber (Figure 2). The location and volume of attraction flow can be adjusted to provide optimum conditions for fish attraction. The frequency of hopper lifts over the dam can be adjusted to provide the maximum efficiency of fish passage during a variety of flow and seasonal conditions.

Attraction flow entering the fishlift approach channels is provided via two vertically orientated perforated pipe diffusers (supplementary attraction flow valves), located on either side of the fishlift entrance slot (Figure 2). These operate when the hopper is in the travel phase to maintain attraction flows to the fishlift entrance slot and were intended to operate in conjunction with the hopper chamber attraction flow valves in the hopper chamber during high tail water periods.

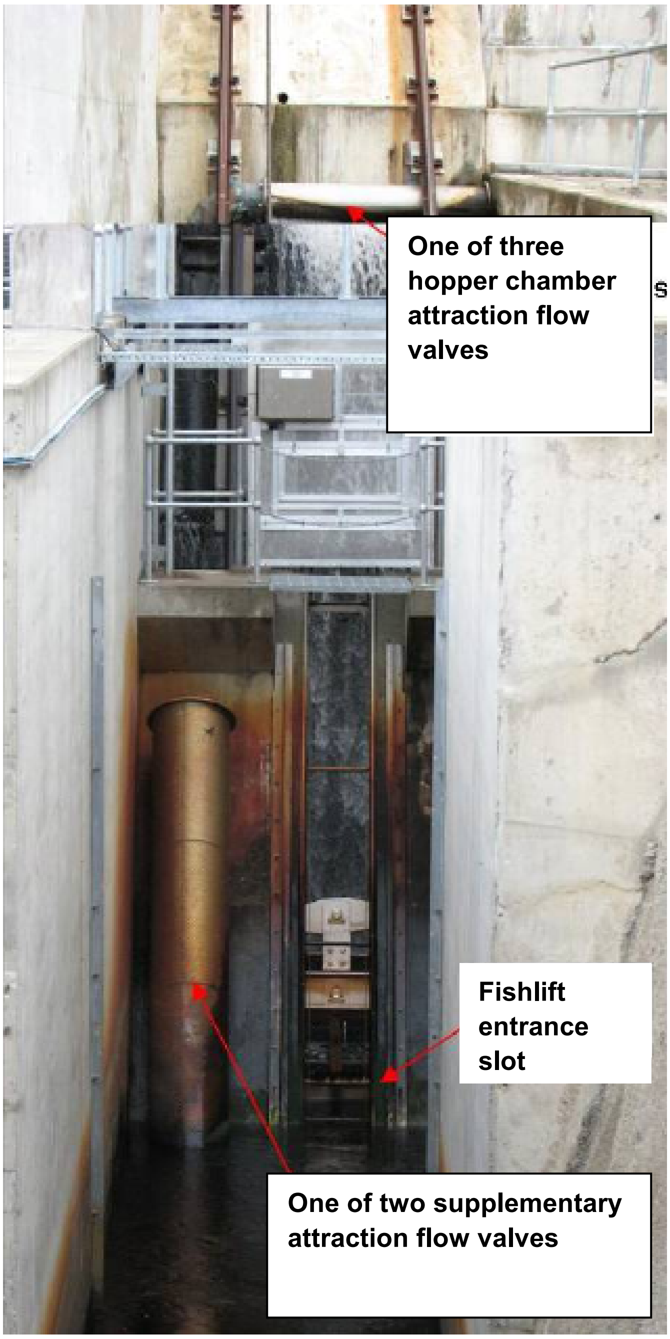

Figure 2 Entrance to the fishlift and attraction flow valve arrangement (looking upstream from within the fishlift approach channel)

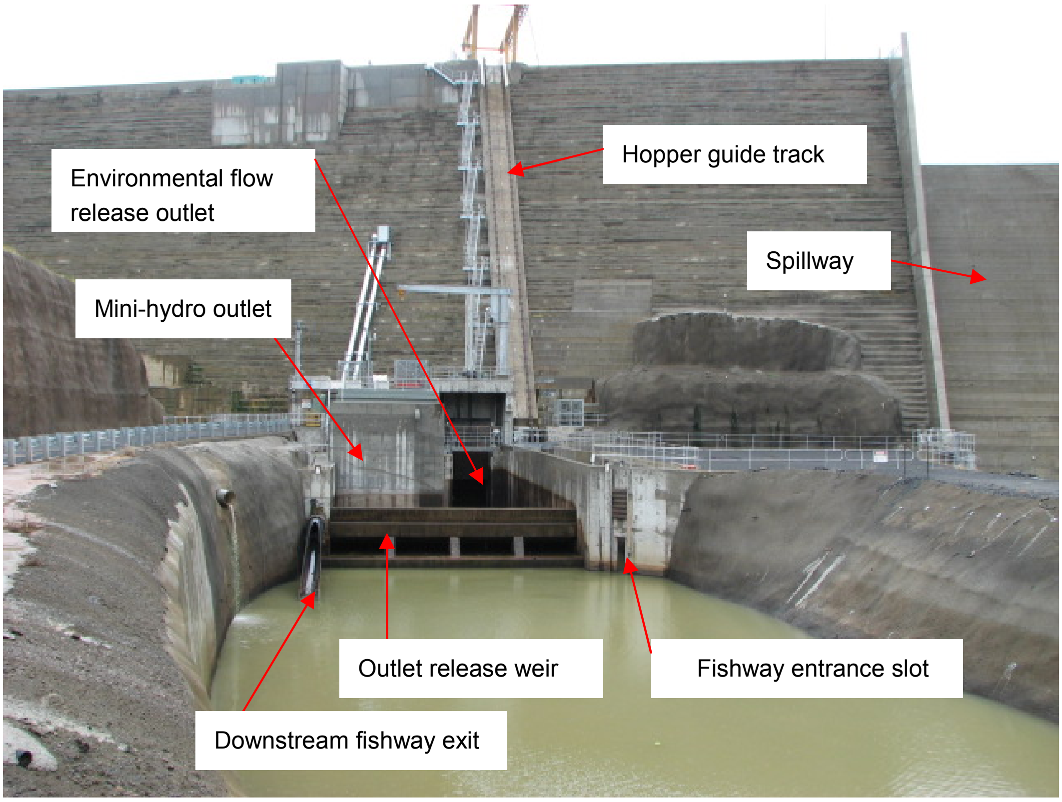

Figure 3 Upstream fishway entrance and layout of dam infrastructure (looking upstream)

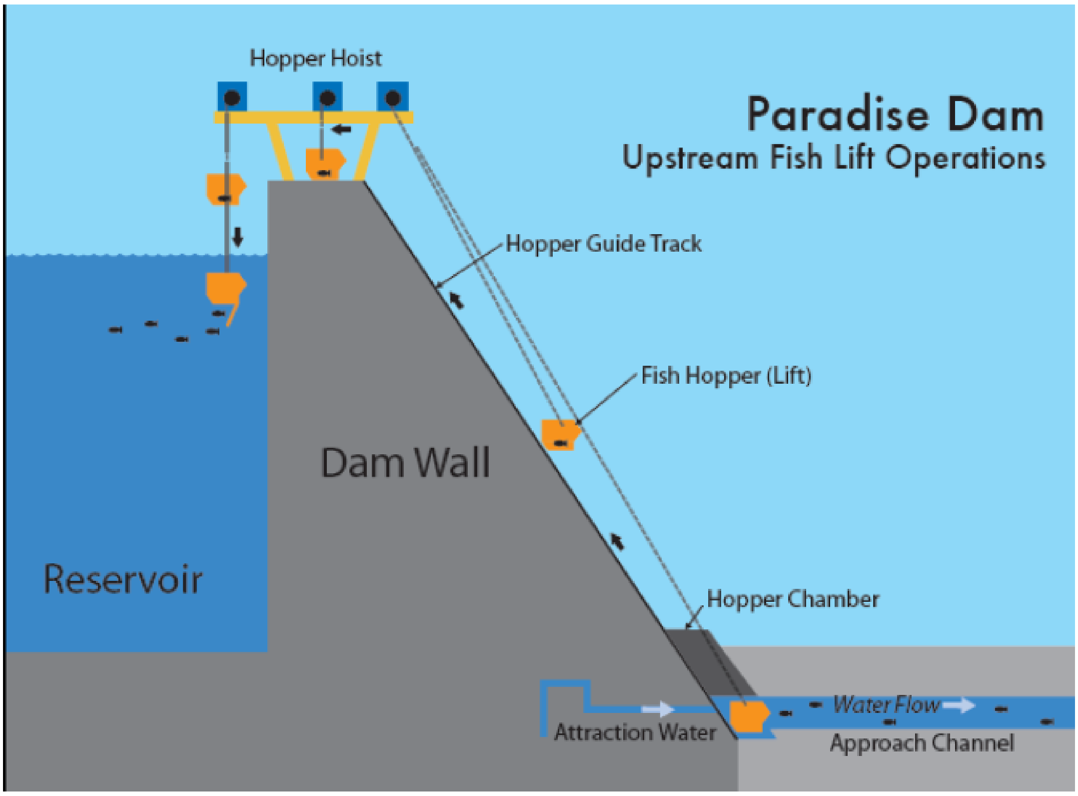

Figure 4 Schematic of the upstream fishlift at the Paradise Dam.

Methods

A number of methods were employed throughout the monitoring program in order to collect information required to address the monitoring objectives. Information required to answer a specific monitoring question may have been derived from either a single method only or from a combination of methods.

Fishway Monitoring

Introduction

The fishlift at Paradise Dam is the first of its type in Australia, and for this reason its effectiveness for providing passage for fish in the Burnett River is unknown. Fishlifts are traditionally monitored in a similar way to other technical fishways such as fishlocks. This involves the direct trapping of the fishway entrances and exits. The numbers, size and species of fish captured in these traps are then compared to ascertain the effectiveness of the fishway. Previous fishway studies on the Burnett River including those on Ned Churchward Weir and Ben Anderson Barrage have used this approach for assessment (Berghuis, *et al* 2000; Stuart and Berghuis, 1999).

Direct trapping of the upstream fishway was employed at Paradise Dam with the entrance of the fishway defined as the area within the fishlift approach channels, and the exit of the fishway defined as the hopper. Once fish had entered and remained within the hopper, they were considered as being successfully transferred past the dam.

The main factor in determining the success of a fishway is that it is able to successfully provide passage for the entire migratory fish community. In order to provide comparative data for fish identified using the Paradise Dam fishway, a sample of the migratory community downstream of dam was also collected.

Method

Three main methods were used to assess the effectiveness of the upstream fishway, including direct trapping, fyke netting and boat electrofishing. All of these methods were used in conjunction with each other during a three to four day sampling period.

Table 1 below outlines the sampling regime for the upstream fishway. A sampling regime consisted of setting either; a trap in the fishlift approach channel of the fishway, or the hopper, for a period of 24 hours. During this first 24-hour period, fyke nets were set in the riverine section below the dam. At the end of this 24-hour period, both the trap or hopper and the fyke nets were cleared and the respective catch recorded. In the second 24-hour period, the trap or hopper (whichever had not been set previously) and riverine fyke nets were set. Once again the respective catches were recorded after sampling. On the final day of sampling, boat electrofishing was conducted to determine areas of fish aggregations below the dam.

For all sample methods, the first 100 individuals of each fish species were measured, with the remainder counted. Data was entered into a purpose built Microsoft Access database and cross checked for validity.

Sampling of the hopper was also undertaken opportunistically throughout the monitoring program to provide further information to address the monitoring objectives. This included the assessment of fishlift entrance conditions on the ability of fish to enter the hopper, the effect of cycling times and the timing and extent of migrations through the fishway under a range of flow conditions.

Table 1 Sampling regime for assessment of the upstream fishway

Day 1	Day 2	Day 3
Set downstream riverine fyke nets	Clear Fyke nets and record catch	Clear Fyke nets and record catch
Set Trap or Hopper	Set downstream riverine fyke nets	Clear Trap or Hopper and record catch
	Clear Trap or Hopper and record catch	
	Set Trap or Hopper (whichever was not set previously)	Boat electrofishing – Zones of Aggregation.

Direct Trapping

When this regime was undertaken, the trap or hopper was randomly chosen to be set first. The trap sample consisted of a single trap with 6 mm mesh and dual cone entrances (at higher tailwater levels, a second set of cone entrances came into effect) lowered and set into the fishlift approach channel (Figure 5). The trap was left in place for 24 hours and lifted at the end of this period. Fish were then sorted, measured, transported and released into the headwater of the dam.

Figure 5 The upstream trap set in place within the fishlift approach channel.

The hopper sample consisted of setting the hopper (Figure 6) in the attraction phase for an amount of time to a maximum of 24 hours. The hopper (Figure 7) is a large solid-based vessel that has a holding capacity of 7500L. The upper portion of the hopper is made of 6 mm stainless steel mesh that allows water to flow through the hopper entrance cone, attracting fish into the hopper and limiting the potential for escapement. After 24 hours the hopper was lifted to the top of the dam where fish were sorted, measured, transported and then released into the dam impoundment.

By using the trap and hopper in consecutive days (24-hour samples each), a paired sample of fish that; 1) entered the fishlift approach channel and 2) were able to enter the fishlift (hopper) and complete migration past the dam, was collected.

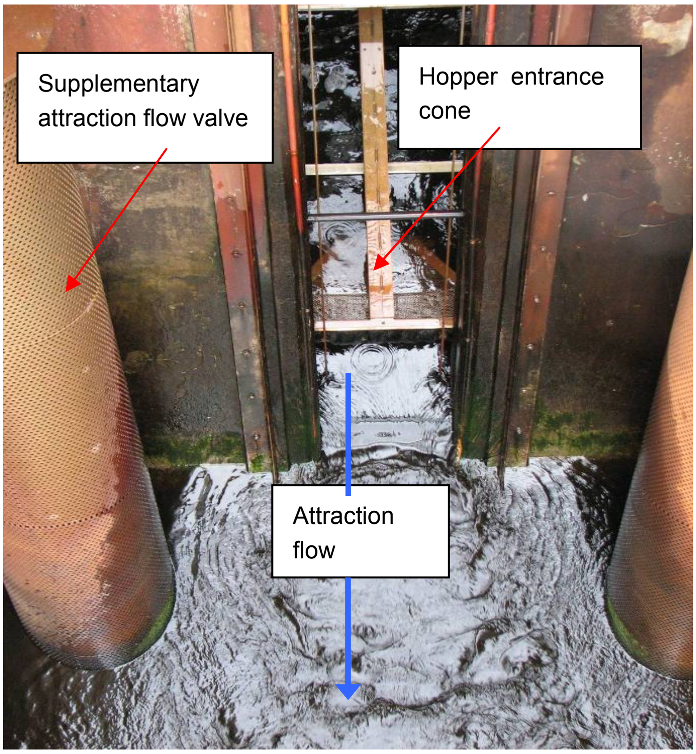

Figure 6 The hopper set in attraction phase within the hopper chamber.

Figure 7 The hopper being lifted over the dam

Fyke Netting

Fyke nets constructed with 12 mm or 4 mm mesh, two 5 metre wings and a single 5 metre funnelled cod end were set in the main river channel approximately 500 metres downstream of the dam (Figure 8). Four to six nets were used in this sample method to reduce the variability in fyke net catches. Each of the nets were set lying parallel to the bank of the river with the opening of the net facing downstream to allow the capture of upstream migrating fish. Fyke netting was undertaken to compare the numbers and species of migrating fish in the main river channel below the dam with those fish that could locate the fishlift approach channel and the hopper.

Figure 8 A fyke net set in position in the main river channel below Paradise Dam

Boat Electrofishing

Boat electrofishing was conducted using a 5.3 m boat fitted with a 7.5 kW Smith–Root electrofisher that produced a pulsed DC waveform. Two operators at the bow of the boat collected stunned fish with dip nets, 4 mm and 12 mm mesh, and placed them into a tank of aerated water until processed. A third person operated the boat and the electrofisher controls. A number of areas below the dam were specifically targeted to determine zones of fish aggregations and the abundance of fish at the dam under varying flow conditions, descriptions are provided below in Figure 9. In addition to these areas, electrofishing was also undertaken directly below the spillway during overtopping events. Comparisons with fish species and numbers collected by other methods were also made. Boat electrofishing sampling began in July 2007 after repairs were made to the boat electrofishing unit.

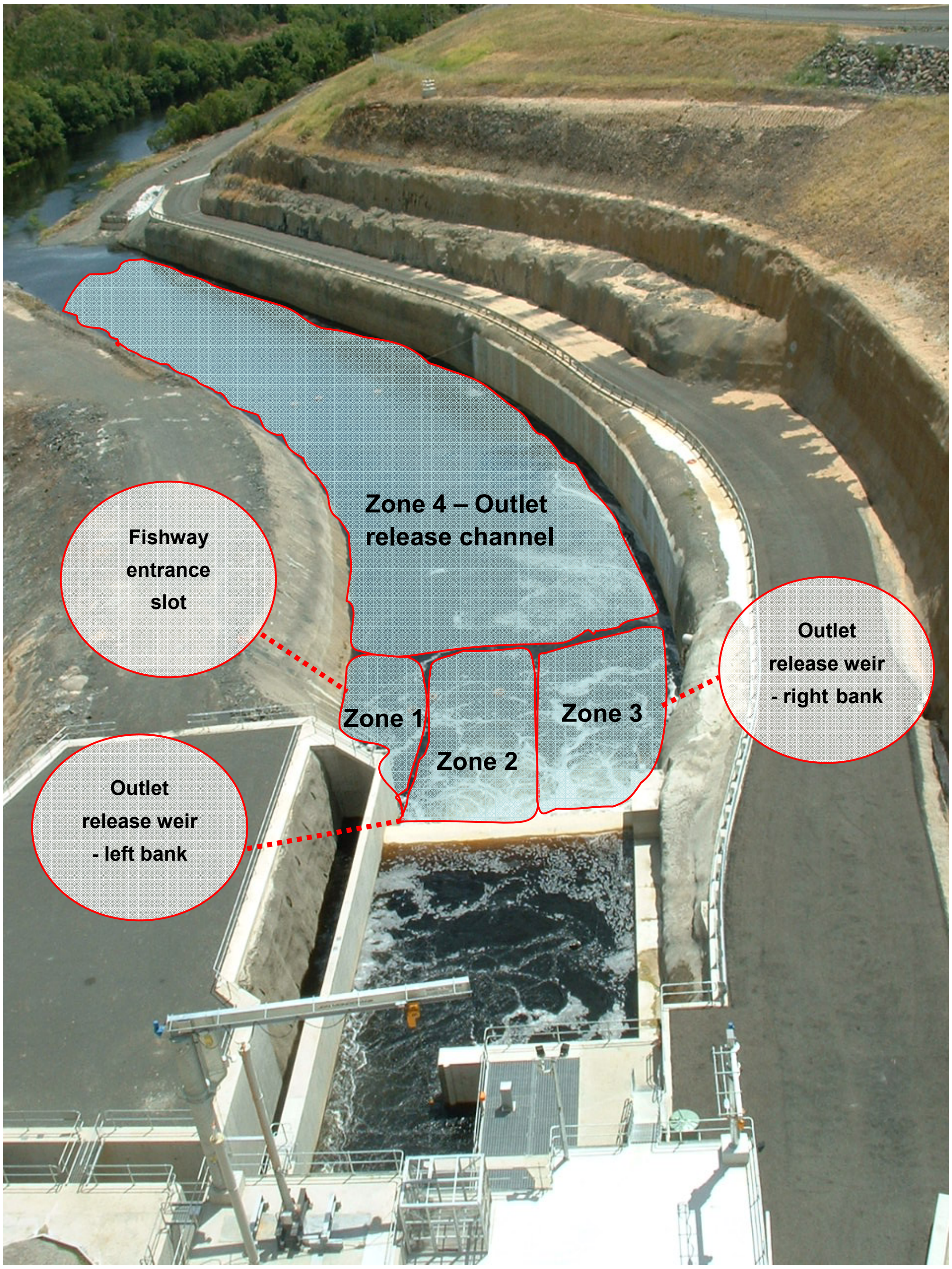

Figure 9 Areas boat electrofished to determine zones of fish aggregation.

