UPSTREAM PASSAGE OF QUEENSLAND LUNGFISH AT NED CHURCHWARD WEIR FISHLOCK

March 2004

A.P. Berghuis C.D Broadfoot

Queensland Fisheries Service, Bundaberg

Queensland Government
Department of Primary Industries

FOR THE DEPARTMENT OF STATE DEVELOPMENT

UPSTREAM PASSAGE OF QUEENSLAND LUNGFISH AT NED CHURCHWARD WEIR FISHLOCK

March 2004

A.P. Berghuis C.D Broadfoot

Queensland Fisheries Service, Bundaberg

Queensland Government
Department of Primary Industries

FOR THE DEPARTMENT OF STATE DEVELOPMENT

Cover images: Ned Churchward Weir fishlock and S. Piltz with a tagged lungfish prior to release.

TABLE OF CONTENTS

1. Summary

The Queensland lungfish (*Neoceratodus forsteri*) is endemic to the Mary and Burnett catchments and has also been translocated to other catchments in southern Queensland. Ned Churchward Weir (formerly Walla Weir) was constructed to a height of 15m in 1998 and fitted with a fishlock type fishway. Previous studies at Ned Churchward Weir found that whilst large numbers of lungfish approached the weir only a small number utilised the fishlock to migrate upstream. Subsequently, doubts were raised as to whether the design and operation of the fishlock was providing adequate passage for lungfish.

As a result of ongoing water infrastructure development in the Burnett catchment, the Department of State Development under the "Burnett Program of Actions" funded the current study. The objective of the study was to provide more detailed knowledge of lungfish passage through the Ned Churchward Weir fishlock. In order to achieve continuous and non-intrusive monitoring of lungfish as they approached and utilised the fishlock, a reader system to detect the presence of passive integrated transponder (PIT) tagged fish was installed at Ned Churchward Weir. A total of 1285 lungfish were captured and PIT tagged at sites upstream and downstream of the weir from October 2002 to November 2003. Data on the behaviour of PIT tagged lungfish at Ned Churchward Weir were collected from January to December 2003.

A total of 41 individual lungfish were recorded at the downstream entrance of the fishlock of which only 7 continued through the fishlock. As a result of the continuous nature of the data collection, response to factors such as river flow and fishlock cycling provided further insight into lungfish behaviour at fishways. Data collected in this study indicates that passage past Ned Churchward Weir is important and that the fishlock does not appear to be providing optimal passage for lungfish. Recommendations to improve the suitability of fishways for lungfish by altering the operation and design of the current fishlock and future mechanical fishways are provided.

It is recommended that the PIT tag reading system at Ned Churchward Weir be maintained over the longer term and that further monitoring and tagging of lungfish be undertaken within the vicinity of the weir. Should the proposed raising of Ned Churchward Weir proceed or any of the suggested modifications to the design and operation of the fishlock are undertaken, the reader system can be used to monitor the passage of lungfish.

2. Introduction

2.1 Previous studies of Queensland lungfish migration

In 1998 a lock-type fishway was incorporated into the construction of the Ned Churchward Weir on the Burnett River to facilitate passage of migratory fish. An assessment of the effectiveness of the fishlock was undertaken over an 18-month period from January 1999 to June 2000 (Berghuis, Broadfoot et al. 2000). A total of 31,154 fish representing 27 species were identified attempting to migrate upstream through the fishlock. The assessment established that the fishlock provided adequate access over the weir for the majority of upstream migrating fish species and size classes. Twelve Queensland lungfish were recorded using the fishlock in the 1999-2000 study and were abundant below the weir and in all methods of fish community sampling (Berghuis, Broadfoot et al. 2000). Given the observed abundance and the low number of lungfish recorded using the fishlock further investigation was required before the structure could be considered to provide suitable passage for this important species.

A previous study of the ecology and demography of the Queensland lungfish in the Burnett River utilised radio telemetry, PIT and dart tagging to identify the movement patterns of lungfish. The results of the study indicated that the movement patterns of lungfish varied between populations. Individuals within impounded waters undertook regular longitudinal movements whereas individuals from riverine sections were largely sedentary. A conclusion of the study was that the free passage of lungfish in both upstream and downstream directions was likely to be biologically important, particularly given the fragmentation of suitable habitat by ongoing water resource developments (Brooks and Kind 2002). Prior to the construction of Ned Churchward Weir, the area downstream contained several semi-permanent waterholes that would have provided a dry season refuge for Queensland lungfish. Downstream of the waterholes an extensive area of suitable breeding habitat for Queensland lungfish has become established due to sustained water releases from Ned Churchward Weir (Brooks and Kind 2002).

2.2 Continuous monitoring methods

Although methods that rely on the capture of migrating fish are useful in gaining knowledge on the suitability of fishway design for highly abundant, strongly migratory species they are labour intensive and therefore generally short-term studies. Continuous remote monitoring provides an opportunity to record the behaviour of fish not only as they migrate through the fishway but also as they attempt to enter or fail to successfully migrate through the fishway. The data can then be compared to fishlock operation and abiotic factors such as water temperature, flow, diel period or season.

Passive integrated transponder (PIT) tags have been widely used to detect migrating fish in studies overseas and more recently in Australia (Berghuis and Broadfoot in press). However, fixed antenna reading systems have been limited to full-duplex transponder systems. The antenna design restrictions and high cost of these systems have limited their use in Australia. Researchers in the USA substantially resolved many of the problems by developing a half-duplex system applicable to fishways (Barbin-Zydelwiski, Haro et al. 2001).

Half-duplex systems offer greater design flexibility with much lower costs and subsequently this technology was adapted to the fishlock arrangement at Ned Churchward weir. A major benefit of PIT tags as a method for identifying fish is their durability, because PIT tags are implanted into the animal the shedding rate is very low (Lucas and Baras 2000). Unfortunately the 11mm long PIT tags used by Brooks and Kind (2002) in a previous study of lungfish in the Burnett River were suited to a full duplex system and were not able to be detected by the PIT tag readers used in this study.

3. Methods and Materials

3.1 Study site

The Burnett River catchment covers an area of 34,240 km^2 with a mean annual discharge of 1.4 x 10^6 ML a year (Sinclair-Knight-Merz. 1998) and with 25 instream storages is one of the most highly regulated river systems in Queensland (Brizga, Arthington et al. 2000). The Ben Anderson Barrage at adopted middle thread distance (AMTD) 25.9 km is the first barrier on the Burnett River (Figure 1). The recent retrofitting of a modified vertical-slot fishway provides passage for a diverse range of fish fauna across the barrage (Stuart and Berghuis 2002). The second barrier, Bingera Weir at AMTD 42.5 km is usually inundated by the Ben Anderson barrage impoundment but when not submerged the full supply level of Bingera Weir impounds water for 19 km. Impounded water therefore extends upstream to AMTD 67.3 km, resulting in approximately 7.2 km of unimpounded riverine habitat between the barrage and Ned Churchward Weir (Brizga, Arthington et al. 2000). Ned Churchward Weir is the third barrier present on the Burnett River and is located at 74.5 km AMTD and impounds water 34.5km upstream to 109.0km AMTD.

Ned Churchward Weir (formerly Walla Weir) is a 15.0 m high, concrete gravity structure with a total storage capacity of 29,500 ML at full supply level and fitted with fishlock fishway (Brizga, Arthington et al. 2000). The weir was constructed on a rock-bar that spans the width of the river. Another rock-bar directly downstream is used as a tailwater control. Further development of the weir (Stage II), is planned with the use of a two metre inflatable rubber dam to increase the storage capacity to 42,600 ML (Sinclair-Knight-Merz. 1998). Ned Churchward Weir provides water primarily for surface water irrigation within the Bundaberg Irrigation Area. Construction of the weir was completed and subsequently filled in November 1998.