Data analysis

A number of statistical methods were employed to determine if there was a significant difference in the fish community captured within the fishlift approach channel (fishway entrance) compared to those captured in the hopper (fishway exit). Non-metric multidimensional scaling (nMDS) ordination (PRIMER 6.0, Plymouth Marine Laboratory, UK) of fish community data was used to examine the similarity between and within entrance and exit samples.

Abundance data for each species was log (1+y) transformed to allow for the Bray-Curtis similarity to take into account rarer and less abundant species in the comparison. This focuses attention on patterns within the whole community, mixing contributions from common and rare species (Clarke and Warwick, 2001).

A one-way Analysis of Similarities (ANOSIM) was used to test the significance of the fish community differences using the ranked Bray-Curtis similarity. If there was a significance difference detected then a similarity percentages (SIMPER) analysis was used to determine which species contributed to the difference between the samples. nMDS ordination was also used for the riverine fyke net samples to graphically represent the differences between the sample replicates. ANOSIM and SIMPER analysis was also performed on this data to determine and explain detected differences.

Length frequencies of abundant species from both the entrance and exit of the fishway were graphed. The ‘D’ statistic for the Kolmogorov-Smirnov two-sample test was calculated and tested to establish if there were any significant differences in the size distribution of each species between the entrance and exit of the fishway. Similarly, the Wilcoxon signed rank test was carried out to test if there were significant differences in the abundance of each fish species between the entrance and exit of the fishway. This test was also used on fish captured in each paired fyke net sample.

Where required for comparative analysis, data collected over different time frames was rescaled to a common Catch per Unit Effort (CPUE). For example when comparing the rates of migration through the hopper, the number of fish captured in a given time was rescaled to the number of fish per minute.

A relative abundance index for each species was calculated from the capture and Passive Integrated Transponder (PIT) detections of fish sampled throughout the entire monitoring program at Paradise Dam. The number of fish was standardised to account for different sampling effort using a Catch per unit effort (CPUE) for each method used (Fyke netting – fish/minute, direct trapping – fish/minute, boat electrofishing – fish/second and PIT tag detections – individual fish detected/day). Data was pooled for each given species during the same months and flow condition that occurred during the monitoring program. The maximum rate of capture/detection for each species (CPUE) was assigned an abundance index of 1. All other rates of capture/detection for each species were related to this value to determine a relative abundance index for each month and flow condition. The final abundance index was then calculated based on the number of methods employed to capture or detect each species during each of the conditions. The relative abundance of each species was compared to the month of capture or detection with the flow conditions that occurred during capture or detection.

PIT tagging program

Introduction

The use of Passive Integrated Transponder (PIT) tags with fixed readers is an established method of recording fish passage through fishways (Castro-Santos *et al*, 1996; Nunnalee, *et al*, 1998). This technique does not require surgery, further handling, or interception of fish during migratory runs. The PIT tags themselves weigh less than 0.6 g and are therefore suitable for relatively small fish. The tags are injected under the skin or within the gut cavity and have no obvious effect on behaviour (Ombredane, et. al, 1997; Braennaes et. al, 1994; Prentice and Flagg, 1987). For this reason the PIT tag reader system, when operational, provided continuous automatic data of fish using the fishway. The detection of a tagged fish at the hopper chamber quad leaf gate (hopper entrance) with no subsequent detections would indicate that the fish has been lifted over the dam wall. Alternately if a fish is not detected at the hopper entrance or is last recorded at the fishlift approach channel antenna then it has not been provided passage over the dam.

Methods

PIT tag reader

The system installed within Paradise Dam incorporates Texas Instruments low frequency (134 kHz) RFID half-duplex technology. Each reader/antenna station comprises of a control module (RI-CTL-MB6A), remote antenna radio frequency modulator (RI-RFM-008B), an antenna-tuning module (RI-ACC-008B) and a double-wire loop antenna. On the upstream fishway, PIT tag reader antennae have been installed in both entrance slots of the fishway and at the fishlift entrance slot (Figure 2 and 3). Any PIT tagged fish detected were recorded and stored on the programmable logic controller (PLC) of the fishway. Fish tag reports from the PLC provided the tag number, location, fishway operational phase and ambient water quality parameters at the date and time of detection.

PIT tags and tagging of fish

In order to obtain quality data from the PIT tag reader system, a number of fish were implanted with PIT tags. Access to 25 tagging sites downstream of the dam were established at both public areas and from within private landholdings. At these sites, fish were collected using a 5.3 m boat fitted with a 7.5 kW Smith–Root electrofisher that produced a pulsed DC waveform. Two operators at the bow of the boat collected stunned fish with dip nets and placed them into an aerated water tank containing a dilute solution of the anaesthetic, AQUI-S (20 mg/L) for light sedation; a third person operated the boat and the electrofisher controls.

All fish captured were measured and scanned to ascertain whether they had been already tagged. Untagged fish above 100 mm in total length were then tagged in the gut cavity except for Queensland lungfish which were tagged in the dorsal muscle. The 23mm Eco-line glass transponders (RI-TRP-REHP) weighing 0.6 grams were implanted using a sterile needle and Henke-ject™ applicator gun. Most tagged native fish were marked with an external plastic t-tag bearing an identification code, the project name and a contact phone number for reporting of re-captures by the public. Brochures were distributed to stakeholders and signs erected at public boat ramps detailing what to look for and how to handle and report a tagged fish.

Fish morphometrics and capture information were recorded against the unique PIT identification number. Occasionally, fish that had been tagged during previous surveys were recaptured in subsequent surveys and the tag details of these recaptured fish were recorded, the fish re-measured and released at the capture point.

The details of PIT tag detections and their timing was analysed and interpreted against flow releases from the dam (SunWater, 2010), downstream riverine flow and water temperature at the Figtree gauging station (This information was provided by the Department of Environment and Resource Management, 2010). This data was used to determine the timing of migrations, factors that may influence these migrations, and conditions most conducive to successful fish passage.

Hydraulic conditions in the fishlift approach channel

Introduction

Determining and quantifying the hydraulic conditions that exist within the upstream fishway is vital in maximising the efficiency of the fishway. The ability of native fish to successfully use the fishway is restricted by the velocities and turbulences that exist in the fishway under various conditions. For this reason flow patterns in the fishlift approach channel and entrance slots were quantified using an Acoustic Doppler Velocimeter (ADV).

Method

A Sontek 10 MHz Splashproof ADV was used to measure the flows in the fishway during low flow conditions in June 2009. This instrument was mounted vertically on an adjustable frame. To ensure accurate results were achieved a suitable frame and bracket system was developed to house and operate the instrument safely and efficiently. Testing was carried out and a final system which allowed the ADV to be lowered and manoeuvred within the approach channel was fabricated (Figure 10). The ADV was then placed at various locations within the fishlift approach channel and entrance slots (Figure 11) to measure the hydraulics in zones of interest.

Figure 10 ADV mounted on an adjustable frame for measuring hydraulic conditions within the fishway.

The zones measured in the fishlift approach channel were:

Zone A – The area directly at the entrance to the fishlift in the same plane as the fishlift entrance slot and quad leaf gate.
Zone B – The area approximately 50 cm downstream of the fishlift entrance slot.
Zone C – The area approximately 90 cm downstream of the fishlift entrance slot.
Zone D – The area adjacent to the supplementary attraction flow diffusers, approximately 180 cm downstream of the fishlift entrance slot.
Zone E – The area 480 cm downstream of the fishlift entrance slot.
Zone F – The area directly at the fishway entrance slot adjacent to the outlet release weir.

Measurement of the flow velocities consisted of lowering the ADV at predetermined localities within the approach channel. This included a total of six transects within the fishlift approach channel. Figure 11 outlines the position of these measuring locations. At each transect location; measurements were taken at regularly spaced intervals in the vertical (depth) and horizontal (width in channel) plane.

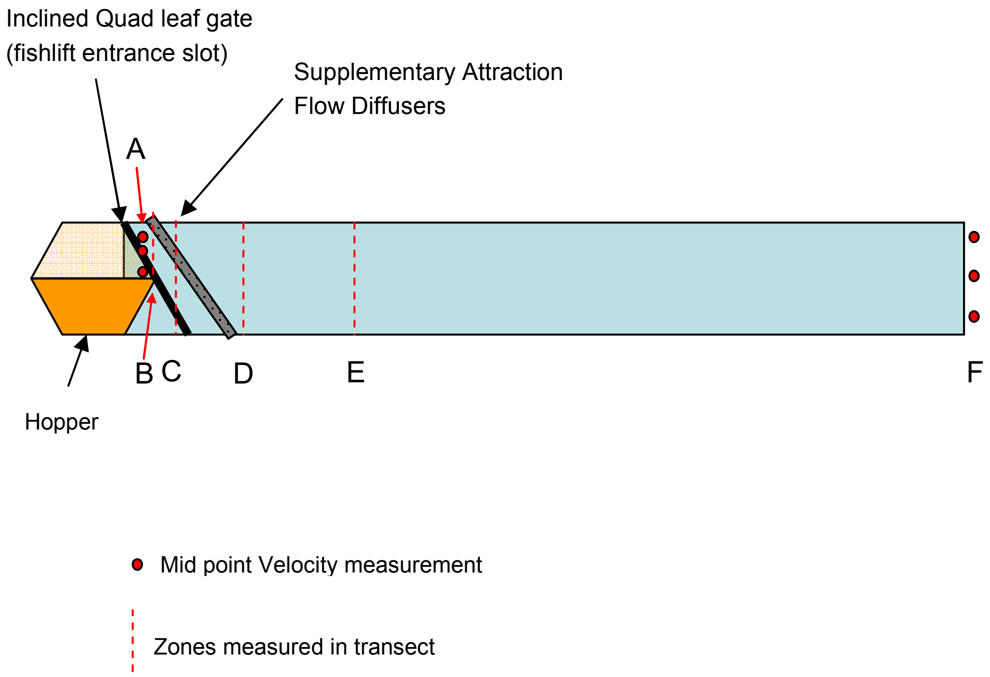

Figure 11 Side view of fishlift approach channel and locations of measurement transects

Points were measured in a grid pattern in the vertical and horizontal plane. Each point in the vertical plane was 200 mm apart and between 200 and 500 mm apart in the horizontal plane. Measurements commenced at 100mm from an edge and 100mm under the surface of the water. Data was recorded at each measurement point for a period of 2 minutes. The ADV was then lowered by 200 mm increments in the vertical plane until 100 mm from the bottom. The ADV was then moved horizontally to the next point across and vertical measurements taken. This was done until the entire width of the channel had been measured.

Midpoint velocity measurements were undertaken in confined areas within the fishlift entrance slot and the fishway entrance slot to provide velocity profiles for these locations.

Post processing and analysis of data was performed using a computer with Sontek Horizon software and WINADV software. Calculation and determination of the velocity magnitude and turbulence intensities were performed. These components are defined as follows. The magnitude of the velocity vector is a measure of the combined velocity vectors (streamwise, u, cross stream, v, and vertical, w, velocities) and provides the overall velocity of water flow at a given point (Odeh, *et al*. 2002)

Turbulence intensities reflect the magnitude of fluctuating components of velocity around the mean velocity (Wilcox and Wohl, 2007). Root Mean Squared (RMS) turbulence of all velocity vectors (u, v, and w) at each location were calculated to describe the turbulence around the mean velocities as described by Odeh, *et al*. 2002.

Assessment and investigative program results and discussion

UA-1 Upstream fish migration at Paradise Dam

What is the species composition and abundance of upstream migrating fish at the site?

Captures from all methods of sampling over the whole duration of the upstream fishway monitoring program yielded 29 fish species, including two non-native species (Table 2). Data includes fish captures from electrofishing surveys performed during overtopping flows when the fishlift was inoperative.

Fish captured downstream of the dam from electrofishing and fyke netting yielded 28 species of fish. The six most numerically abundant species collected downstream of the dam from electrofishing and fyke net samples that corresponded with fishway sampling activities were olive perchlet (*Ambassis agassizii*), western carp gudgeon (*Hypseleotris klunzingeri*), fly specked hardyhead (*Craterocephalus stercusmuscarum*), bony herring (*Nematolosa erebi*), Midgley's carp gudgeon (*Hypseleotris sp. A*) and Hyrtl's tandan (*Neosilurus hyrtlii*) (Table 3). The only species not recorded in the downstream samples was silver perch (*Bidyanus bidyanus*).

Fish captured from fishlift hopper samples only over the entire duration of the monitoring program yielded 25 species (Table 2). The six most numerically abundant species captured in the hopper samples were the same as for the downstream sample (Table 3) with the exception being bony herring. This species was replaced by the non-native mosquito fish (*Gambusia holbrooki*) representing 1.3% of the catch. Species not captured in the hopper samples were the non-native goldfish (*Carassius auratus*), striped mullet (*Mugil cephalus*), barramundi (*Lates calcarifer*) and Rendahl's catfish (*Porochilus rendahli*).

Fish captured from the fishlift approach channel trap samples over the entire duration of the monitoring program numbered 24 species (Table 2). The six most numerically abundant species captured in the approach channel samples were the same as for the downstream sample (Table 3) with the exception being Midgley's carp gudgeon which was replaced by banded grunter (*Amniataba percoides*) representing 3.9% of the catch. Species not captured in the approach channel trap samples were silver perch (*Bidyanus bidyanus*), goldfish (*Carassius auratus*), barramundi (*Lates calcarifer*), Australian bass (*Macquaria novemaculeata*) and Pacific Blue-eye (*Pseudomugil signifer*).

Table 3 Proportion of the six most abundant species of fish captured downstream of the dam, within the hopper and within the fishlift approach channel trap.

		Proportion of species captured		
Common Name	**Genus**	**Downstream**	**Hopper**	**Trap**
olive perchlet	*Ambassis agassizii*	29.1%	8.2%	35.1%
western carp gudgeon	*Hypseleotris klunzingeri*	22.4%	71.1%	22.0%
flyspecked hardyhead	*Craterocephalus stercusmuscarum*	21.9%	7.8%	12.6%
bony herring	*Nematolosa erebi*	9.2%	0.2%	4.7%
Midgley's Carp Gudgeon	*Hypseleotris sp. A*	3.6%	3.4%	3.6%
Hyrtl's tandan	*Neosilurus hyrtlii*	3.4%	5.4%	11.3%

Table 2 Abundance of fish species sampled from all methodologies from 2006 to 2010. N.B. ☹ = non-native species.

Common Name	Genus	Downstream Electrofishing	Downstream Fyke Net	Hopper	Fishlift approach channel trap	Size Range (mm)
olive perchlet	*Ambassis agassizii*	2383	18998	17175	23659	17-86
banded grunter	*Amniataba percoides*	853	47	618	2642	23-180
long-finned eel	*Anguilla reinhardtii*	155	103	703	359	95-1175
blue catfish	*Arius graeffei*	210	896	156	1464	81-488
snub-nosed garfish	*Arrhamphus sclerolepis*	2342	0	2	4	76-208
silver perch	*Bidyanus bidyanus*	0	0	1	0	425-425
goldfish ☹	*Carassius auratus*	54	2	0	0	150-324
flyspecked hardyhead	*Craterocephalus stercusmuscarum*	8658	7402	16371	8469	17-96
mosquito fish ☹	*Gambusia holbrooki*	202	15	2690	359	18-41
mouth almighty	*Glossamia aprion*	170	71	6	3	26-139
western carp gudgeon	*Hypseleotris klunzingeri*	5444	10993	148848	14827	11-55
Midgley's carp Gudgeon	*Hypseleotris sp. A*	1900	716	7208	2427	18-53
barramundi	*Lates calcarifer*	6	0	0	0	900-1111
spangled perch	*Leiopotherapon unicolor*	981	41	1050	1221	32-284
golden perch	*Macquaria ambigua*	298	11	573	168	85-540
Australian bass	*Macquaria novemaculeata*	8	1	19	0	260-485
Duboulay's rainbow fish	*Melanotaenia duboulayi*	526	196	1246	681	12-103
Purple-spotted Gudgeon	*Mogurnda adspersa*	1	50	9	12	25-114
striped mullet	*Mugil cephalus*	34	0	0	1	317-589
bony herring	*Nematolosa erebi*	94415	859	497	3197	42-314
Queensland lungfish	*Neoceratodus forsteri*	31	38	3	4	372-1280
Hyrtl's tandan	*Neosilurus hyrtlii*	11	2518	11278	7606	66-376
sleepy cod	*Oxyeleotris lineolatus*	1	3	2	1	302-418
flathead gudgeon	*Philypnodon grandiceps*	2	92	160	195	16-73
Rendahl's catfish	*Porochilus rendahli*	1	47	0	43	83-190
Pacific Blue-eye	*Pseudomugil signifer*	0	5	1	0	28-37
Speckled Goby	*Redigobius bikolanus*	0	1	50	18	14-42
Australian smelt	*Retropinna semoni*	61	2	555	32	19-65
freshwater catfish	*Tandanus tandanus*	27	91	124	73	47-506
	TOTAL number of fish	118774	43198	209345	67465	11-1280
	Sampling Time (minutes)	*6191*	*219035*	*29759*	*23230*	

When is migration occurring?

Seasonality of migration and response to flows

Data for relative abundances of each species compared to month of record, flow condition and sampling methodology are provided in Appendix C and provide an overview of when migration was occurring at the site. These graphs show the fish community at the Paradise Dam undertaking migrations throughout all times of the year and over a wide range of flows. Data presented in previous reports (Paradise Dam Upstream Monitoring Program Annual Report, 2008 and 2009) demonstrated an increase in the numbers of fish migrating as riverine water temperatures increased as well as responding to changes in flow releases. The following information summarises the migration patterns observed during different seasons and under the three flow release scenarios.