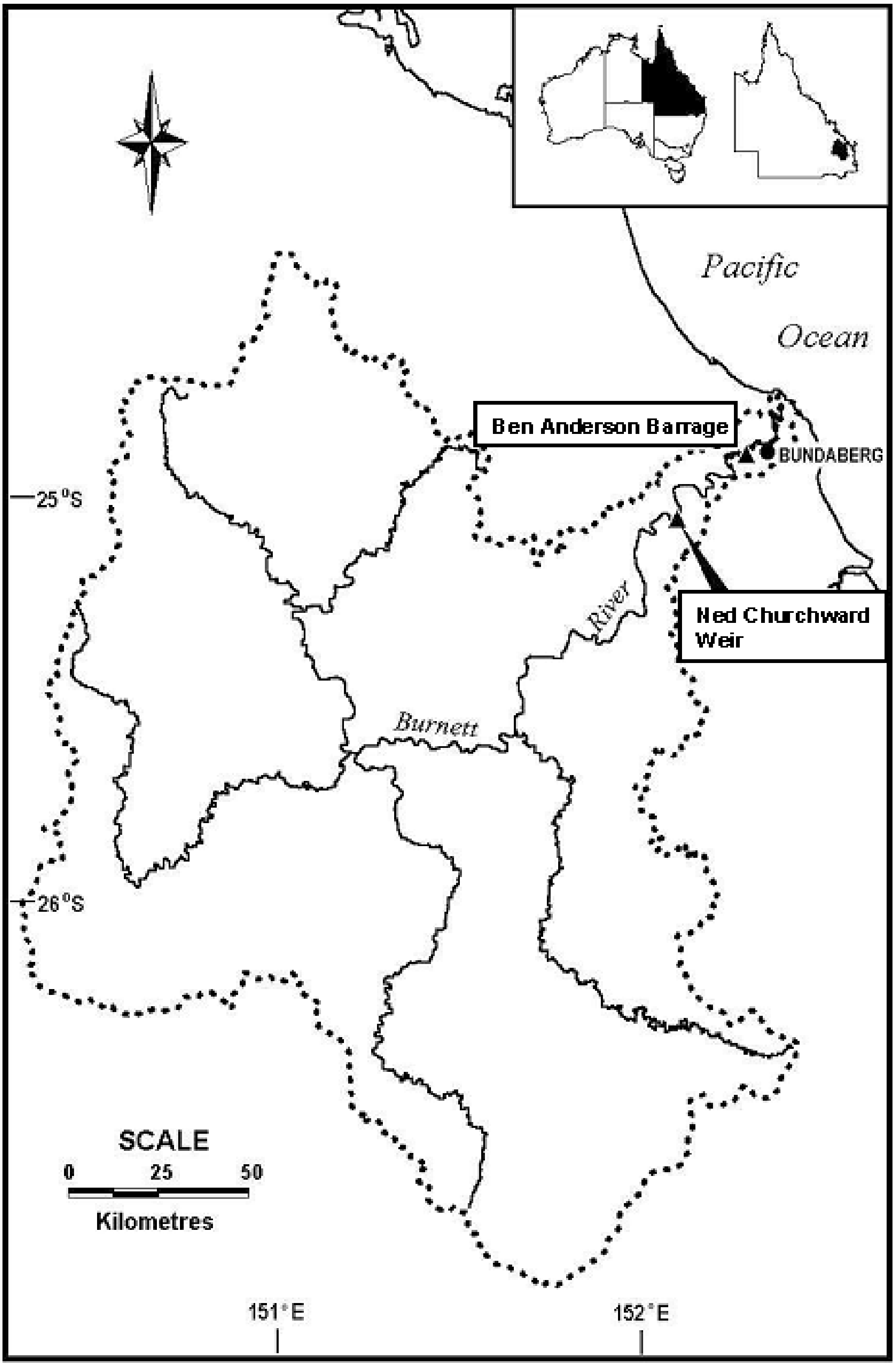

Figure 1. Map of the Burnett River Catchment indicating the position of the Burnett River Barrage and Ned Churchward Weir.

3.2 Fishlock operation

The fishlock consists of a downstream channel at the base of the weir, connected to a vertical lock chamber (Figure 2) and upstream channels located at the top of the weir (Figure 3). A Programmable Logic Control (PLC) unit controls operation of the fishlock with hydraulically actuated gates and valves operated in a set sequence. The water supply for fishlock attraction and fill phases is sourced from the left hand outlet works, utilising near surface water extracted via selective baulks. Operation of the fishlock for upstream migration involves four main phases:

- **Attraction**- migrating fish are initially attracted to the downstream fishlock channel by a flow of water released through a diffuser pipe on the floor. After a preset amount of time the downstream lock chamber gate opens and a flow entices fish to enter the lock chamber.

- **Filling**- the downstream lock chamber gate closes and the lock chamber fills with water and fish rise to the level of the storage.

- **Exit**- the exit gate opens and fish are encouraged into the upstream fishlock channel and out into the storage by a flow of water. The flow is created when the lock drain valve is opened and water is released through the diffuser pipe on the downstream fishlock channel floor.

- **Draining-** the exit gate closes and the lock chamber is drained to the level of the tailwater, with the water again released through the downstream fishlock channel.

No attraction flow is provided during the fill phase. The drain and exit phase flows are released from different points to the dedicated attraction flow and as a result there is variation in the intensity of flows, with the drain flow generally having a higher velocity. Fishlock operators are able to monitor the fishlock and regulate the intensity and duration of attraction and exit flows, as well the timing of each phase of a cycle.

An average fishlock cycle during this study took 65 minutes to complete. Attraction flow was provided at the downstream fishlock channel for 47.3 minutes (73.3%) in each cycle. Periods of up to 2 minutes with no attraction flow preceded the opening of the downstream lock chamber gate, which remained open for 23.5 minutes (36.2%) in each cycle.

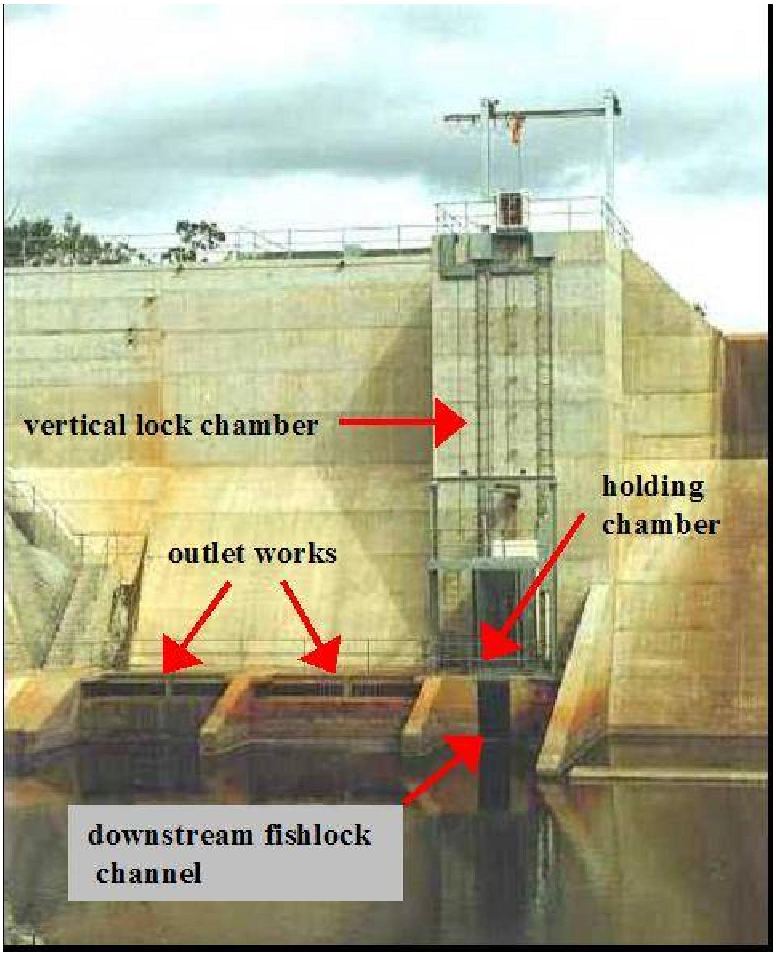

Figure 2. View of Ned Churchward Weir fishlock from the tailwater pool.