Low Flows

Most species were recorded migrating during low flow periods with a large number of small bodied species undertaking migrations during these times. For example a single fishlift hopper sample during a 2 ML/day release through the fishway in August 2007 captured a total of 14,230 fish comprising of fly-specked hardyhead, western carp gudgeons, Midgley's carp gudgeons and Australian smelt. A review of PIT data showed that increases to rates of fish detections occurred during low flow periods immediately after irrigation releases were stopped (Paradise Dam Upstream Monitoring Program Annual Report, 2008 and 2009).

Medium Flows

During medium flow releases made through the irrigation release outlets, a number of fish species recorded increased rates of migration particularly when medium flow releases were made directly after high flow releases, during significant inflows to the dam or after localised rain events (see *Timing of PIT tag fish detections* below, Figure 12 and Figure 13 below**,** and Paradise Dam Annual Reports 2008 & 2009). For example, 15242 fish dominated by Hyrtl's tandan (10725), fly-specked hardyhead (1906) spangled perch (795), and Duboulay's rainbow fish (697), were captured in the hopper during a single 24 hour period in March 2007 following localised heavy rain at the dam (see Table 7 in the June 2007 Annual Report). During this time 253 ML/day was being released from the irrigation outlets. Similarly, high numbers of long-finned eels (350), golden perch (324), freshwater catfish (60) and Hyrtl's tandan (152) were captured in a 779 minute period during a release of 807 ML/day from the irrigation release outlets and the fishway in September 2010. This release occurred on days in between high flow releases from the environmental release outlet and indicates a significant migratory response for these species.

High Flows

The high flow event in March 2010 resulted in the dam overtopping for the first time. During the recession of this flow event (17^{th}, 19^{th}, 22^{nd} and 24^{th}), electrofishing below the spillway recorded high abundances of bony herring (91614), golden perch (290), snub-nosed garfish (2282), long-finned eels (141), blue catfish (193) and spangled perch (218). No fish were sampled from within the hopper during the same time as the fishlift was inoperable due to mechanical faults. A single trapping event within the spillway fishlift approach channel during a 24 hour period recorded substantial numbers of large bodied fish species including 1206 blue catfish, 1216 bony herring, 151 golden perch and 290 long-finned eel.

During subsequent high flow events in September and October 2010, the fishlift was only operated in between releases made from the environmental release outlet. During these times, water was released through the irrigation release outlets and fishway outlets only. Very high numbers of small and large bodied fish species were captured in the hopper during this period (Table 8) Western carp gudgeons, golden perch, long-finned eel, Hyrtl's tandan, olive perchlet and freshwater catfish were the dominate species during this time.

Timing of PIT tag fish detections

A total of 512 PIT tagged fish from 15 species have been detected at the upstream fishway since the commencement of the monitoring program. The detection of PIT tagged fish represents only a small proportion of all fish that may be present at the fishway at any given time with the recapture rate of all PIT tagged fish of 6.8% (unpublished data, QPI&F) throughout the Burnett River demonstrating that the majority of the fish population remains untagged. Table 4 below shows the number of individual fish detected at the Paradise Dam upstream fishway. Although not all fish detected can be considered undertaking an upstream migration, a change in the number of fish detected at the dam during and after environmental changes (ie. flow and temperature) indicates a behavioural response. Detection data graphed in Appendix C provides an overview of the detections of PIT tagged fish at the dam during various flow conditions over all months.

Data on fish detections at the PIT tag readers when compared with fishway operation and flow releases from the dam (see Table 4, Figure 12 and Figure 13 below, and Paradise Dam Annual Reports 2007, 2008, 2009) identified the following trends:

- Small increases in flow release volumes immediately resulted in increased fish detections.
- Fish detections were greater following increases from low to medium flows.
- Fish detections increased significantly when medium releases were ceased and all flow was then through the fishway.
- The events of March/April 2010 and September/October 2010 demonstrated a migratory response of fish to increased flows (flood flows). Increased detections were recorded even during periods when the fishway was not operational. .
- Releases made from the dam during inflows in August and September 2010 triggered fish to migrate, in particular Australian bass and golden perch.
- Fish were being detected during high flows in September 2010, but significant increases in fish detections occurred on days when the environmental release outlet (flows 1468 to 21660 ML/day) was turned off and smaller medium flow releases were then made through the irrigation release outlets (342 to 807 ML/Day).
- During most years there was a reduction in the number of fish detected at the fishway when water temperatures were below 19.5^{o}C. Increases in detections occurred when water releases were made from the dam or temperatures increased rapidly.

Table 4 Fish detected at the Paradise Dam upstream fishway PIT tag readers and the operational status of the upstream fishway during detections (Fish PIT tagged as part of the Paradise Dam Upstream Fishway Monitoring Program, July 2005 to November 2010).

Common Name	**Number of fish PIT tagged downstream of dam**	**Number of fish detected at the UPSTREAM FISHWAY**	
		UNDER ALL OPERATING CONDITIONS	WHEN FISHWAY OPERATIONAL
banded grunter	11	4	4
long-finned eel	69	8	2
blue catfish	35	8	4
mouth almighty	1	0	-
spangled perch	183	79	55
golden perch	471	225	155
Australian bass	79	16	16
Tarpon	5	0	-
striped mullet	758	18	16
barramundi	6	0	-
bony herring	5	2	-
Queensland lungfish	1773	78	56
Hyrtl's tandan	65	7	3
sleepy cod	4	0	-
freshwater catfish	231	67	54
TOTAL	**3739**	**512**	**365**

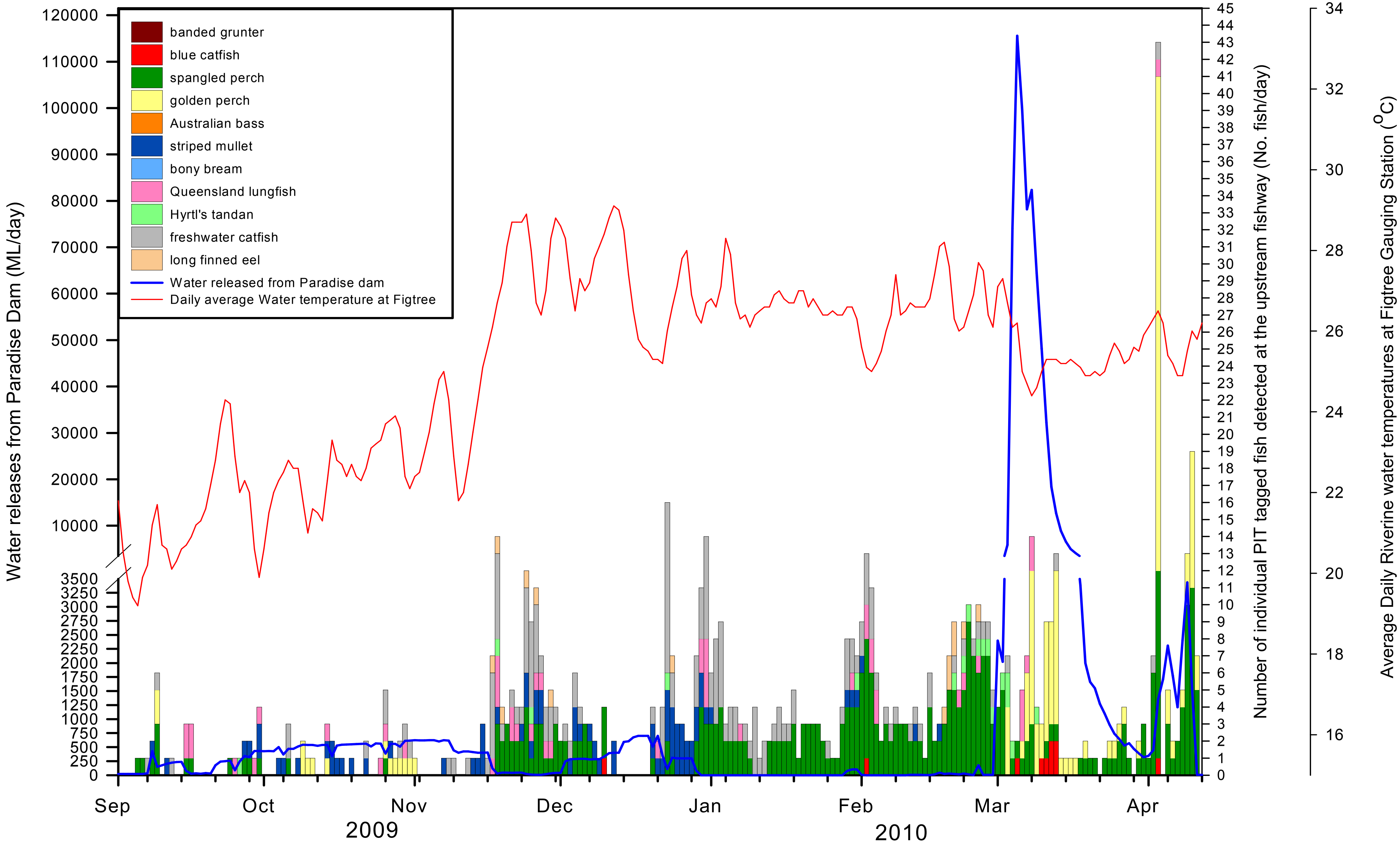

Figure 12 Detection of PIT tagged fish at the upstream fishway and flow release volumes at Paradise Dam from September 2009 to April 2010.

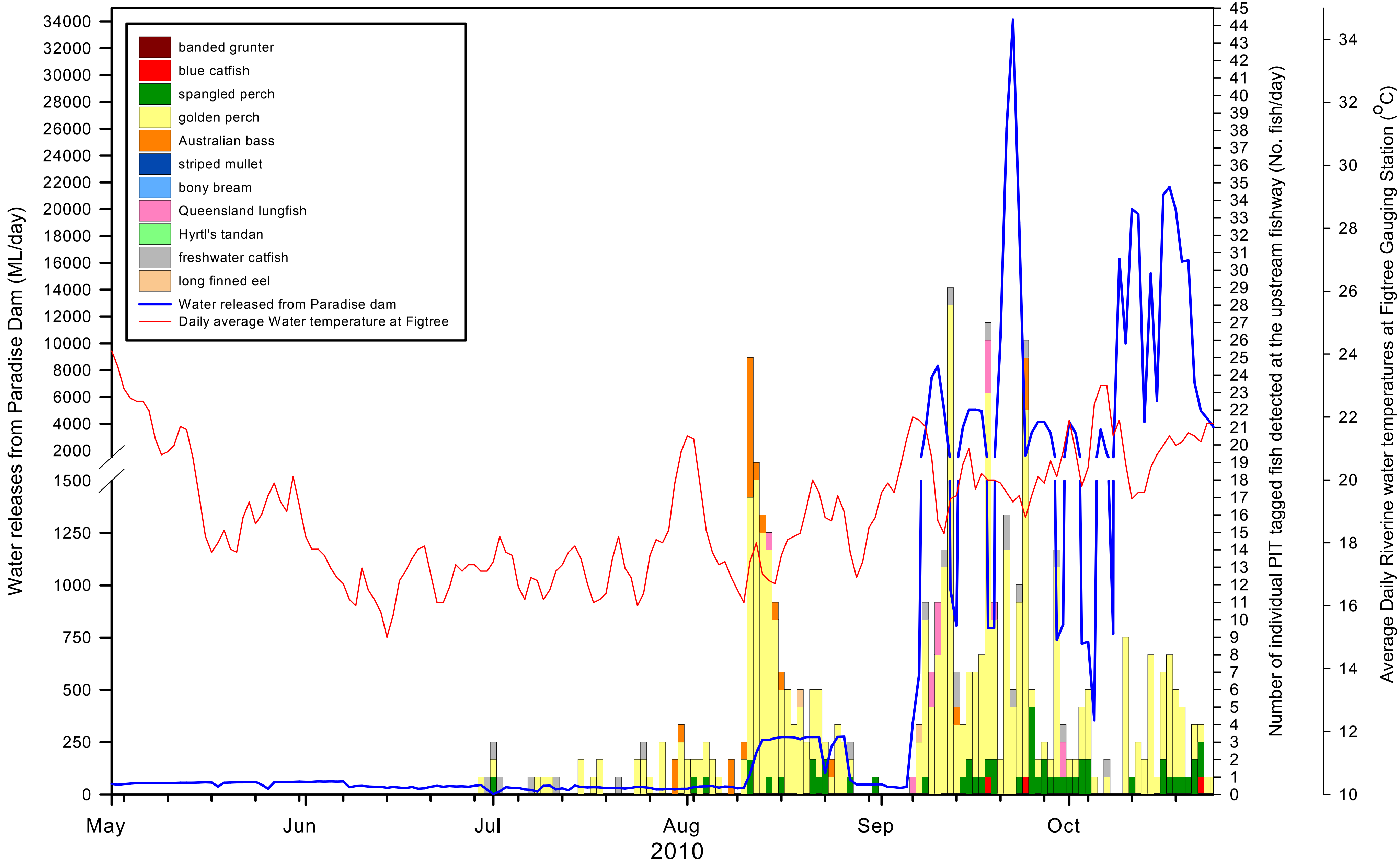

Figure 13 Detections of PIT tagged fish at the upstream fishway and flow release volumes at Paradise Dam from April to October 2010.

Diel patterns of fish activity at the upstream fishway

Fish were detected at the fishway PIT tag readers on a regular basis and during all flow conditions. The time of day in which the detections of fish occurred at the upstream fishway were collated and compared between high flow and low to medium flow conditions (Figures 14 and 15). Detections of PIT tagged fish during low and medium flows demonstrated a peak in activity from around 5pm to 1am. Detections of PIT tagged fish during high flows did not show a discernable peak of detections throughout the day period.

A number of fishlift hopper samples during the monitoring program were separated into day and night time samples. Day time samples used for this comparison were collected over 11 days during July 2008, February, August, October 2009 and August, September, October 2010. These samples were undertaken between 7:10 am and 4:48 pm. During the day samples, captures consisted predominantly of small bodied fish dominated by western carp gudgeon, olive perchlet, Midgley's carp gudgeon, fly-specked hardyhead and Australian smelt (Table 5).

Night time samples were collected over 9 days during August 2009 and August, September 2010. The sample time that these samples were undertaken ranged between 5:00 pm and 9:25 am. Although there were some day time components within some of these samples due to time constraints and logistics of sampling, the majority of total trapping time for each sample was during night periods. This may also explain why there were some small bodied fish species in these samples. Night-time sampling of the fishlift hopper captured few small bodied fish species and was dominated by large bodied species such as long finned eel, golden perch, Hyrtl's tandan, freshwater catfish and blue catfish (Table 5).

Table 5 Fish captured during day and night samples in the hopper during the monitoring program.

Common name	Number of fish captured in hopper during day only samples (time=2513 minutes)	Number of fish captured in hopper during night only samples (time=7526 minutes)
olive perchlet	2464	17
banded grunter	0	28
long-finned eel	48	566
blue catfish	0	38
silver perch	0	1
fly-specked hardyhead	112	0
western carp gudgeon	60103	68
Midgley's carp gudgeon	1331	5
spangled perch	3	8
golden perch	20	502
Australian bass	1	3
Duboulay's rainbow fish	36	7
bony herring	109	12
Queensland lungfish	0	2
Hyrtl's tandan	15	216
flathead gudgeon	56	3
speckled goby	2	0
Australian smelt	183	1
freshwater catfish	0	99
TOTAL	**64483**	**1576**

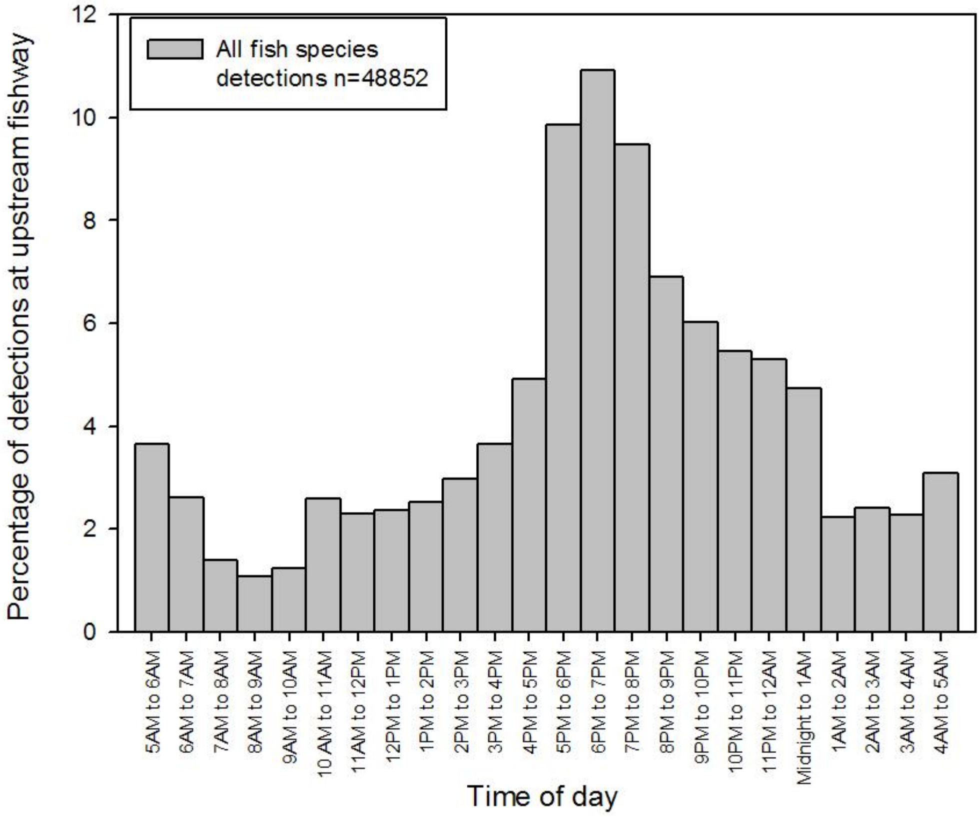

Figure 14 Times of detections of PIT tagged fish detected at the upstream fishway during low to medium flow events

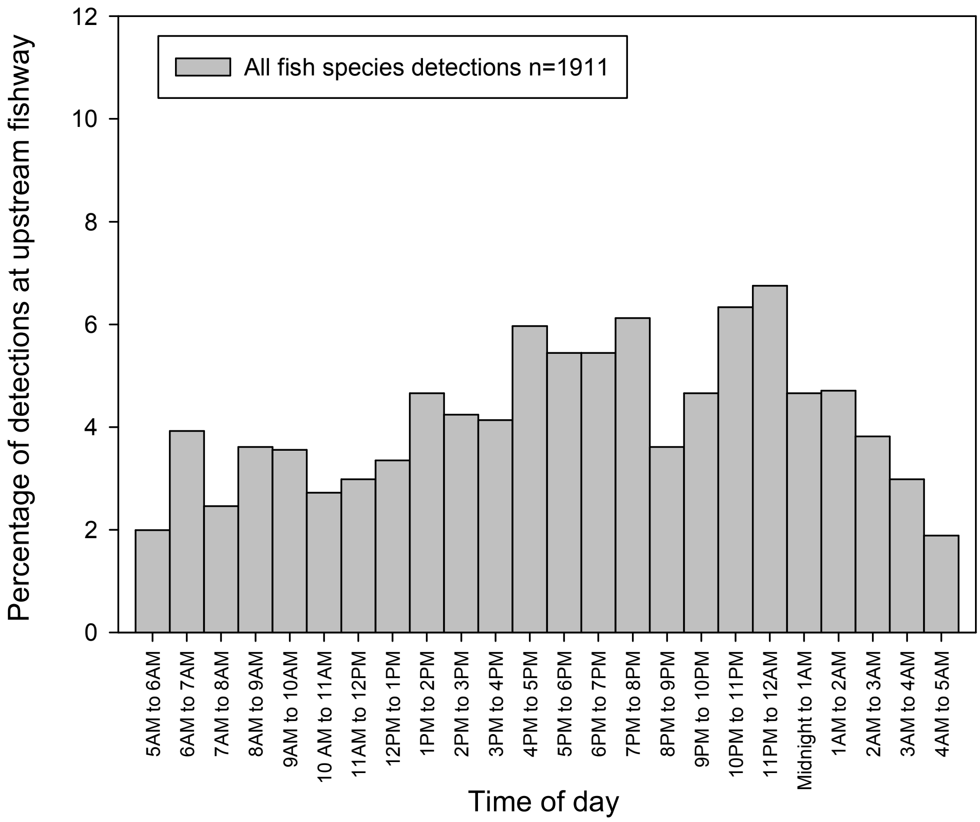

Figure 15 Times of detections of PIT tagged fish detected at the upstream fishway during high flow events.

UA-2 Fish attraction and operational range

Is the operation/design of the fishlift attracting fish to fishway under the full operational range?

During the monitoring program period between 2006 to November 2010 the Paradise Dam fishlift was operational for 50.02% of the time that water was being released from the dam (Table 6). Non-operational periods were due to mechanical failures or unsuitable fishway entrance or exit flow conditions. Attraction flow conditions at the fishway entrances varied according to releases from the fishway irrigation release outlets, the environmental flow release outlet and flows over the spillway. As the Paradise Dam did not fill until March 2010, all data pertaining to environmental flow release outlet and spillway overtopping flows is from this date onward.

Table 6 Hours of operation for the Paradise Dam fishlift from December 2005 to October 2010 during flow releases. *N.B* * indicates operation during a trial monitoring event within the study.

Fishway status	Flow release condition			
	Irrigation Outlets and/or fishlift	Environment flow release outlet	Spillway overtopping	Total
Hours operational	16481.42	0	4.5*	16485.92
Hours non-operational	16470.58	923	993.5	18387.08
Total hours	**32952.00**	**923**	**998.0**	**34873.00**

The hopper chamber attraction flow valves were designed to supply attraction flow into the hopper chamber at EL 30.9 m, EL 34.0 m and EL 38.0 m in order to cater for the range of tailwater operational levels. During early commissioning of the fishlift the attraction flow, released from the uppermost and middle flow valves during low tailwater, cascaded down the incline of the abutment wall, and then flowed through the back wall of the hopper. It was considered that this attraction release created a more natural fish attraction condition by creating an audible cue for fish and highly oxygenated water. All attraction flows were then released equally through all three hopper chamber attraction flow valves at the back wall of the hopper chamber.

Low and medium flow conditions

The fishlift was routinely operated during irrigation and fishway outlet releases and fishway only flow releases. Large numbers of fish were captured in both the upstream fishway trap and the hopper, indicating that fish are attracted in sufficient quantities to the fishlift approach channel and the hopper chamber under low and medium flow conditions. All species were well represented in the fishway when compared to those in the downstream riverine environment (Paradise Dam Upstream Monitoring Program Annual Report, 2008 and 2009).

Hydraulic conditions were found to be suitable for even small or poor swimming fish species (Annual Report 2009) at a 0.17 cumec (~14.7 ML/day) attraction flow. Attraction velocities through the fishlift entrance slot during a 0.17 cumec attraction flow averaged 0.43 m/s. Further experiments, conducted in September 2010, to determine a suitable attraction flow velocity for fish entry into the fishlift hopper were performed at flow rates of 0.25 m/s (0.10 cumecs), 0.8 m/s (0.19 cumecs), and 1.6 m/s (0.28 cumecs) for 5 or 30 minutes attraction cycles. The experiments were undertaken during daytime periods when small bodied fish, in particular western carp gudgeons, were migrating in high numbers (8^{th} and 14^{th} September 2010). Data was standardised to number of fish per minute. These flow trials demonstrated that substantially more small fish were able to enter the hopper during flow velocities of 0.25m/s compared to any other treatment (Table 7). Figure 16 demonstrates the data distributions of fish numbers from all treatments in the trial.

Table 7 Number of fish successfully entering the hopper during varying flow velocities through the fishlift entrance slot (n=3 for each velocity trial).

Velocity	**0.25 m/s**		**0.8 m/s**		**1.6 m/s**	
Common Name	Fish/minute	Length (mm)	Fish/minute	Length (mm)	Fish/minute	Length (mm)
olive perchlet	144.3	34-76	29.5	36-59	1.0	NR
long-finned eel	0.3	135-170	1.0	110-160	1.6	115-165
fly-specked hardyhead	3.4	36-59	0.9	36-58	0.0	-
western carp gudgeon	9509.9	26-49	327.8	31-43	53.4	31-48
Midgley's carp gudgeon	5.1	25-46	2.3	27-43	0.0	-
Duboulay's rainbow	1.1	46-67	0.1	55-65	0.0	-
Hyrtl's tandan	0.6	186-278	3.8	190-277	0.6	207-258
flathead gudgeon	0.6	18-62	0.0	-	0.0	-
Australian smelt	18.5	32-46	0.1	39-43	0.8	39-43
TOTAL	**9683.8**	**18-278**	**365.6**	**21-277**	**57.4**	**31-258**

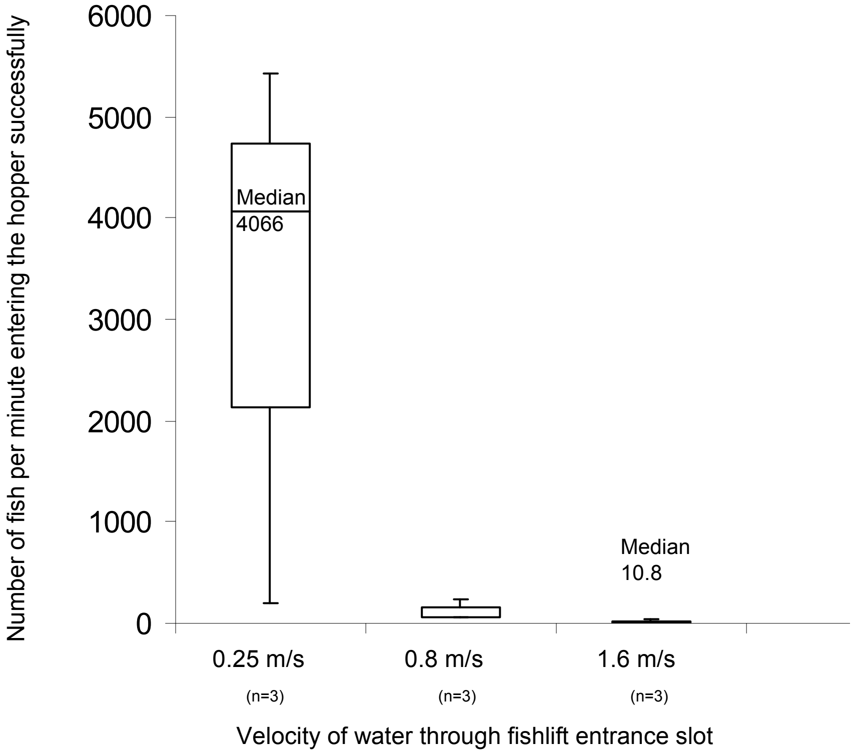

Figure 16 Box and whisker plots demonstrating data distributions of the number of fish identified during different flow release treatments through the Paradise Dam fishlift entrance slot.

The ability to manipulate attraction flows through the fishlift entrance slot is suitable; however the use of pulsed attraction flows would as specified and designed in BDA 2004 are not currently achievable. The provision of pulsed attraction flows will improve the number of fish using the fishlift. The total open area of the fishlift entrance slot could be increased to improve the range of attraction flows that could be released through the fishlift entrance slot.

High flow conditions – environmental flow releases

Flow from the environmental release outlet accounted for 18% of the duration of flow since the filling of the dam in March 2010. Releases greater than 20 cumecs (~1730 ML/day) created a differential whereby the water level in the fishlift approach channel was locally higher than the level in the outlet release channel. Due to the water level differential, a jet of high velocity water was released from the fishlift approach channel into the outlet release channel. In addition the flow jet from the environmental release outlet created a highly turbulent area directly downstream of the fishway entrance slot under all flow release volumes. Figure 17, Figure 18, Figure 19 and Figure 20 demonstrate flow conditions at 20, 40, 60 and 240 cumecs respectively.

Figure 17 Flow conditions downstream of the fishway entrance slot during an environmental outlet release of 20 cumecs.

Figure 18 Flow conditions downstream of the fishway entrance slot during an environmental outlet release of 40 cumecs.

Figure 19 Flow conditions downstream of the fishway entrance slot during an environmental outlet release of 60 cumecs.

Figure 20 Flow conditions in the fishway entrance slot during an environmental outlet release of 240 cumecs and 120mm spillway flow 23rd September 2010.

High flow conditions – spillway releases

Spillway overtopping flows accounted for 17% of the duration of flow since the filling of the dam in March 2010. Spillway overtopping flows created a differential where the water level in the main river channel was higher than in the fishlift approach channel. Due to the water level differential a jet of high velocity water entered the fishlift approach channel via the spillway in a reverse direction flow (Figure 21).

Figure 21 Fishway entrance slot (spillway) with reverse flow during a 170mm spillway flow and environmental outlet release of 40 cumecs 3rd March 2010.

Reverse flows were observed entering through the spillway fishway entrance slot under all spillway flow conditions and during high volume environmental outlet flow releases. The hopper attraction and supplementary flows required to operate both the spillway and outlet release channel fishway entrance slots created adverse conditions for fish entry into the hopper (Figure 22).

Figure 22 Flow conditions at fishlift entrance slot during increased supplementary attraction flow (Left supplementary diffuser valve at 100%, Right supplementary valve at 7%).

A single trapping event over 24 hours to assess fish entering the approach channels via the outlet release channel and spillway entrances was performed during spillway flows in March 2010. During this time the fishway entrance slot adjacent to the outlet release weir was blocked and the supplementary attraction flow valves were opened at or near full capacity. Substantial numbers of large fish species (refer to section - *When is migration occurring?*) and low numbers of small species were captured. Trials to assess whether fish were able to enter the hopper under spillway flow conditions were attempted during the September 2010 flow event but were abandoned due to fluctuating water levels in the fishlift approach channel and SunWater safety concerns. The control system could not cope with the fluctuations detected by the level sensors and tripped out the operation of the fishway. Opportunity to further evaluate fish entry success into the hopper during spillway overtopping flows did not become available in the time frame of the current monitoring program.

Flow patterns directly downstream of the spillway leading up to the fishway entrance slot appeared to be suitable during overtopping flows with no areas of obvious high turbulence or reverse flows. The embankment of the dam provided adequate protection of the fishway entrance slot from water flowing over the dam wall.

The PIT tag readers continued to provide data on tagged fish throughout the full range of flow conditions. During overtopping flows, fish were still detected at the fishlift entrance slot despite there being no fishlift attraction flow. Data presented above in UA-1 of the current document details information on fish detections at the fishlift entrances.

At the top of the quad-leaf gate, a hoist with a screen was installed to prevent human injury when the fishlift was operating. At tailwater levels where the fishlift entrance slot is set above the top of the quad-leaf gate, fish access into the hopper will be blocked by the screen (Figure 23). This would reduce the effective operating range of the fishway.

Figure 23 Quad leaf gate arrangement at the fishlift entrance slot, red outline shows the screen over the gate hoist.

During low and medium flow conditions, the operation and design of the fishlift is attracting fish to the fishway. However, a number of improvements can be made to increase the effectiveness of the fishlift system. During high flow conditions the fishlift was not operational. Without modifications to the operation and design of the system, the fishlift would not be effective at attracting fish to the fishway in order to provide effective fish passage.

UA-3 Suitability of fishlift capacity, cycling and entrance conditions

Is the capacity of the fishlift suitable for passage of the migratory biomass within an acceptable timeframe?

The capacity of the hopper was identified as an important feature of the Paradise Dam upstream fishway in its ability to safely transport the migrating biomass of fish over the dam wall and into the impoundment. A number of factors determine the carrying capacity of any fish transport system including the efficiency of the aeration system, duration of the transport, water temperature, fish size and fish species (Piper et al. 1982). Most data relating to this topic is centred on the aquaculture industry and truck and transfer technologies of the USA and UK, particularly for coldwater fish species. With such a scarcity of information on this topic, the theoretical carrying capacity of the hopper at Paradise Dam was unknown at the commencement of this program.

The volume of the hopper at Paradise Dam is 7500 L and the time for the hopper to be lifted from the bottom of the dam and lowered into the impoundment is relatively short (approximately 12 minutes). Due to this short time frame, high numbers of fish can be moved upstream without risks to fish health resulting from high levels of ammonia and other waste products. The depletion of dissolved oxygen from the hopper as it travels was identified as a potential issue during peak migration periods when high numbers of fish would be using the fishway. However, fish released from the hopper were always observed to be in excellent condition and displayed normal behaviour.

Results collected throughout the monitoring program demonstrate that extremely high numbers of fish can be safely moved within the hopper and the carrying capacity may only be limited by physical numbers of fish during peak migration periods (i.e. during flood flows). During 496.48 hours of hopper monitoring the fishlift transferred 209,345 fish at a maximum rate of over 50,000 fish per day. Up to October 31st 2010 the fishlift had operated for 16486 hours so it is likely that the fishlift has transferred millions of fish. The expected maximum biomass demand was calculated from previous fishway assessments on weirs in the Burnett River. The maximum number of fish identified utilising the Ned Churchward Weir fishlock was 3823 in 24 hours, fish comprising mostly bony herring (Berghuis, Broadfoot et al. 2000).

Unprecedented high numbers of fish were sampled within the hopper on a number of occasions throughout the monitoring program (Paradise Dam Annual Reports 2008, 2009). Table 8 details the density and calculated biomass of fish captured within the hopper on four separate sampling events. The December 2007 sample recorded the highest density of fish within the hopper, with 51743 fish. This sample was comprised of mainly small bodied fish such as western carp gudgeons with the overall mean length of all fish 37 mm and the total weight of all fish 28.8 kg. Large bodied fish species were also recorded in high densities within the hopper immediately following high flow releases through the environmental release outlet in September 2010. Although there were only 905 fish at an average length of 306 mm, the total weight was estimated at 495 kg. A five minute sample in September 2010 recorded the highest migration rate throughout all the monitoring with 5423 fish per minute (an estimated 2.2 kg/minute) entering the hopper. This was dominated by western carp gudgeons with an average length of 36 mm.

Small fish need more water per weight than larger fish (Piper et al, 1982) and do not require as much physical room as evidenced by the extremely high numbers captured in the hopper (Table 8). The load densities observed in the hopper during the monitoring program were well within guidelines (0.2 kg/L) set for fish salvage operations without sophisticated aeration systems (DPI&F, 2004). The increased biomass at Paradise Dam is likely to be due to the high numbers of small bodied fish species present at the dam site and the conditions in the fishway being highly suitable to small bodied fish under low and medium flow conditions.

All fish captured in the hopper during these peak migration rates were in excellent condition with no evidence of stress identified despite the high abundances observed in a relatively small volume of water. The physical size and capacity of the hopper and speed at which fish are transferred into the impoundment is suitable. The number and condition of fish captured the hopper demonstrates that the fishlift is suitable for the passage of the migratory biomass within an acceptable timeframe.

On a number of occasions throughout the monitoring program, small bodied fish species and eels were observed escaping from the hopper whilst in travel mode. These fish were able to escape through the joint between the solid and mesh sections of the hopper. This was particularly evident after the hopper had changed direction causing a wave action to the water inside. Investigations should be made to completely seal this joint to minimise the risk of fish escaping from the hopper during travel mode.

Table 8 Density of fish and biomass captured in the hopper during monitoring.

Sample Date	27.03.2007 (Day and night)			13.12.2007 (Day and night)			12.09.2010 (Night only)			14.09.2010 (Day only)		
Sample time (minutes)	1410			1440			779			5		
Water temperature (°C)	23			25			23			23		
Size grouping of fish (small bodied species includes gudgeons, hardyhead, rainbows, perchlets, gobies, smelt)	Large bodied fish species	Small bodied fish species	Total all species	Large bodied fish species	Small bodied fish species	Total all species	Large bodied fish species	Small bodied fish species	Total all species	Large bodied fish species	Small bodied fish species	Total all species
Total number of fish	12139	3103	15242	39	51704	51743	898	7	905	1	27114	27115
Number of fish per Litre	1.6	0.4	2.0	0.01	6.89	6.9	0.1	0.001	0.1	0.0001	3.6	3.6
Mean length (mm)	124	52	92	176	37	37	308	65	306	170	36	36
Weight of fish (kg)	141.3	3.7	145	5	23.8	28.8	494.7	0.019	494.8	0.008	10.8	10.8
Fish weight to Volume (kg/L)	0.02	0.0005	0.02	0.001	0.003	0.004	0.07	0.000003	0.07	0.000001	0.001	0.001
Migration rate (fish/minute)	8.6	2.2	10.8	0.03	35.9	35.9	1.2	0.01	1.2	0.2	5422.8	5423.0
Biomass rate (kg/min)	0.1	0.003	0.103	0.003	0.017	0.02	0.635	0.00002	0.635	0.002	2.2	2.2

N.B. The weight of fish has been determined by the length weight relationship for each species, using data collected by Heidenreich and Lupton, 1999, from sites within the Burnett River system.

Are all of the most abundant species and size classes directly downstream of the dam successfully utilising the fishlift?

Most species have been represented in the exit of the fishway (hopper samples) when compared to those species found in the fishlift approach channel (trap samples) and downstream riverine areas (fyke net and electrofishing samples) (UA-1 in this report, Paradise Dam Annual Report 2008). Barramundi, Rendahl's catfish, striped mullet and the non-native goldfish are the only species that have not been captured or recorded using the fishlift, but have been captured in either the fishlift approach channel (trap samples), or the downstream riverine fyke net and electrofishing samples.