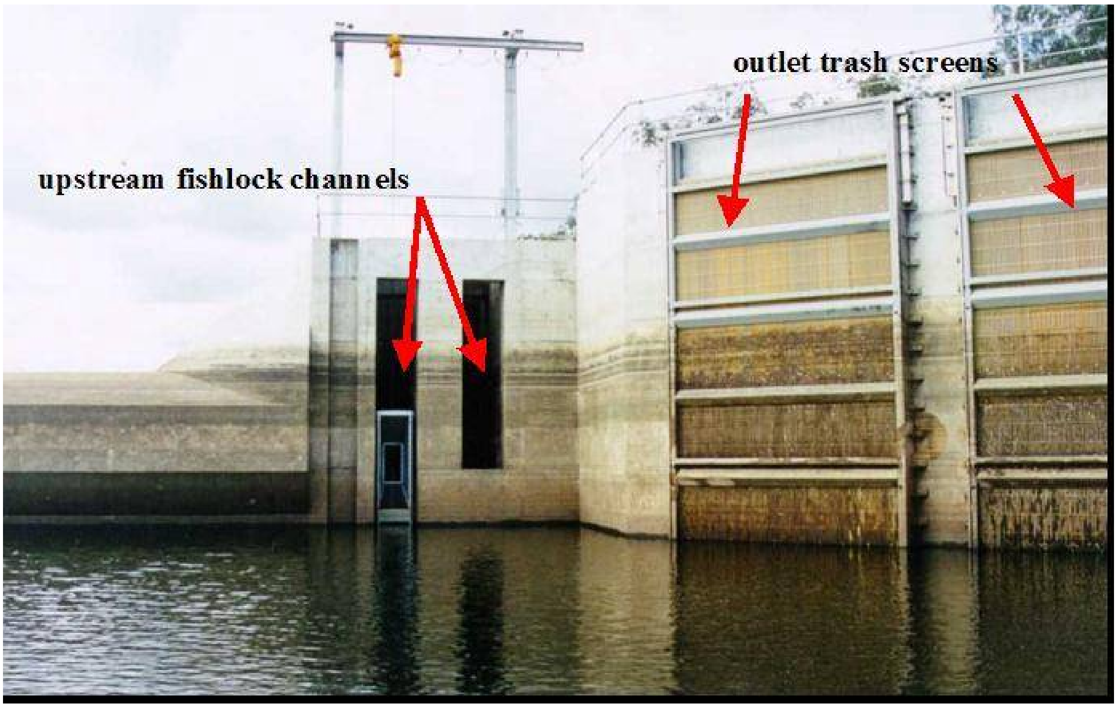

Figure 3. View of Ned Churchward Weir fishlock from the headwater pool, cone trap pictured in upstream fishlock channel.

3.3 PIT tag reader system

The PIT tag reader system incorporated low frequency (134 kHz) RFID technology by Texas Instruments. Each reader station comprised of a control module (RI-CTL-MB6A), a remote antenna radio frequency modulator (RI-RFM-008B), an antenna-tuning module (RI-ACC-008B) and an antenna. Antennas consisted of single or double wire (3-4mm copper cable) loops and were positioned to detect fish at: the entrance to the downstream fishlock channel, the downstream lock chamber gate, the upstream lock chamber gate and the exit of the upstream fishlock channel.

When tagged fish enter the detection area the PIT tag is energised by the inductive field of the antenna, which then allows the tag to transmit the unique identification number to the control module. This identification number is then transmitted to a computer and recorded with the antenna position and a date and time stamp. Read accuracy was tested with a PIT tag attached to a plastic rod in similar orientations as a fish would be expected to move through the antenna field. This was repeated until the antenna was tuned to the optimum read range with the tag being read on every pass through the antenna. Data was downloaded from the computer at regular intervals and time matched to the operation of the fishlock.

Due to problems with conducted electrical interference from the control building (Refer to Appendix A), commissioning of the system was delayed until the 10th January 2003 and limited the system to two functioning antenna, one at the exit of the upstream fishlock channel and the other at the entrance to the downstream fishlock channel.