Investigation using SIMPER analysis showed that dissimilarities in species representation between the sample locations were caused by species which only occurred in low abundances. Species that are undertaking upstream migrations in large numbers in the riverine areas below the dam are well represented in the hopper at similar times. This demonstrates that most species can successfully locate the entrance to the fishway and are then able to move within the approach channel and enter the hopper. The number of species captured successfully migrating upstream at the Paradise Dam fishlift exceeds the number of fish successfully migrating upstream at other fishways in the Burnett River. Previous fishway designs have had limited successful passage of small fish (Stuart and Berghuis, 1999; Berghuis, Broadfoot *et. al.* 2000).

Most size classes were well represented in the exit of the fishway when compared to the entrance samples and with fish captured downstream of the dam (Paradise Dam Upstream Monitoring Program Annual Report 2008, 2009). Results showed that fish from a variety of species, including western carp gudgeon, as small as 11mm, and Queensland lungfish, as large as 969 mm, were able to successfully use the fishway and migrate past the dam.

UA-4 Fishlift attraction flows and fish retention

Are the attraction flow and cone traps sufficient to retain fish in the holding chamber during hopper travel phases?

Dewatering of the fishlift approach channels and subsequent collection of fish remaining in the approach channel during hopper travel phases was deemed impractical. Alternative methodologies were employed to resolve the above monitoring question. The PIT tag reader data for tagged fish detected at the fishlift entrance slot under a range of conditions provided an indication of fish behaviour. Seventy-two percent of fish detected at the fishlift entrance slot during fishway operation from March 2006 to October 2010, were recorded when the quad-leaf gate was open and 28% of fish when it was closed (i.e. while the hopper was being hoisted up and over the dam wall into the impoundment or while the hopper was being hoisted back over the dam wall to recommence its cycle).

Fish can be detected at the fishlift entrance slot PIT tag reader antenna either as they swim through the fishlift entrance slot into the hopper or as they swim past the fishlift entrance slot, remaining in the fishway approach channel. If the last detection of a PIT tagged fish was at the fishlift entrance slot PIT tag reader antenna and there were no subsequent detections at any other upstream fishway antenna location it was assumed that the fish had successfully migrated upstream. Of the 214 PIT tagged fish detected when the quad leaf gate was open, 177 or 83% were considered to have successfully migrated through the fishway. This relatively high percentage indicates that the cone trap is sufficient to retain fish within the hopper. During the sampling program, golden perch were the most detected species with 150 fish detected, of these 122 were detected when the quad-leaf gate was open and 121 or 99% of these individuals successfully migrated upstream through the hopper. Data on the success rates of other species is provided below in Table 9.

Trials to determine a suitable cycle time for the upstream fishlift provided an indication of the efficiency of the upstream fishlift to retain fish during the hopper travel phase. The data from the cycle time experiments provided in UI-2 below (Table 10) demonstrated that a longer attraction period with the quad leaf gate open provides greater opportunity for fish to enter and be retained in the hopper. Although analysis of the detection data did show fish remaining at the entrance to the fishlift during travel phases, fish were more likely to successfully use the fishway when the quad leaf gate was open.

Table 9 PIT tagged fish species, number of fish tagged and detections of fish when the quad leaf gate was open or closed and number of fish the successfully utilised the fishlift. (Fish PIT tagged as part of the Paradise Dam Upstream Fishway Monitoring Program, July 2005 to November 2010).

Common Name	Total number of fish tagged downstream of the dam	Number of fish detected at the FISHLIFT ENTRANCE SLOT: DETECTIONS WHEN FISHWAY OPERATIONAL	FISHWAY OPERATIONAL Quad leaf gate **CLOSED** **(NO opportunity for fish to use fishlift)**		FISHWAY OPERATIONAL Quad leaf gate **OPEN** **(Opportunity for fish to use fishlift)**		Number of PIT tagged fish successfully using the fishway(1)	
banded grunter	11	3	-	-	3	100%	2	67%
long-finned eel	69	2	-	-	2	100%	2	100%
blue catfish	35	3	2	67%	1	33%	1	100%
mouth almighty	1	-	-	-	-	-	-	-
spangled perch	183	44	23	52%	21	48%	11	52%
golden perch	471	150	28	19%	122	81%	121	99%
Australian bass	79	15	2	13%	13	87%	13	100%
Tarpon	5	-	-	-	-	-	-	-
striped mullet	758	11	6	55%	5	45%	1	20%
barramundi	6	-	-	-	-	-	-	-
bony herring	5	-	-	-	-	-	-	-
Queensland lungfish	1773	33	16	48%	17	52%	10	59%
Hyrtl's tandan	65	1	-	-	1	100%	1	100%
sleepy cod	4	-	-	-	-	-	-	-
freshwater catfish	231	34	5	15%	29	85%	15	52%
TOTAL	**3739**	**296**	**82**	**28%**	**214**	**72%**	**177**	**83%**

(1) Success of a PIT tagged fish using the fishway has been determined by the following assumption: the last detection of a PIT tagged fish was at the hopper entrance and there have been no subsequent detections at any other upstream fishway antenna location.

UI-1 Water quality conditions in the fishlift hopper

Is the water quality (dissolved O^2) in the fishlift hopper maintained for the entire lift phase and is there a significant difference between water quality in the hopper and the impoundment?

Dissolved oxygen levels within the hopper were not evaluated during the monitoring program as observations of fish behaviour and condition provided a more suitable indication of the impact of water quality conditions on fish in the hopper. With unprecedented high numbers of fish sampled within the hopper during the monitoring program there was a potential risk resulting from oxygen depletion. Monitoring of conditions within the hopper showed that fish were always in excellent condition and displayed normal behaviour. Fish did not display any evidence from the effects of oxygen depletion such as increased respiration, flared gills and gasping at the surface. These observations were recorded during a number of peak migration times and during warmer months of the year. Table 8 lists the density of fish captured in the hopper when large migrations were recorded.

It was not possible to conduct intensive monitoring of the fishway during flood flows (due to safety concerns for monitoring personnel) when high numbers of both large bodied and small bodied species may be using the fishway simultaneously. However, as outlined in UA-3, small fish consume more oxygen by unit of body weight than large fish. Fish would therefore be at the greatest risk from exposure to low dissolved oxygen levels at times when large numbers of small bodied fish are being moved in the hopper as it travels over the dam wall and into the impoundment. Data collected on the migration rates of fish during opportunistic sampling (Table 8) demonstrated that a high biomass of fish could be expected to enter the hopper during peak migration times. Intensive monitoring of the fishway has revealed peak migration rates of over 50,000 mainly small bodied fish utilising the fishway in a single 24 hour period. These fish were observed to be in excellent condition. The load densities observed in the hopper during the monitoring program were well within guidelines (0.2 kg/L) set for fish salvage operations without sophisticated aeration systems (DPI&F, 2004).

Water quality conditions within the hopper appear to be suitable for fish provided there are no delays in transporting the fish into the impoundment.

UI-2 Optimum cycle time for each season and flow condition

What is the optimum cycle time for each season and flow condition?

As shown in UA-1 fish were recorded migrating through the fishway during all seasons and responded quickly to changes in flow conditions irrespective of the season. Experiments to evaluate the optimum cycle time for the fishlift were performed using a combination of various attraction times from the supplementary attraction flow valves and releases through the fishlift entrance slot.

During periods of increased releases from the dam in August and September 2010 high numbers of migratory fish were recorded using the fishway. During this period the fishway was operated at 30 minute and 120 minute attraction times. The analysis and comparison of the fish detection data was performed on whole days in August (11^{th}, 14^{th} and 15^{th}) and September (18^{th}, 19^{th} and 29^{th}) where similar flow release conditions occurred (medium flow releases of 97-795 ML/Day). Attraction flows through the fishlift entrance slot during these times were similar during both attraction cycle times. High numbers of PIT tagged fish, dominated by Australian bass and golden perch were attempting to use the fishway during this time. Analysis of PIT tag detections during the two different attraction cycle times showed a marked difference in the success of fish using the fishway (Table 10) outlines the success rates and shows that an average of 53% of all PIT tagged fish detected at the upstream fishway, successfully used the fishway during the 120 minute attraction cycle time. An average of 35% of all PIT tagged fish detected successfully used the fishway during the 30 minute attraction cycle time. Further analysis showed a greater proportion of fish (92%) had the opportunity (i.e. when the quad leaf gate was open) to enter the hopper during the 120 minute attraction time when compared to the 30 minute attraction time (52%).

Table 10 Detections of PIT tagged fish during 120 and 30 minute fishlift attraction cycle times

	120 minute Attraction Cycle Time				30 minute Attraction Cycle Time			
	Day 1	**Day 2**	**Day 3**	**Mean**	**Day 1**	**Day 2**	**Day 3**	**Mean**
Total number of all PIT tagged fish detected at the fishlift entrance slot	25	15	11	17	26	11	14	17
Percentage of all PIT fish detected successfully using fishlift	44%	60%	55%	53%	42%	27%	36%	35%
Percentage of detected fish at fishlift entrance when quad leaf gate open (opportunity to enter hopper) during attraction mode	92%	93%	91%	92%	62%	45%	50%	52%
Percentage of detected fish successfully using fishlift when the quad leaf gate was open (opportunity to enter hopper).	48%	64%	60%	57%	69%	60%	71%	67%
Percentage of fish successfully using fishlift when 1st detection was during attraction mode with quad leaf gate open	73%	78%	83%	78%	64%	67%	80%	70%
Percentage of fish successfully using fishlift when 1st detection was during the hopper travel mode (entered fishlift on subsequent cycles)	27%	22%	17%	22%	36%	33%	20%	30%

The experiments determined that in order to increase fish passage efficiency, maximising the period that the quad leaf gate is open and hopper accessible is the most important factor. An optimum cycle time is therefore one where proportionally the period of time when the hopper is inaccessible is minimised.

Results from comparing the success of PIT tagged fish using the fishway during 30 minute and 120 minute attraction cycle times showed that fish have greater opportunity to enter the hopper during longer attraction cycle times. The success (ability) of fish entering the hopper during different attraction cycle times is of a similar proportion. However fish are much more likely to successfully use the fishway when they first attempt to migrate upstream if the hopper is in attraction mode irrespective of the cycle timing. Analysis of individual fish movements does show that fish will remain and/or return to attempt to enter the hopper again if it is not present and a considerable number of fish return at a later date and successfully use the fishway. Not all fish enter the hopper despite having the opportunity to enter, even over considerable time periods. It is beneficial to run the hopper for extended periods of time, at least so that the proportion of attraction time is greater than the time the hopper is travelling and the quad leaf gate is closed. Table 11 outlines the proportion of time that fish are able to enter the hopper.

Table 11 Proportional time of hopper attraction and total cycle time
N.B. The end of attraction time to the start of the next attraction time takes 26 minutes at full supply.

Time for Attraction Phase	Time of Hopper Travel	Total cycle time	Percentage of time fish have opportunity to enter hopper	Number of cycles per day
30	26	56	54%	25.7
60	26	86	70%	16.7
120	26	146	82%	9.9
240	26	266	90%	5.4

During flood flow periods when high numbers of both large bodied and small bodied species may be using the fishway simultaneously, the fishway should operate at a cycle rate that would not allow too many fish to accumulate within the hopper prior to being lifted over the dam. Operating the fishway at 120 minute attraction times was more efficient for successful fish passage than during a shorter time frame. For this reason, 120 minutes of attraction time is considered an acceptable compromise between the risks of too many fish accumulating in the hopper against allowing enough time for fish to enter the hopper, especially during peak migration times. Cycling the fishway regularly would reduce predation within the hopper itself particularly during the transition of day and night fish behaviour patterns recorded during most flow conditions at the dam (ie. small bodied fish species migrating during the day against large bodied fish species migrating at night). The adoption of 120 minute attraction times in conjunction with pulsed attraction flows would restrict the overall biomass of small bodied fish species within the hopper on each cycle and provide a buffer against potential effects of low oxygen levels within the hopper during travel time.

It is recommended that a 120 minute attraction time be adopted regardless of the season or flow condition.

UI-3 Suitability of attraction channel entrance slots

Is the proportion of flow through each entrance slot equivalent to the number of fish present at the entrances under the full operational range?

As detailed in UA-2 the release conditions under which the fishway was operated were low and medium flow releases. The PIT tag reader data from UA-1 demonstrated the response of fish to changes in flow conditions over the full range of flow conditions.

Low flow releases

Assessment of zones of fish aggregations during fishway only releases (ie. flow releases only through the fishway) found that there were no aggregations of fish at the adjacent outlet release weir or fishway entrance slot (outlet release channel).

Medium flow releases

During irrigation outlet releases small aggregations of fish were identified below the outlet release weir. Corresponding fishlift hopper trapping and fishlift approach channel trapping have identified high numbers of fish entering and using the fishway under these conditions.

High flow releases

- Environmental flow releases

Observations of flow conditions at the fishway entrances and fish capture data during releases from the environmental flow release outlet compromised fishway entrance conditions.

- Spillway flow releases

Observations of flow conditions at the fishway entrances during overtopping flows indicate that the current design and operation of the fishway compromises entrance conditions.

The physical locations of the fishway entrances were suitable under most flow conditions. The ability to operate fishway attraction flows under low flows is suitable. However, to achieve increased attraction flows from fishway entrance slots during medium and high flows relies upon the use of the supplementary attraction flow valves. The operation of the supplementary attraction flow valves during fishway attraction is detrimental to fish entry during the hopper attraction phase.

The conditions at the fishway entrance slot (outlet release channel) appear to be suitable for fish during low and medium flow releases. Releases from the environmental release outlet and over the spillway negatively impacted on fishway entrance slot conditions. Investigation into the operation of the fishway to attract fish to the fishway entrance slots during all flow conditions established the following.

1) Only one fishway entrance slot can be used at any given time to attract fish into the fishlift approach channels.

2) When low and medium flows are being released from the dam (fishway only and/or the irrigation outlets), only the fishway entrance slot located adjacent to the outlet release channel should be operational.

3) When flows are being released from the dam through either the environmental release outlet or as a result of flows over the spillway, only the fishway entrance slot adjacent to the spillway should be used. This is due to the head differential of water levels between the outlet release channel, fishlift approach channels and the spillway tailwater area. Operating both entrance slots simultaneously creates a venturi effect and large head differentials as water flows through the spillway entrance slot and then out the outlet release entrance slot.

4) Attraction flow velocities through the fishway entrance slots dictate the ability of fish to locate the fishway entrance slots during medium and high flow releases.

   a) When releases of water are being made from the dam through the irrigation release outlets, environmental release outlet or during flows over the spillway increased attraction flows are required at the fishway entrance slots. To achieve this in the current configuration requires the release of water through the supplementary attraction flow valve/s in order to meet the designed water velocities of 0.8 m/s through the entrance slot.

   - When the supplementary attraction flow valve is operating, hydraulic conditions leading up to the fishlift entrance slot are extremely turbulent with high velocity, air entrained water cutting directly across the fishlift entrance slot (Figure 22). The movement of fish past this point is difficult and these conditions reduce the efficiency of the fishway. Fish are also attracted away from the fishlift entrance slot even when low volumes of water are released through the supplementary attraction flow valves.

5) Attraction flow velocities through the fishlift entrance slot dictate the ability of fish to enter the hopper.

   - The cross sectional area of the fishlift entrance slot during attraction is less than the fishway entrance slots located downstream. As a result, when attraction flow is set at the design velocity of 0.8 m/s through the fishlift entrance slot, the design velocity of 0.8 m/s at the fishway entrance slots (the outlet release channel and spillway) is not achieved. This effect is proportionally extenuated as the tailwater level increases including times when releases are being made through the irrigation outlets. At low tailwater levels however, the only way to achieve the design velocity at the fishway entrance slots is to supplement the hopper chamber attraction water with releases through the supplementary attraction flow valves. The use of the supplementary attraction flow valves to increase attraction flow then impacts on entry conditions into the hopper as discussed previously.

UI-4 Occurrence of predation and crowding in the hopper and condition of released fish

Is predation and crowding occurring in the hopper and are fish able to swim away immediately after release into the impoundment?

As detailed in UA-3, over 50,000 small fish and substantial numbers of large fish were successfully held in the hopper during 24 hour sampling, with no evidence of crowding or physical injury. Some evidence of predation of smaller fish by fish such as blue catfish and long-finned eels was evident but it is likely that this is linked to the long cycle times (up to 24 hours) used during sampling. Operation of the fishway in a normal frequent cycling mode should reduce predation within the hopper and minimise the fatigue levels of small fish trying to migrate.

During a number of hopper and trap sampling events, eels and blue catfish were observed regurgitating partially eaten fish and displayed evidence of full stomachs. Blue catfish have a habit of regurgitating their food when handled, during routine processing and measuring these fish occasionally regurgitated freshly consumed food. Table 12 below lists the fish species, numbers and mean lengths of fish that were retrieved from 51 blue catfish during a single 24 hour sample.

Table 12 Fish species, number of fish and mean lengths and mean number of consumed fish that were retrieved from 51 blue catfish in a single 24 hour fishway sample.

Common name	Genus	Number of fish	Mean number of fish consumed per catfish	Mean length (mm)
olive perchlet	*Ambassis agassizii*	218	4.27	48. 7
Duboulay's rainbow fish	*Melanotaenia duboulayi*	47	0.92	68.5
flyspecked hardyhead	*Craterocephalus stercusmuscarum*	46	0.90	57.3
Midgley's Carp Gudgeon	*Hypseleotris sp. A*	21	0.41	36.3
bony herring	*Nematolosa erebi*	17	0.33	91.7
Hyrtl's tandan	*Neosilurus hyrtlii*	8	0.16	91.4
spangled perch	*Leiopotherapon unicolor*	5	0.10	114
banded grunter	*Amniataba percoides*	3	0.06	73.7
snub-nosed garfish	*Arrhamphus sclerolepis*	1	0.02	123.0
Total	*All species*	366	7.18	55.8

Directly sampling fish as they exited the fishway hopper into the impoundment was not considered practical or safe and as such observational techniques were employed. Operation of the fishlift demonstrated that as the hopper was drained a small number of fish would swim against the flow of water exiting the hopper and become trapped on the inside walls of the hopper. Trapped fish would then remain in the hopper until it relocated itself downstream of the dam or fall out of the open hopper exit gate onto the water or onto the concrete surfaces of the dam, which often proved fatal.

In order to prevent fish from remaining in the fishlift hopper, the hopper emptying process was altered in January 2008 so that the hopper was lowered back into the water twice with the exit trapdoor open. In addition, flushing tubes were installed within the hopper. This allowed fish that were trapped in the hopper after the first emptying process opportunity to safely exit. No fish were observed to remain in the hopper after the emptying process was altered. All fish that were released into the impoundment quickly swam away with no evidence of disorientation or any injuries.

Visual observations of fish that had exited the fishlift hopper indicated all fish rapidly moved away from the location after release. A number of electrofishing samples were performed in the location of the hopper release point with similar numbers and species of fish captured at this point when compared to other locations directly upstream of the dam wall. Predators such as long-finned eels were often observed near the dam wall and along the length of the abutment, however there was no evidence that they were aggregating at the hopper release location.