3.4 PIT tagging of fish

In order to identify longitudinal movements in both directions, lungfish were collected and tagged at sites upstream and downstream of the weir from October 2002 to November 2003. Upstream from Ned Churchward Weir, fish were collected and tagged up to 5km upstream from the weir wall and at Wallaville gauging weir, Booyal Crossing, Goodnight Scrub, Mingo Gorge, Claude Wharton Weir, Jones Weir and Ceratodus gauging weir. Downstream of the weir lungfish were tagged at five sites extending from approximately 17km downstream to directly below the weir (Table 1).

Fish were collected using up to two boats fitted with 7.5kW Smith–Root electrofishers that produced a pulsed DC waveform. Two operators at the bow of each boat collected stunned fish with dip nets and placed them into a tank of water until processed; a third person operated the boat and the electrofisher controls. All lungfish captured were measured and scanned to ascertain whether they had been previously tagged, a sub-sample were also weighed. Previously untagged fish were tagged in the dorsal muscle with 23mm Eco-line glass transponders (RI-TRP-REHP) weighing 0.6 grams and using a sterile needle and Henkeject applicator gun. Morphometrics and capture information were recorded against the unique PIT ID number. Scanning and transcribing of the PIT number was undertaken twice to reduce operator error. Occasionally, lungfish that had been tagged during previous surveys were recaptured in subsequent surveys as well as by the Department of Natural Resources Mines and Energy (NRME) during routine ecological monitoring and the QFS during lungfish monitoring. The tag details of recaptured fish were recorded, the fish were re-measured and released at the capture point.

A total of 1285 lungfish ranging in size from 355mm to 1385mm long were tagged at all sites combined (Table 1). At the downstream sites 917 lungfish were tagged and at the upstream sites 368 lungfish were tagged. During the collection of lungfish various other fish species were also captured and PIT tagged. A table detailing the number of other fish species tagged in this study has been provided in Appendix B. Fish migrating through the fishlock were collected in the top sampling trap for 24 hours as described in Berghuis, Broadfoot et al. (2000) over 9 days from January to April 2003. The trapping exercise resulted in the capture of 3 lungfish in March, ranging in size from 824mm to 881mm long and one 479mm lungfish in April. All fish were tagged and released directly downstream of the weir wall.

Table 1. **Site name, river distance and number of lungfish tagged in the Burnett River. Light shading indicates sites downstream of Ned Churchward Weir and dark shading indicates sites upstream. NC = Ned Churchward Weir**

Site Name	Approx. AMTD (km)	No. lungfish tagged
Isis Pump	54	81
Train Crossing	59	182
McEvoys lower	65	137
McEvoys upper	67	252
Below NC Weir	73	261
NC Weir Fishlock exit	74	4
NC Weir Impoundment	79	8
Walla Gauging Weir	99	118
Booyal Crossing	110	68
Figtree	121	1
Goodnight Scrub	135	31
Claude Wharton	202	88
Jones Weir	240	37
Eidsvold	321	8
Below John Goleby Weir	324	9
	TOTAL	1285

3.5 Abiotic data

Mean daily river flow, outlet release volumes and fishlock cycle data was provided by SunWater. During this study the maximum flow volume over Ned Churchward Weir was 114,683 ML^{-day} and the maximum release volume through the outlet works was 836 ML^{-day}.

3.6 Analyses

Statistical tests were used to determine the relationship between lungfish that were detected at the fishlock and abiotic factors. Logistic regression was used to determine whether the mean daily flow volume from the outlet works and over the spillway had an influence on the detection of lungfish at the fishlock. A Kolmogorov-Smirnov two-sample test was used to determine whether the size classes of lungfish detected at the downstream fishlock channel were representative of the tagged population. Wilcoxon’s rank-sum test was used to detect differences between the number of lungfish detected at the upstream and the downstream fishlock channels.

4. Results

4.1 Lungfish detected in the downstream fishlock channel

A total of 41 lungfish were detected at the downstream fishlock channel, of these seven (17.1%) successfully migrated upstream through the fishlock (Table 2). The maximum number of days that an individual lungfish was detected in the downstream fishlock channel was six, however most fish were detected on only one day. Most of the lungfish swam in and out of the downstream fishlock channel several times over a number of hours before moving through the fishlock or moving away entirely. The longest period between the first and last detection was 40 days, however most detections occurred within ten days of each other. The largest fish to successfully migrate upstream was 1170mm long and the smallest 385mm long (Table 2).