The fishlift was not operated during environmental outlet releases. It is possible that exiting fish would be at risk of being entrained into the intake tower when released from the hopper. On a number of occasions fish were observed being drawn into the environmental release intake tower from within the impoundment.

UI-5 Attraction channel entrance slot conditions

Are substantial numbers of fish being attracted away from the fishway entrance?

The data presented in UA-3 indicates that the fish community downstream of Paradise Dam is similar to that captured in the fishlift hopper and the fishlift approach channel traps during low flow and medium flow releases. Assessment of zones of fish aggregation at the outlet release weir and fishway entrance slot when only the fishway was operating found no significant aggregations of fish adjacent outlet release weir or fishway entrance slot - outlet release channel (Paradise Dam Upstream Fishway Monitoring Annual Report 2008, 2009).

During medium flow releases small aggregations of fish have been identified below the outlet release weir. However, corresponding fishlift hopper trapping and fishlift approach channel trapping has identified high numbers of fish entering and using the fishway under these conditions. As such, medium flow releases do not significantly impede fish from locating and entering the fishway entrance slot.

Flows from the attraction and drain phases of the downstream fishway during fishway only releases are attracting fish away from the fishway entrance slot (outlet release channel) for the upstream fishway. High numbers of fish including gudgeons, banded grunter and bony herring were observed on a number of occasions immediately adjacent to the area where water from the downstream fishway outflow pipe enters the tailwater (Figure 24).

As demonstrated in the PIT tag reader data in UA-1 and shown in UA-2, the opportunity for fish to access the fishway entrance slots is compromised during environmental outlet releases. Due to safety issues in accessing the outlet release channel, no data on fish aggregations was collected during these periods. Fish aggregation data downstream of the dam wall during spillway overtopping flows recorded a high abundance of fish from a range of species located along the full length of the wall. A single trap sample in the fishlift approach channel (spillway) of the fishway indicated that a proportion of aggregating fish were able to locate and enter the fishway entrance slot (spillway) during these conditions.

Figure 24 Downstream fishway outflows during attraction phase in the outlet release channel.

UI-6 Suitability of fishlift entrance conditions

Are any fish unable to enter the fishlift due to behavioural or physical barriers?

During low and medium flow releases high numbers of fish and the majority of fish species from fish communities downstream of the dam were well represented in fishlift hopper samples (as detailed in UA-1). Representation of a wide range of size classes from fish species indicates that they were able to locate and enter the fishlift.

Further investigations into altering attraction flows through the fishlift entrance slot demonstrated that the number of small bodied fish able to enter the fishlift was greatly influenced by the velocity of water (UA-2). Previous investigations into the hydraulic conditions at the fishlift entrance (Annual Report 2009) determined that lower velocity areas occurred near the bottom of the water column. However, date presented in UA-2 demonstrates that as the amount of attraction flow delivered through the fishlift entrance slot increases, the proportion of small bodied fish that may utilise this lower velocity zone is greatly reduced. This is most likely due to an increase in the velocities throughout the entire water column and a reduction in the size of the lower velocity area available for fish to utilise.

As detailed in UA-1, UA-2, UI-3 and UI-5 there are physical impediments that affect access for all species during high flows. Further monitoring under these conditions is recommended.

Conclusion

As the first fishlift to be constructed on a dam or weir in Australia, the design process for the Paradise fishway was unparalleled in Queensland. Design decisions were based on knowledge gained from assessments of other fishway designs within Australia and from knowledge gathered at fishlifts and dams overseas.

Within the monitoring framework of the contract between DEEDI Fisheries Qld and Burnett Water Pty Ltd the following points were required to be addressed:

- Determine whether the fish passage facilities are effective in achieving the design aims.
- Establish the constructed design is operating to specification.
- Provide data for the optimisation of operations and/or design over time.
- Provide information that may be of use in the mitigation of the impacts of future water infrastructure developments.

The fishway monitoring program incorporated standard fishway assessment methodologies and investigations unique to the Paradise Dam upstream fishway. The intent of the monitoring program was to complete most of the standard assessment components within the first three years of the program. The last two years of the program were to be used primarily to address the investigative monitoring components and to complete any outstanding assessment components.

However, the monitoring program was impacted by a four year delay between the completion of the Paradise Dam in 2005 and the filling and overtopping of the dam in March 2010. As a result, some of the assessment and investigative components remain outstanding which in turn affects how well the requirements of the monitoring framework can be addressed. In addition, the routine operation of the fishlift has been interrupted by an extended commissioning phase due to the low storage levels and unexpected mechanical failures of the fishlift and outlet structures.

The remainder of this section will address the four key points of the monitoring framework using the data gained from the assessment components UA1 to UA-4 and investigative components UI-1 to UI-6. Due to overlap between the intent of the first two points of the monitoring framework discussion of these two points is combined below:

Determine whether the fish passage facilities are effective in achieving the design aims.

The design process for the fishways at Paradise Dam incorporated consultation with DEEDI Fisheries Qld to develop a design that would satisfy the requirements of Section 116 of the *Fisheries Act (1994)*. Two physical scale models, one of the entire dam wall and another of a portion of the spillway wall with the upstream fishway channels and outlets, provided an indication of how the fishways would operate under a range of flow conditions. The Waterway Barrier Works approval with concomitant objectives and conditions for the fishways was issued by Queensland Fisheries Service (as they were at the time) in November 2003 (see Introduction). The Burnett Dam Alliance issued a report titled Detail Design Report: Section 10 - Fishway June 2004 (BDA, 2004). This section compares the fishway scope and design specifications referred to in the Detail Design Report with the results from the monitoring program.

Establish the constructed design is operating to specification.

The design aims for the Paradise Dam upstream fishway relate to the objectives of the Waterway Barrier Works approval namely:

1. the fishway shall operate over the entire range of headwater and tailwater levels;

Operation of the fishway has been limited to 50% of the time when there were flow releases from the dam. Since completion of the Paradise Dam in 2005, the upstream fishway has only been able to be operated during low and medium flow releases. Mechanical failures and operational restraints have prevented the fishway from operating during environmental outlet flow releases and during spillway flows. Section 10.1.4.1 in BDA 2004 (points a and b duplicated below) detailed the design criteria drawn from the hydraulic model studies that were the basis of the final design for the upstream fishway:

a. Upstream fishway migration via the outlet channel is expected for:

- Irrigation flows up to 18 cumecs provided the tailwater at 18 cumecs is above EL 32.0m.
- Spillway discharges up 550 cumecs (1.0m surcharge).
- Environmental releases up 40 cumecs with irrigation release of 18 cumecs to establish a velocity-reducing hydraulic jump within the outlet bay.

The upstream fishway was routinely operated during fishway only flows of 0.02 cumecs up to combined fishway and irrigation outlet releases of 9.2 cumecs. Fishlift trapping demonstrated that high numbers of fish from 27 species successfully entered and utilised the fishway during fishway only and irrigation release flows.

During the monitoring program discharges over the Paradise Dam spillway occurred in March and September 2010. In the March spillway flow event, the fishlift was inoperable due to mechanical breakdown during the entire overtopping event and recommenced operation in April after the spillway flow had ceased. In September 2010, the spillway overtopping event peaked at 0.61 m surcharge but only lasted for 2 days before inflow was released through the environmental release tower. The fishlift was operated for 4.5 hours to undertake monitoring of the hopper. Turbulence within the fishlift approach channels and reverse flows due to the water level differentials caused the fishlift to fault as the PLC and level sensors attempted to achieve a stable water level during the fishway attraction mode.

Operation of the fishlift did not occur during environmental outlet flow releases but visual observations suggested that fishlift entrance conditions were compromised at flows greater than 20 cumecs. A possible reason for the limitation to 20 cumecs is the late addition of a mini hydro-power facility on the discharge weir. The narrowing of the release jet due to the mini hydro-power facility causes a high velocity jet to impact across and downstream of the fishway disguising fishway entrance flows.

b. Upstream fishway migration via the spillway entrance

- Irrigation flows up to 18 cumecs provided the tailwater at 18 cumecs is above EL 32.0m.
- Spillway discharges up to 193 cumecs (0.5m surcharge).
- Environmental releases up to 40 cumecs with or without the spillway discharging 90 cumecs (0.3m surcharge).
- But may not occur at spillway discharges between 193 cumecs (0.5m surcharge) and 550 cumecs (1.0m surcharge).

The fishway entrance slot opening at the spillway was not operated during low flow or medium flow releases due to lower tailwater levels. Reverse flows were observed entering through this entrance slot under all spillway flow conditions and during high volume environmental outlet flow releases. The hopper attraction and supplementary flows required to operate both fishway entrances created adverse conditions for fish entry into the hopper.

Attraction flow valve diffusers were designed to supply attraction flow into the hopper chamber at EL 30.9 m, EL 34.0 m and EL 38.0 m in order to cater for the range of tailwater operational levels. As the fishway did not operate during elevated tailwater levels, the use of the upper attraction valves during these times could not be assessed.

The dam's Programmable Logic Controller (PLC) system currently allows the upstream fishway to operate to a maximum headwater level of EL 67.9 m. However, based on conclusions drawn from the Hydraulic Model Study undertaken during the design phase, the fishway entrance slots are expected to operate to a maximum spillway flow of 1.0 metre above the spillway (i.e. EL 68.6 m). The operation of the upstream fishway to a maximum spillway flow of 1.0 m above the spillway cannot currently be achieved without alteration to the fishlift PLC. Section 10.4.1.3.2 stated that the attraction supply was increased to accommodate the extended operating range at a tailwater level of EL 38.0 m (BDA, 2004).

2. ***the fishway shall facilitate the passage of all migratory fish and all size ranges in a safe manner during all times of the year;***

The Paradise Dam upstream fishway has operated during all four seasons of the year during low to medium flow releases. A wide range of fish species and size classes have successfully migrated upstream through the fishway. Small bodied fish species were the dominant users of the fishway with high numbers of fish identified in both low and medium flow releases.

High numbers of large bodied fish were identified downstream of the dam during high flows when the fishway was inoperative. Peak migration periods for fish were not greatly influenced by season as high numbers of fish were identified downstream of the dam during all high flows throughout the monitoring program. Operation of the upstream fishway during high flows is critical to achieving successful passage for fish at the Paradise Dam.

The ability of the fishway to carry a high biomass of small bodied fish was established with unprecedented high numbers of small fish using the fishway. Water quality conditions within the hopper appear to be suitable for fish provided there are no delays in transporting the fish into the impoundment.

Some predation of small fish within the hopper was observed during fishway sampling but it is likely that this is linked to the long cycle times (up to 24 hours) used during sampling. Frequent cycling of the fishlift hopper should reduce predation within the hopper. The fate of fish released into the impoundment was not intensively studied but there was no evidence that fish were negatively affected after their release.

3. conditions at the fishway entrances (both upstream and downstream) should be such that all fish seeking to migrate are attracted to the entrances;

The conditions at the fishway entrance slot (outlet release channel) appear to be suitable for fish during low and medium flow releases. Releases from the environmental flow release outlet and over the spillway negatively impacted on fishway entrance conditions. Investigation into the operation of the fishway to attract fish to the fishway entrances during all flow conditions established the following.

i. Only one fishway entrance can be used at any given time to attract fish into the fishlift approach channels.

ii. When low and medium flows are being released from the dam (fishway only and/or the irrigation outlets), only the fishway entrance slot located adjacent to the outlet release channel should be operational.

iii. When flows are being released from the dam through either the environmental flow release outlet or as a result of flows over the spillway, only the fishway entrance slot adjacent to the spillway should be used. This is due to the head differential of water levels between the outlet release channel, fishlift approach channels and the spillway tailwater area. Operating both entrance slots simultaneously creates a venturi effect and large head differentials as water flows through the spillway entrance slot and then out the outlet release entrance slot.

iv. Attraction flow velocities through the entrance slots dictate the ability of fish to locate the fishway entrances during medium and high flow releases (irrigation outlets, environmental outlet and spillway).

    a) When releases of water are being made from the dam through the irrigation release /hydro outlets, environmental flow release outlet or during flows over the spillway increased attraction flows are required at the fishway entrance slots. To achieve this in the current configuration requires the release of water through the supplementary attraction flow valve/s in order to meet the designed water velocities of 0.8 m/s through the entrance slot.

    b) When the supplementary attraction flow valve is operating, hydraulic conditions leading up to the fishlift entrance slot are extremely turbulent with high velocity, air entrained water cutting directly across the hopper entrance. The movement of fish past this point is difficult and these conditions vastly reduce the efficiency of the fishway. Fish are also attracted away from the entrance to the fishlift even when low volumes of water are released through the supplementary attraction flow valves.

v. Attraction flow velocities through the fishlift entrance slot dictate the ability of fish to enter the hopper.

    a) The cross sectional area of the fishlift entrance slot during attraction is less than the fishway entrance slots located downstream. As a result, when attraction flow is set at the design velocity of 0.8 m/s through the fishlift entrance slot, the design velocity of 0.8 m/s at the fishway entrance slots (the outlet release channel and spillway) is not achieved. This effect is proportionally extenuated as the tailwater level increases including times when releases are being made through the irrigation outlets. At low tailwater levels however, the only way to achieve the design velocity at the fishway entrance slots is to supplement the hopper chamber attraction water with releases through the supplementary attraction flow valves. The use of the supplementary attraction flow valves to increase attraction flow then impacts on entry conditions into the hopper as discussed previously.

4. ***fishway operations and works should be constructed so as to maximise attraction, capture and transfer of fish;***

Results from the monitoring program have demonstrated that the fishway operation and works were constructed to maximise attraction, capture and transfer of fish at the Paradise Dam.

The physical locations of the fishway entrances were suitable under most flow conditions. The ability to operate fishway attraction flows under low flows is suitable. However, to achieve increased attraction flows from fishway entrance slots during medium and high flows relies upon the use of the supplementary attraction flow valves. The operation of the supplementary diffusers attraction flow valves during fishway attraction is detrimental to fish entry during the hopper attraction phase.

Ability to manipulate attraction flows through the hopper entrance is suitable, however pulsed attraction flows as specified and designed in BDA 2004 are not currently achievable. The provision of pulsed attraction flows will greatly improve the number of fish using the fishlift. The cone entrance on the hopper retains fish in the hopper before being lifted. The total open area of the hopper entrance cone could be increased to improve the range of attraction flows that could be released through the hopper entrance (Figure 25). The physical size and capacity of the hopper and speed at which fish are transferred into the impoundment is suitable.

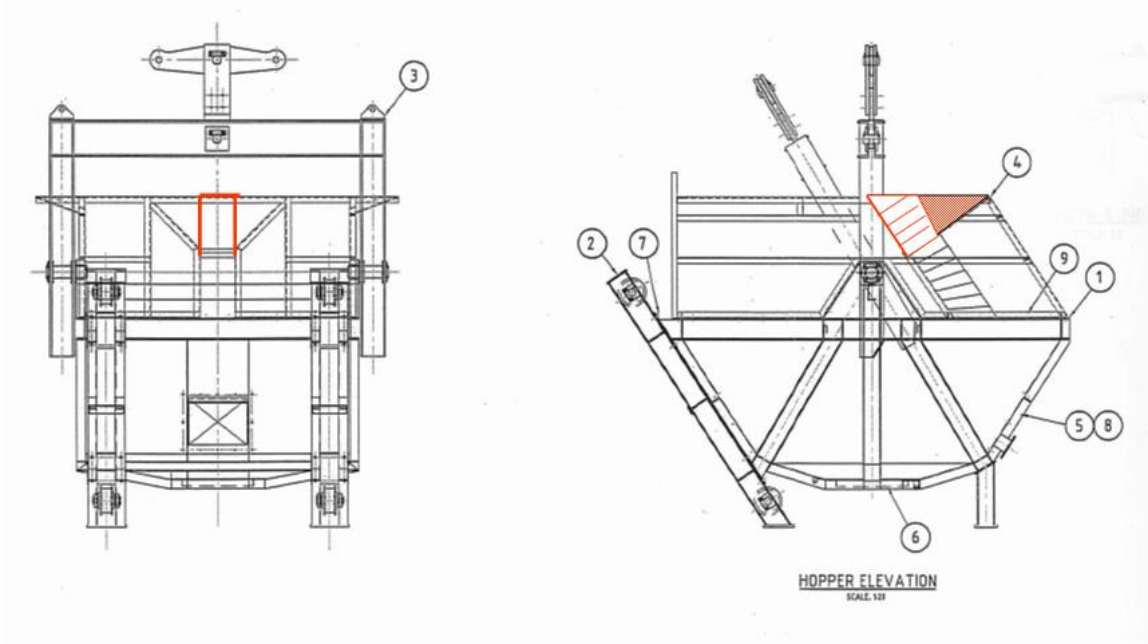

Figure 25 Diagram showing proposed hopper cone entrance modifications that will allow the hopper to be lowered further into the hopper chamber.

Section 10.4.1 in BDA 2004 detailed the design philosophy and arrangement of the upstream fishway. This specified criteria for the upstream fishway from a biological and dam structure basis. The biological criteria were as follows:

- Attraction water flows to suit the passage of the 26 species (ranging from small bony herring to relatively large lungfish) identified in the Burnett River.

The current study identified that during low to medium flows the fishlift has provided passage for 25 of the 29 species identified in the vicinity of the dam including bony herring and Queensland lungfish. The smallest fish to successfully use the fish lift during sampling was an 11mm long western carp gudgeon and the largest fish during sampling was a 959mm long Queensland lungfish. The number of species captured successfully migrating upstream at Paradise Dam fishlift exceeds the number of fish successfully migrating upstream at other fishways in the Burnett River. Previous fishway designs have limited successful passage of small fish (Stuart and Berghuis, 1999; Berghuis, Broadfoot *et. al.* 2000).

- A trapping arrangement with a gate system that allows for a range of water levels and the Burnett River fish species to be collected without harmful stressing.

During the current study the operational range of the fishlift was limited to fishway only and irrigation release outlet flows. The fishway was inoperative during environmental tower release flows and spillway overtopping flows. The cone entrance on the hopper retains fish in the hopper before being lifted. The physical size and capacity of the hopper and speed at which fish are transferred into the impoundment is suitable. The current study identified over 50,000 fish using the fishlift hopper in a single day with no evidence of stress identified.

- A water volume in the transporting hopper to provide for an expected biomass demand.

Results collected throughout the monitoring program demonstrate that extremely high numbers of fish can be safely moved within the hopper and the carrying capacity may only be limited by physical numbers of fish during peak migration periods (i.e. during flood flows). The increased biomass at Paradise Dam is likely to be due to the high numbers of small bodied fish species present at the dam site and the conditions in the fishway being highly suitable to small bodied fish under low and medium flow conditions.