During this study PIT tagged fish from other species were also detected at the fishlock. Appendix B provides details on the total number of fish detected with passage time and success rate for each species.

In order to determine whether fish detected at the fishlock could be assumed to be representative of the tagged population, differences in length frequency of lungfish detected at the downstream fishlock channel were compared against the classes of tagged lungfish (Figure 4). Using the Kolmogorov-Smirnov two-sample test, no significant difference (1.77 on 2 d.f. p=0.412) was found between the two samples. Using recapture data from this study and growth data from Brooks and Kind (2002), the assumption was made that tagged fish were unlikely to have grown substantially in the period between tagging and subsequent detection.

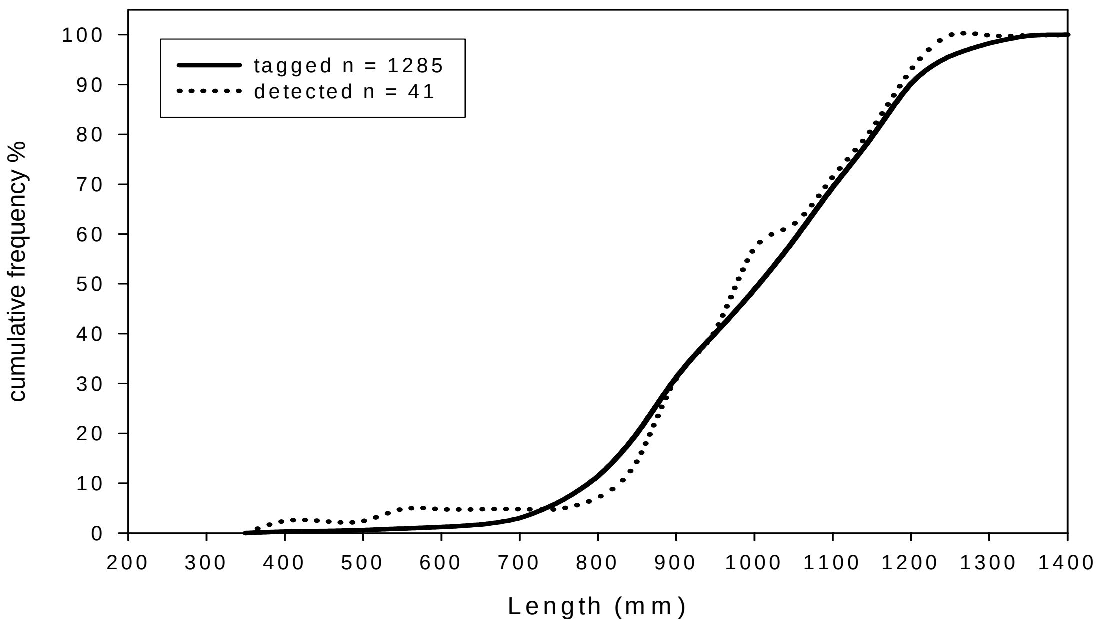

Figure 4. Cumulative length frequencies of all tagged lungfish and tagged lungfish detected at the downstream fishlock channel.

A Wilcoxon's rank-sum test was used to detect differences between the number of lungfish detected at the upstream and the downstream fishlock channels. The result of this test indicated that there was a significant difference (*P*=<0.001, N=50) with significantly more fish detected at the downstream fishlock channel.

4.2 River flow

River flow that resulted in the Ned Churchward Weir overtopping occurred from February to May 2003, supported by high-level outlet flow releases between flow peaks (Figure 5). In line with the Storage Operational Management Plan (SOMP) water levels within the weir impoundment were stabilised and releases predominantly made through the fishlock with an average release of 13.6 ML^{-day} from 1st of June to 31st of October 2003. On 1st November outlet releases resumed with an average release of 382 ML^{-day} for the month. Detections of lungfish in the downstream fishlock channel were compared against mean daily river flow using logistic regression. Within the confines of the logistic regression model river flow was not found to be significant in influencing lungfish migrations.