During flood flow periods when high numbers of both large bodied and small bodied species may be using the fishway simultaneously, the fishway should operate at a cycle rate that would not allow too many fish to accumulate within the hopper prior to being lifted over the dam. Operating the fishway at 120 minute attraction times was more efficient for successful fish passage than during a shorter time frame. For this reason, 120 minutes of attraction time is considered an acceptable compromise between the risks of too many fish accumulating in the hopper against allowing enough time for fish to enter the hopper, especially during peak migration times. Cycling the fishway regularly would reduce predation within the hopper itself particularly during the transition of day and night fish behaviour patterns recorded during most flow conditions at the dam (ie. small bodied fish species migrating during the day against large bodied fish species migrating at night). The adoption of 120 minute attraction times in conjunction with pulsed attraction flows would restrict the overall biomass of small bodied fish species within the hopper on each cycle and provide a buffer against potential effects of low oxygen levels within the hopper during travel time.

Provide information that may be of use in the mitigation of the impacts of future water infrastructure developments.

In addition to the recommendations, the following points summarise recommended improvements to mitigate future infrastructure developments:

- Future infrastructure developments need to incorporate finer control of attraction flow valve operation, improved sensitivity and reliability of level sensors and other systems that control the operation of flows throughout the fishway over a range of flow conditions.

- All intake screens at future infrastructure developments need to have a suitable aperture to prevent fish from being entrained into dam pipe work and outlet facilities, thereby causing fish mortalities. For example, an aperture size of 2.5 mm would prevent fish as small as 25 mm from entrainment (Clay, 1995).

- Future hopper designs should incorporate higher angled floors and/or other modifications to reduce the potential of fish standings during the emptying phase.

- The success of fish entering the hopper was greater during longer attraction cycle times. A compromise in the amount of attraction time, hopper capacity and fishway cycling must be established to reduce the risk of increased predation as more fish enter the hopper. Accordingly a minimum of eighty percent of the total fishway cycle time should be adopted for future fishlift designs.

- The requirement, configuration and operation of supplementary attraction flows must not negatively impact on fishlift entrance conditions.

- The hopper chamber walls need to be extended vertically to improve the reliability and control of the fishway during extended tailwater operational levels.

- Providing variable flow velocities at key areas of flow constriction (i.e. at entrance slots) will allow poor swimming species access to the fishway, thus catering for the wider fish community.

Recommendations for the optimisation of operations and/or design over time.

Data collected and analysed from the upstream monitoring program established that the operation and/or design of the fishway can be optimised and improved. The following points outline the recommended improvements:

1. During low and medium flow releases the fishway entrance slot (spillway) must be completely closed. (Refer to UI-3, pp 43-44)

2. During high flow releases the fishway entrance slot (outlet release channel) must be completely closed. (Refer to UI-3, pp 43-44)

3. Flows discharged beneath the downstream fishway exit chute during the attraction cycle of the downstream fishway. Upstream migrating fish are being attracted away from the fishway entrance slot (outlet release channel). Relocating the discharge point to a position in the vicinity of the fishway entrance slot (outlet release weir) would address this issue. (Refer to UI-5, pg 47)

4. Improve attraction flows, at the design velocity of 0.8 m/s, through all operational entrance slots of the fishway and fishlift whilst maintaining access for upstream migrating fish to the fishlift over a range of flow conditions by:

   a. Modifying the hopper entrance cone to improve access to the hopper and allow the quad leaf gate to be further opened in the attraction phase. (Refer to UI-3 pp 43-44, Conclusion, pp 53-54).

   b. Improving the control, response and sensitivity of the attraction flow valve and level sensor arrangement to improve resultant velocities and conditions through both of the fishway entrance slots and the fish lift entrance slots. (Refer to UI-3 pp 43-44, Conclusion, pp 53-54).

   c. Altering the supplementary attraction valve arrangement and operation to ensure fishlift entrance conditions are suitable for fish during all flows. (Refer to UI-3 pp 43-44, Conclusion, pp 53-54).

   d. Investigating the potential of 'keyhole' entrance slots to reduce the cross sectional area of the fishway entrance slots (spillway and outlet release channel) to achieve design velocities over a range of flow conditions. (Refer to UI-3 pp 43-44, Conclusion, pp 53-54).

5. Do not run the supplementary attraction flow valves during the attraction phase of fishway operation. (Refer to UI-3, pp 43-44)

6. Operate the upstream fishway with 120 minute attraction time at all times. (Refer to UI-2, pp 41-42).

7. Instate pulsed flows from all of the hopper chamber attraction flow valves within each attraction cycle, by reducing the flow velocity through the fishlift entrance slot from 0.8 m/s to 0.25 m/s for the last portion (e.g. 5-10 minutes) of the attraction phase. (Refer to UA-2 pg 28, Conclusion, pg 54).

8. Attraction flow to the fishlift entrance during low and medium flow conditions to be delivered through all of the hopper chamber attraction flow valves equally. (Refer to UA-2, pg 26).

9. Attraction flow to the fishlift entrance during high flow conditions to be delivered through the upper hopper chamber attraction valve/s to deliver suitable attraction flows relevant to the position of the hopper. Observation and further investigation of flow conditions would be required during high flows to determine if suitable attraction flows can be achieved under this arrangement. (Refer to UA-2, pg 26, Conclusion, pg 52).

10. Review the control system, and reprogram if necessary, to enable the fishway to operate at the design headwater and tailwater levels of EL 68.6 m and EL 38.0 m, respectively. (Refer to UA-2, pp 28-33, Conclusion, pp 51-52).

11. To reduce the risk of fish entrainment in the environmental flow release intake tower, the operation of the fishway should be suspended during releases from the environmental release outlet. (Refer to UI-4, pg 46).

12. Remove and reposition the quad leaf gate screen and drum hoist, or identify an alternative engineering solution that will allow fish to enter the hopper during high flow conditions. (Refer to UA-2, pg 33).

13. Remove gaps between the hopper solid section and mesh section to prevent small fish and eels from escapement during transfer.(Refer to UA-3, pg 35).

14. Continue with the adopted 'double dunk' procedure to empty the hopper into the impoundment. (Refer to UI-4, pg 45).

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Appendix A

Burnett River Dam Upstream Fishway Monitoring Program, June 2005

Section 1.01 BU1. Background

Burnett Water is currently constructing of a new dam located at 131.2 km AMTD on the Burnett River. The Burnett River Dam was issued with a Waterway Barrier Works Approvals and associated Fishway Directives under the *Fisheries Act 1994*. The Fishway Directives required that adequate provision was made to provide fish passage past the structures in the form of a fishway. The final fishway design was developed through a highly successful consultative process between the Dam Owner and the Department of Primary Industries and Fisheries (DPI&F). The fishway designs have been developed to meet the objectives of the *Fisheries Act 1994* approvals relating to fish passage.

Under the conditions of the *Fisheries Act 1994* approvals, a monitoring program that determines the effectiveness of the fishways is required. A Monitoring Framework has been developed for the Burnett River Dam. The monitoring framework identified that the following is required to be addressed:

- Establish the constructed design is operating to specification.
- Determine whether the fish passage facilities are effective in achieving the design aims.
- Provide data for the optimisation of operations and/or design over time.
- Provide information that may be of use in the mitigation of the impacts of future water infrastructure developments.

A fishway management plan for the Burnett River Dam is yet to be completed however it is required under the Waterway Barrier Works Approval and will provide specific links to a program of monitoring and Continuous Improvement.

Section 1.02 BU2. Scope

This monitoring proposal has been developed using similar aims and requirements set out in the Eidsvold Weir Monitoring Plan and as such, to address the monitoring requirements under the conditions of the Waterway Barrier Works Approvals.

The monitoring proposal sets out the key assessment and investigation components that have already been identified to the Dam Owner by DPI&F. These are based on design and operational issues that could not be resolved ex-situ as well as the 'standard' fishway assessment components. As in the Eidsvold Weir monitoring plan this proposal has identified monitoring components as core (assessment) or non-core (investigative). The Burnett River Dam fishlift will be the first example of fish passage over a high dam in Australia and the first use of this type of fish transfer technology in Australia. Subsequently, to determine the success of the fishway it is important that both core and non-core components be fully investigated from the outset of the monitoring program.

Costings for all components are included in this proposal. It is possible that additional non-core components will be developed following the results of monitoring and costs will represent a variation in the monitoring plan contract.

The question of long-term effectiveness of fish passage provision is fundamental and the proposed monitoring methodologies recognise this. Furthermore, conditions relevant to fish at the dam are likely to remain in flux beyond the scope of the initial monitoring program. The proposed monitoring program will establish a PIT tagged fish population. This population will also be able to be monitored remotely beyond the initial five years.

The more intensive fishway trapping and downstream electrofishing-based sampling will be concentrated in the first three years of monitoring. The fourth and fifth years will concentrate on monitoring that is tied to flow events and also on more detailed investigations of emerging patterns or issues identified in the initial investigations and seasonality of fish migration. Additional monitoring considered necessary beyond the five year time frame will require a variation in the contract.

An assessment of the impact of the new water infrastructure on fish communities of the Burnett River has not been included in this monitoring program. However, a requirement to monitor lungfish populations within the lower Burnett has been placed upon Burnett Water. Expansion of the methodologies to assess lungfish and indeed the entire freshwater fish community in combination with the methodologies to be utilised in this monitoring program may be achieved with little additional cost.

Section 1.03 BU3. Costing

The total cost of the Burnett River Dam upstream fishway monitoring program is **$425,000 (excluding GST) over five years**. Details of the costs are provided in Table i below.

Because of the long term nature of the study, the unpredictability of flows and peak sampling periods, the budget for the program has been based on salaries, operating and equipment costs rather than on a daily rate.

While the anticipated cost of equipment construction, maintenance, repair and replacement has been factored in to the budget, DPI&F will provide the electrofishing boat and nets as well as the hydroacoustic equipment at no additional cost. These items would represent a considerable capital outlay for the project if they were to be purchased by the Dam Owner or another party. Electrofishing boats operated and endorsed under the Australian Code of Electrofishing Practice are not available outside government organisations, with one exception based in Western Australia. The hydroacoustic equipment that DPI&F proposes to use is also not being used for this application elsewhere in Australia, however it is used and endorsed overseas for fish movement monitoring.

Salaries for the dedicated monitoring team are included in the costing, however all employment costs relating to Andrew Berghuis, the Program Supervisor will also be met by DPI&F (refer Section 5.6.1 for details of experience). Andrew will oversee all the fishway monitoring, data handling and reporting. He will also assist in the field where an additional person or qualified electrofisher/boat driver is required or where particular technical skills with hydroacoustics and other remote monitoring equipment are necessary.

The Monitoring Team will be based at the DPI&F offices in Bundaberg which also has facilities for vehicle, boat and net storage and workshop facilities for modification, construction and/ or maintenance of nets and other equipment. By locating the team within one hours drive of the Burnett River Dam, overnight accommodation and travel costs will be minimised and there is the distinct advantage of a quick response time to flow events.

	Years 1 to 3	**Years 4 and 5**

		PO3, TO2 salaries and 50% previous operating
Salaries	$219,898	$59,150
Operating (car, office, accommodation etc)	$38,403	$14,847
Electrofisher and nets maintenance/repair/modification	$18,582	$6,700
Hydroacoustic equipment maintenance/repair/modification	$18,582	$6,700
PIT tags and materials	$30,970	$11,167
Period Total (inc. CPI @ 3.2%)	**$326,436**	**$98,564**
	5 Year Total	**$425,000**

Table bu(i). Costings for Monitoring the Burnett River Dam Upstream Fishway

(a)

(b) BU3.1 Cost estimates for contract variation

Variations in the monitoring program are likely to comprise the additional investigative components not identified in this fishway monitoring program (i.e. investigative requirements based on findings of core monitoring). Where these investigative components can be fitted in to the work program during the first three years of the monitoring when the full team is operational the only additional costs would be the cost of additional materials and equipment for these tasks, and any additional operating costs (eg fuel, accommodation etc).

If the additional investigative components are undertaken in the fourth or fifth years and a third team member is required then the cost of that salary (PO1=$46,700 per annum including on-costs) for the period of the monitoring and associated analysis, report writing etc. would also be included in the variation cost. It is anticipated that most of the investigative components agreed to by the Dam Operator will be addressed in the fourth or fifth years.

If work under a variation is required beyond the fifth year of the program, depending on how long the monitoring is likely to extend, this can be charged at a daily rate or an annual rate. The daily rate will be based on the DPI&F non-statutory fees for Fishway Evaluations. While the 2005/2006 rate is included in the table below, allowances should be made for increases with CPI.

Fishway evaluations	Daily Rate (GST exclusive)
Boat Electrofishing	$1810.70
Fishway sampling	$1168.19
Report Write up	$817.72

Table bu(ii). Daily Rate Costings for Fishway Monitoring as at July 2005

Section 1.04 BU4. Fishway Design

The fishway designs for the Burnett River Dam are considered innovative and as yet unproven in situ. Importantly both these fishways also cater for the whole fish community at the site, including very large bodied fish, such as the listed Queensland lungfish, down to very small and juvenile fish. This holistic approach to sustaining fish communities is in contrast to targeting designs to facilitate the movement of one or two commercial species, as practised in the USA and Europe, and illustrates the Queensland government commitment to ecologically sustainable development.

(a) BU4.1 Burnett River Dam Upstream Fishway

The chosen fishway type for providing passage upstream at the Burnett River Dam is a fishlift. This is the first use of a fishlift in Australia and it is also the only fishway on a high level dam in Australia, with a spillway height of 37.6 m. The fishlift consists of an attraction chamber at the foot of the spillway, adjacent to the outlet works. This chamber has two entrances. Fish are attracted into the chamber above a hopper and after a set period of time the gate to the chamber closes and the 7 m^3 hopper is lifted up through the chamber, collecting the trapped fish and then raised to the top of the dam crest. The hopper is lowered into the headwaters of the impoundment. Fish are released through a release gate, the hopper is raised out of the water and returned back down to the foot of the dam wall and the process is repeated.

As with all new fishways, one of the key design solutions that needs to be confirmed is the ability of the fishlift to attract fish into the entrance chamber under different flow and release conditions. During the modelling phase there were some concerns about flow patterns in the entrance channel under some flow conditions. These were further complicated by the late installation of a mini-hydro structure in the channel of the outlet works. It is vital that the attraction capabilities for fish and the entrance channel conditions are monitored and if necessary, are adjusted.

The capacity of the hopper to safely transport fish during the cycle and in water of a similar quality as the impoundment water also needs to be confirmed. This is the first use of a hopper system in Australia and the dimensions of the hopper were based on best available. The maintenance of water quality within the hopper is also of concern during periods of peak fish migration as it is possible that levels of dissolved oxygen may be depleted or that differences between water quality in the hopper and the impoundment may result in fish becoming stressed.

Section 1.05 BU5. MONITORING

(a) BU5.1 Fishway commissioning

Prior to commencement of operation, the fishway will be wet commissioned to establish that the design complies with the requirements set out in the functional specifications. In particular it will be necessary for the Dam Owner to check that the following are suitable:

- Physical dimensions, including water depths;
- Operation of gates;
- Operation of diffusers in lock chamber (including visual check of turbulence and flow patterns);
- Filling times of lock;
- PLC programming;
- Measurement of water velocities at entrance;
- Measurement of water velocities at exit; and
- Operation of trapping facilities.

In order to establish the suitable settings for the initial operation of the fishways it is important that DPI&F are involved in these wet commissioning tests. Following the wet commissioning, and using results from the fishway monitoring program it is likely to be necessary to alter the operational settings on fishway to suit storage levels. Within the monitoring program DPI&F will visually inspect conditions in the fishway on a regular basis so as to establish whether suitable conditions are being maintained. The co-operation of the weir/Dam Operator will be required so that settings can be changed at short notice and re-assessed. Reports to the relevant operating committee for the dam and fishway, i.e. Burnett River Dam Operating Committee (BRDOC)[1], will detail observations and recommended changes that will assist in the optimisation of the fishway.

(b) BU5.2 Outcomes of monitoring

The Burnett River Dam Upstream Fish Passage Monitoring Program has been designed taking into consideration the requirements under the Waterway Barrier Works Approval. Thus the monitoring will evaluate the effectiveness of the fishway in facilitating the passage of all fish at all times of the year. It will also assess the conditions at the fishway entrances to evaluate whether these are maximising attraction of fish to the fishway as well as maximising capture and transfer of fish.

The monitoring will not only evaluate the fishway in these terms but will identify where the fishway is sub-optimal. One of the most important outcomes of the monitoring will be the use of the data to suggest to the Dam Operator ways in which the fishway and dam operation can be optimised in order to fulfil the design objectives. Where possible and appropriate, immediate feedback can be given to the Dam Operator on these issues.

Additionally this information and findings on sub-optimal design components can be utilised by the Dam Owner to inform the Continuous Improvement Program required under the Approval. Feedback will be used to determine what the priority actions are under this program and also what solutions there may be to optimisation issues.

Frequent reporting will mean that issues associated with the fishway and fish passage can be identified and relayed without delay. Quarterly reports will be provided to the BRDOC. Annual reports following completion of field work will also be provided to the Dam Owner. At the completion of the monitoring program a final report will be provided to the Dam Owner. This will include a document setting out the most effective operation of the dam and the fishway in order to maximise fish passage. It is anticipated that this document will be for the use of the Dam Operator.

Furthermore, these important outcomes and information from the monitoring program can be used to further improve future fishway designs, and in particular lift type fishways in Queensland and elsewhere in Australia.

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[1] BRDOC is yet to be established.

Summary of outcomes

- Results from monitoring of design outcomes relating to the monitoring conditions under the Waterway Barrier Works Approval
- Provide options for optimising the operation of the dam and fishway to facilitate fish passage
- Provide data to inform the Continuous Improvement Program and enable prioritisation of actions under this program
- Provide ongoing feedback to the Dam Operator on the operation of the fishway
- Quarterly reports to BRDOC
- Annual reports to Dam Owner
- Final report to Dam Owner at the conclusion of the monitoring program that includes optimal operation guidelines for the dam and fishway to maximise fish passage
- Body of work to inform future fishway designs in the Burnett and in particular, fishlift designs.

(c) BU5.3 Duration of the Monitoring Program

The funding requirements for monitoring in this proposal extend over a five year period. Although both core and non-core monitoring will be undertaken from the outset of the program, it is proposed that the bulk of the core monitoring would be completed in the first three years of the program. The remainder of the monitoring work plus additional non-core monitoring will be undertaken in the following two years. Timing and in particular the completion of the monitoring would depend on when the full recommended range of flows were experienced at the site. In line with the Eidsvold Weir Fish Passage Monitoring Plan this program will include a sunset clause of five years on the core monitoring regardless of flow conditions experienced during that period.

The commencement of monitoring at the Burnett River Dam fishway would be delayed until the dam has filled sufficiently that the upstream fishway is operational. However, in this proposal it is assumed that this will happen within the first 12 months of the dam being closed, as predicted in the Burnett Water hydrological modelling. Prior to the dam filling, the initial effort will focus on the establishment of a PIT tagged population of fish and testing of the hydroacoustic system. Fishway monitoring will most likely commence during summer 2005/2006.

Monitoring work at the Burnett River Dam is likely to overlap with that proposed for the Eidsvold Weir and the team will be working at both sites in the same years. It is unlikely that assessment of the long-term effectiveness of the fishways will be completed within a five year period. This has informed the choice of monitoring methodologies and justifies the investment in capital items such as PIT technology. A significant proportion of the effort throughout the five years of this monitoring plan will be spent on tagging a broad cross-section of fish species and size classes to enable these fish to be monitored using remote readers. The behaviour of these fish in relation to passage, particularly downstream passage can then be followed over several years and during many flow conditions.

(d) BU5.4 Methodologies

In order to undertake a rigorous monitoring plan that will achieve the aims detailed above a range of assessment methodologies will be necessary. The following is a list of methodologies to be used.

(e) BU5.4.1 Direct fishway sampling

Trapping of fish entering and exiting fishways is the main method of determining whether a fishway is effective or not. The disadvantage of this method is that it is a capture dependent methodology. Furthermore it does not give any indication whether fish attempting to migrate are able to find the entrances or of delays in locating entrance and behavioural impediments. At the Burnett River Dam floating traps will be used to assess the condition and behaviour of fish as they are released from the fishways. Floating traps will be constructed by the DPI&F.

(f) BU5.4.2 Fish aggregation monitoring

Boat electrofishing of fish aggregating at barriers during river flow and outlet releases provides an indication of how many fish are present and where they are located. The disadvantage of this method is that it is capture dependent and may affect whether a fish continues to migrate. Additionally efficiency can be affected by water quality and river flow.

Netting of fish is a standard method of determining fish species and abundance; however efficiency is limited when used in turbulent flowing water. Netting will be used as an adjunct to electrofishing where suitable.

Hydroacoustics is an established method of determining fish numbers, biomass and size in marine environments. Recent advances in technology have resulted in hydroacoustics also being applicable to the shallow freshwater environment, as a result it is now utilised to detect fish migrations overseas. Hydroacoustics has not previously been used for this purpose in Australia but the DPI&F has recently purchased a system costing over $80,000. Prior to commencing this monitoring program the system will be exhaustively tested to determine its suitability at the Burnett River Dam.

(g) BU5.4.3 Monitoring fish behaviour

PIT tag readers are to be installed on the fishways at the Burnett River Dam. Data on the behaviour of PIT tagged fish at other fishways in Queensland has contributed to improvements in the design of the Burnett Water structures. Data collected in this sampling program will contribute information on how to optimise the operation new fishways and possible design improvements. The main disadvantage of PIT tag readers is that they only detect PIT tagged fish, a major component of this monitoring program will dedicated to establishing a tagged population of fish.

Hydroacoustics also be used to identify the behaviour of fish in the vicinity of the dam as well as for counting of fish entering and exiting the fishways.

(h) BU5.5 Outline of the Monitoring Program

The monitoring program presented in this document has been developed and built upon that developed for Eidsvold Weir by Martin Mallen-Cooper on behalf of the Weir Owner. The tables presented on the following page have retained the format that delineates between assessment and investigative portions of the fishway monitoring program. Codes developed in the Eidsvold

Weir Monitoring Plan serve to identify how components of the program relate to questions provided in the monitoring plan.

As the Burnett River Dam represents Australia's first fishlift it will be necessary to address all facets of both core and non-core monitoring. Data collected from components of the program may result in modification requirements to the operation and possible structural alterations to the fishways.

(i) BU5.5.1 Burnett River Dam Monitoring Outline

	Question	***Method/s***
	Upstream Fishlift Assessment Program	
UA-1	What is the species composition and abundance of upstream migrating fish at the site? When is migration occurring?	Estimate abundance directly downstream using hydroacoustics, electrofishing, fyke nets and seine nets as well as trap fishlift entrances and data from PIT readers. Targeted sampling over widest possible range of seasons and flows.
UA-2	Is the operation / design of the fishlift attracting fish to fishway under the full operational range?	Assess zones of aggregation under the full range of operational flows using electrofishing, hydroacoustics directly downstream of the dam and in the outlet works and fishway entrances. Compared with detections of PIT tagged fish plus a specific lungfish program using radio telemetry.
UA-3	Is the capacity of the fishlift suitable for passage of the migratory biomass within an acceptable timeframe? Are all of the most abundant species and size classes directly downstream of the dam successfully utilising the fishlock?	Determine species and size classes of fish entering the fishlift using traps. Fish abundance directly below the dam determined using electrofishing and hydroacoustics and compared to trap catch.
UA-4	Is the attraction flow and cone traps sufficient to retain fish in the holding chamber during hopper travel phases?	Counts of fish entering and leaving holding chambers during attraction phase without being lifted; using hydroacoustics and PIT reader data. Plus de-water entrance channels to validate spp and numbers.
	Upstream Passage Investigative Program	
U1-1	Is the water quality (dissolved O^2) in the fishlift hopper maintained for the entire lift phase and is there a significant difference between water quality in the hopper and the impoundment?	Continuous monitoring of water quality during lift and comparison with levels in the impoundment.
UI-2	What is the optimum cycle time for each season and flow condition?	Manipulation of cycle times and counts of fish in the hopper during periods of high and low migration combined with data from UA-2
UI-3	Is the proportion of flow through each entrance slot equivalent to the number of fish present at the entrances under the full operational range?	Use data from UA-2 and UA-3 to determine fish numbers and adjust flow and entrance sill levels to suit.
UI-4	Is predation and crowding occurring in the hopper and are fish able to swim away immediately after release into the impoundment?	Visual observation and counts of fish in the hopper. Trapping of fish in floating pen in the impoundment and observation of behaviour following release from hopper using hydroacoustics.
UI-5	Are substantial numbers of fish being attracted away from the fishway entrance?	Use data from UA-2 to alter flow patterns / operation to improve attraction and re-assess.
UI-6	Are any fish unable to enter the fishlift due to behavioural or physical barriers?	Use data from UA-1 to UA-4 to identify species and size classes that are not represented at the fishlift, modify and assess

(j) BU5.6 Implementation

(k) BU5.6.1 Staffing

The monitoring and associated analysis and reporting would be undertaken over a five year timeframe. A dedicated team of three staff will work full-time on fishway monitoring program for the first three years. This will be decreased to two full time staff for the fourth and fifth years. The staff and monitoring program will be under the supervision of the current DPI&F Southern Fishway Team leader, Andrew Berghuis. Andrew will also assist with fieldwork as required.

Andrew Berghuis, Supervising Biologist
Andrew has over ten years experience working on Queensland fishways. He undertook the pre-construction fish sampling at both sites and has been closely involved in the fishway design processes for both fishways.

Andrew's expertise has been recognised nationally and he has been an important member of the Murray Darling Basin Commission's interstate Fishway Design Review Committee for the current $30 million Murray Fishway Restoration Program.

Andrew has also recently undertaken investigative studies for the Western Australian Government determining at the feasibility of re-establishing fish passage at the Ord River Dam and associated weir.

Andrew has been at the forefront of the application of remote monitoring technologies for fish passage in Australia. He has trialled PIT tag technology at Ned Churchward Weir fishlock and at Boggabilla Weir fishway on the Macintyre River for recording fish behaviour and fish movement and fishway function at those sites.

Andrew has also trialled the use of hydroacoustics for monitoring larger scale fish movements and will be attending training on this type of system in the USA in June 2005.

Andrew has been working on fish passage and fishways in the Bundaberg region since 1997. He has a unique understanding of fish communities and fish movement in the Burnett catchment and also of the hydrology of the system. Andrew has also built up relationships with local Department of Natural Resources and Mines water managers and also SunWater managers and operations staff. Andrew's salary and costs will be met by DPI&F.

Shane Piltz, Technician TO2
The technician's position will be filled by Shane Piltz. Shane has been employed on DPI&F fishway and lungfish projects over 3 years and has worked with Andrew on investigations at Neville Hewitt Weir and Boggabilla Weir during that period. He has also undertaken the field sampling for the temporary fishways at the Burnett River Dam site. Shane has over 400 hours of electrofishing experience, gained mainly in the Burnett River catchment and has participated in projects monitoring adult lungfish and lungfish spawning sites throughout the Burnett River catchment.

PO3 and PO1 biologist positions will be filled on confirmation of this proposal. The PO1 fisheries biologist would possess a minimum of a tertiary level degree or equivalent and is likely to be a recent graduate. As well as a relevant degree, the PO3 biologist would be expected to have significant experience (at least five years) in designing and running research or monitoring type projects, producing reports and presenting project results to a wide audience as well as sound staff management experience.

It should be noted that in Australia, all electrofishing boats are operated under a national code of conduct. To be endorsed as an operator under this code requires 50 hours experience and attendance at a training workshop. Most DPI&F staff who operate electrofishers have also received training from the electrofishing unit manufacturers (who are based in the USA). By the commencement of the monitoring, DPI&F staff will also have received training from the hydroacoustic system manufacturer by attending a dedicated training course in the USA. It is unlikely that this level of expertise in both sampling techniques exists elsewhere in Australia.

(l) BU5.6.2 Location

As previously mentioned the team will be based at the DPI&F offices in Bundaberg, within two hours drive to The Burnett River Dam. This will allow field sampling to be undertaken at short notice and in response to localised flow events. It will also reduce costs in travel and overnight accommodation.

Intensive field sampling will be carried out by the team during spring, summer and autumn flows. The rest of the year will be used to organise, download and analyse data and for major report writing. There will also be some sampling during the cooler months and lower flows to look at lungfish movements for spawning and downstream passage of species such as mullet.

Sampling programs will be designed to enable rigorous statistical analysis of the data. It is anticipated that results from this monitoring will eventually be submitted as papers to international scientific journals and thus will be endorsed by the scientific establishment.

(m) BU5.6.3 DPI&F advantages

The following summarises some of the advantages of DPI&F Bundaberg undertaking the upstream fishway monitoring at the Burnett River Dam:

- Familiarity with the development of the fishway design including modelling
- Unparalleled experience in fishway and fish passage monitoring within the Burnett River system and knowledge of fish communities in the Burnett
- Experience in remote monitoring methodologies such as the deployment and use of PIT tags and radio tags, including successful surgical implantation procedures on threatened fish species
- Possession of electrofishing boats and operators certified under Australian Code of Electrofishing Practice
- Possession of hydroacoustic monitoring system and trained operator
- Salary costs of Program Leader provided by DPI&F
- No capital costs for the boat electrofisher, nets and hydroacoustic equipment will be included in the costing
- Locally based resulting in rapid response time to flow events and travel cost savings
- Established network of contacts among water managers and other stakeholders in the Burnett region

Section 1.06 BU6. Milestones and Reporting

The components of the monitoring proposal that can be completed (and when) in a given year will depend on the availability of fish to move through the fishways or over the spillway, and the incidence of flows. This means that the standard milestone and quarterly reporting structures will rarely be relevant. For this proposal, the milestones and reporting structures reflect the seasonal activities and lulls in flows, fish movement and hence sampling (refer Table bu (iii)).

<u>Milestones</u>

- Signing of contract – June 2005

Year 1 - 3

- Commencement of intensive field seasons – late spring
- Completion of intensive field seasons – early winter
- Experiments associated with optimisation of fishway and dam operation process
- Report on fieldwork to date – late autumn
- Report on initial appraisal of fishway function – late autumn (Year 1 only)
- Field data management/analysis – winter
- Completion of annual report – end winter
- Completion of milestone report – end winter (Year 3 only)

Years 4-5

- Modified upstream and downstream fish passage sampling
- Completion of annual report – end winter (Year 4)
- Complete optimisation of fishway and dam operation process (Year 5)
- Completion of final report – spring (Year 5)

Program activity	Year 1 (05/06)	Year 2 (06/07)	Year 3 (07/08)	Year 4 (08/09)	Year 5 (09/10)
Intensive upstream fishway sampling	First flow of spring – early winter	First flow of spring – early winter	First flow of spring – early winter	Summer and autumn	Summer and autumn
Intensive downstream fish passage sampling	Throughout the year	Throughout the year	Throughout the year	Timing dependent on results for years 1 - 3	Timing dependent on results for years 1 - 4
Flow related sampling	As flows arise	As flows arise	As flows arise	As flows arise	As flows arise
Data management	Winter	Winter	Winter	Winter	Winter
Data analysis	Winter	Winter	Winter	Winter	Winter
Initial appraisal of fishway function	Late autumn				
Fieldwork summary	Late autumn	Late autumn	Late autumn	Late autumn	Late autumn
BRDOC report	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly
Annual report	Winter	Winter	Winter	Winter	Winter
3 year milestone report			Winter		
Final report					Spring

Table bu(iii). Timing of Monitoring and Reporting at Burnett River Dam

Section 1.07 BU7. PAYMENT

The proposed payment schedule is based on annual payments upon acceptance of the annual report by Burnett Water or the Dam Operator. For the first twelve months of the project, payment of 25% of the Year 1 budget will be sought in December 2005 and June 2006 respectively. This will cover costs to DPI&F for the 2005/2006 financial year. The remaining 50% of the Year 1 budget will be sought in September 2006.

	Timeframe	Milestone	Payment (excl GST)
Year 1	December 2005	Commencement of intensive field season	$27,000
	June 2006	Completion of Intensive field season	$27,000
	September 2006	Acceptance of annual report	$54,812
Year 2	September 2007	Acceptance of annual report	$108,812
Year 3	September 2008	Acceptance of annual report	$108,812
Year 4	September 2009	Acceptance of annual report	$49,282
Year 5	December 2010	Acceptance of final report	$49,282
Total			**$425,000**

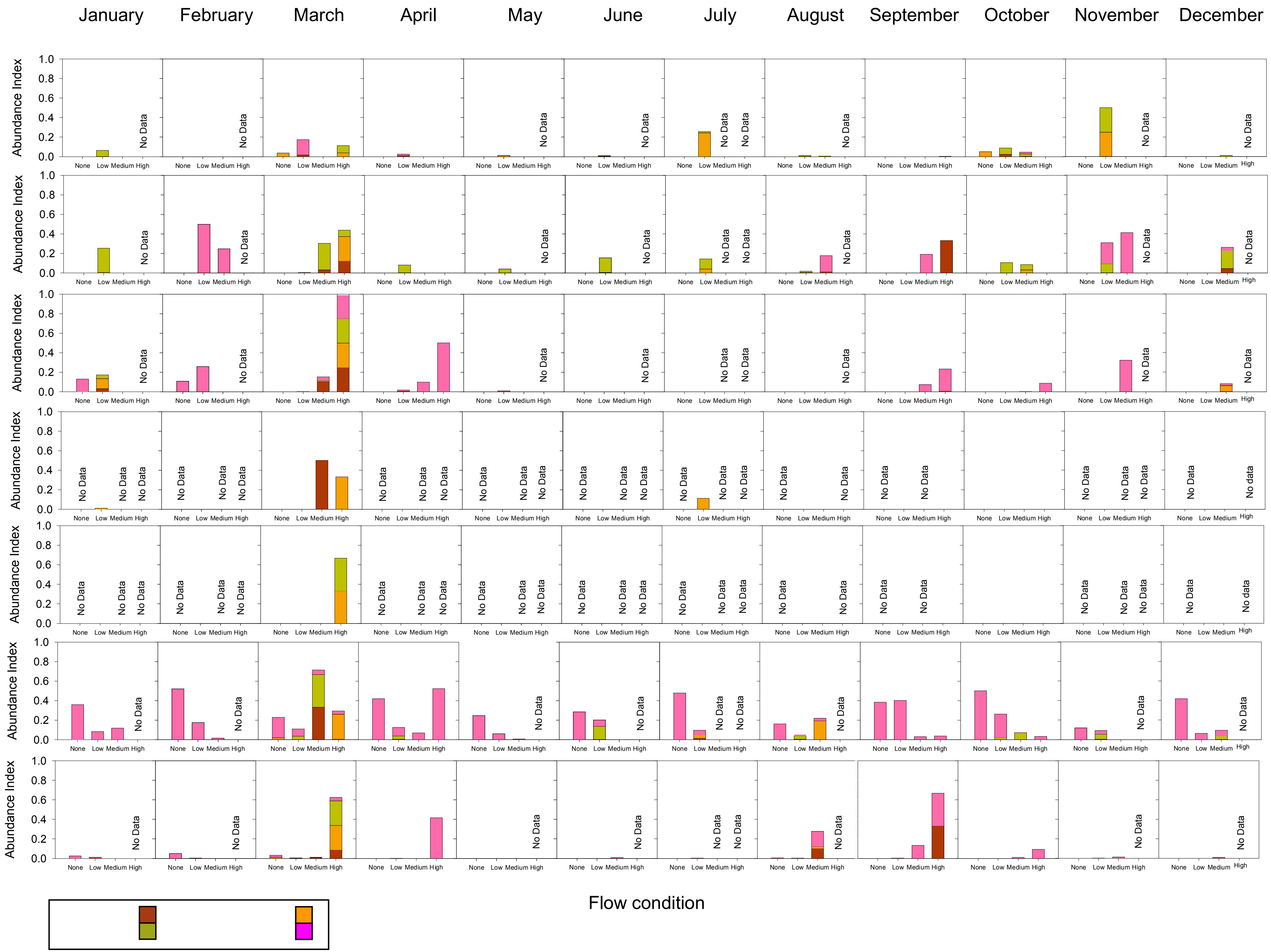
Table bu(iv): Payment schedule for the Burnett River Dam Upstream Fishway Monitoring Program

Appendix B

Paradise Upstream Fishway Monitoring Program Annual Reports – June 2007, September 2008 and September 2009.

Appendix C

January
February
March
April
May
June
July
August
September
October
November
December
Abundance Index
olive perchlet
flyspecked hardyhead
mosquito fish
western carp gudgeon
Midgley's carp gudgeon
Dubouilay's rainbowfish
purple-spotted gudgeon
None
Low
Med
Medium
High
No Data
No data
Flow condition


January
February
March
April
May
June
July
August
September
October
November
December
banded grunter
long-finned eel
blue catfish
snub-nosed garfish
goldfish
spangled perch
golden perch
Abundance Index
None Low Medium High
No Data
No data
Flow condition


January
February
March
April
May
June
July
August
September
October
November
December
mouth almighty
Australian bass
striped mullet
bony herring
Queensland lungfish
Hyrtl's tandan
sleepy cod
Abundance Index
None Low Medium High
No Data
Direct trapping
Fyke netting
Boat electrofishing
PIT detections
Flow condition

January
February
March
April
May
June
July
August
September
October
November
December
Abundance Index
flathead gudgeon
pacific blue-eye
speckled goby
australian smelt
Rendahl's catfish
freshwater catfish
No Data
None Low Medium High
Direct trapping
Fyke netting
Boat electrofishing
PIT detections
Flow condition