4.3 Lungfish activity

Lungfish were regularly detected at the downstream fishlock channel from 16th January to 17th June 2003, however no further detections were recorded until 13th of November 2003 when a previously undetected lungfish was recorded for one read only. One other lungfish was detected and migrated upstream through the fishlock on 24th November 2003; no other lungfish were detected up to end of this study on 28th December 2003 (Figure 4). The greatest number of detections occurred from March to May 2003, with 85% of detections occurring during this period.

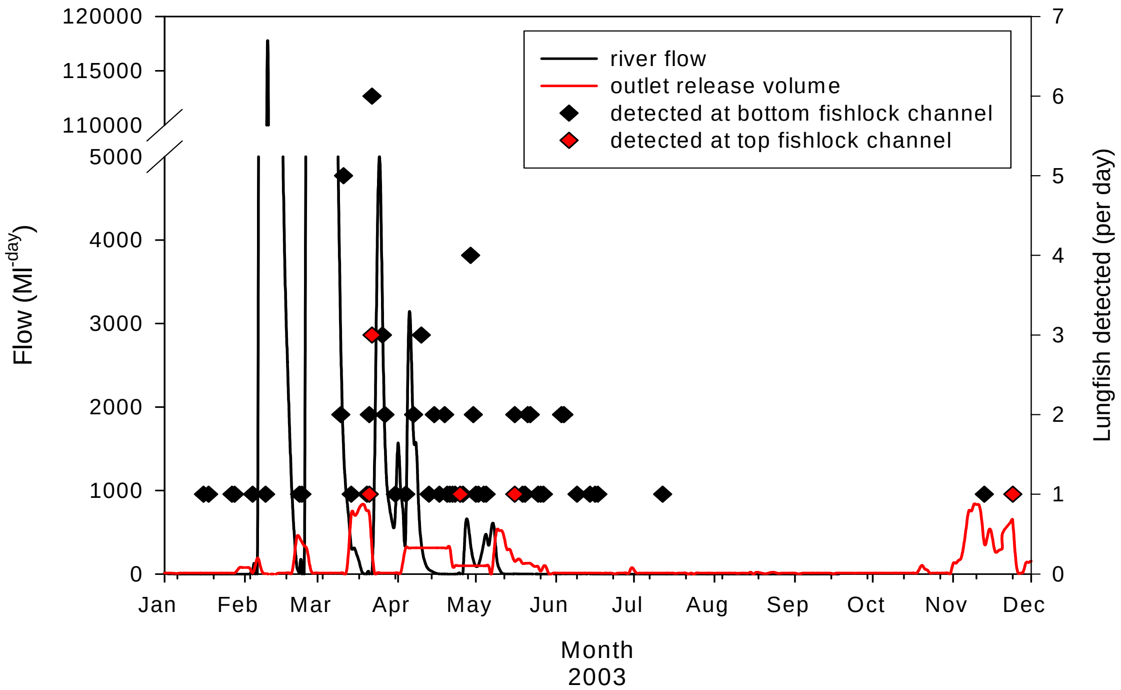

Figure 5. **River and outlet flow at Ned Churchward Weir and lungfish detections at the bottom and the top of the fishlock from January to December 2003.**

4.4 Passage time and fishlock cycling

Passage time for lungfish that were detected as they migrated upstream through the fishlock ranged from 18 minutes to 5.24 hours between the last read at the downstream fishlock channel and the last read at the upstream fishlock channel (Table 2). Of the five lungfish that had unimpeded passage through the fishlock, four migrated through in a single fishlock cycle. Of those fish that migrated through the fishlock in a single cycle the time between when the upstream fishlock channel gate opened and the first detection ranged from 3.6 to 17 minutes.

Table 2. Tag number, tag date, fish length, passage date and passage duration for lungfish.

Pit Tag ID	Date tagged	Length (mm)	Passage date	Passage duration (minutes)
109595734	29/11/02	825	21/03/03	17
109594348	18/02/03	950	22/03/03	16
94082701	29/10/02	1110	22/03/03	4.75
94081852	3/10/02	1170	22/03/03	3.6
109594396	18/02/03	980	25/04/03	3340.8
94082662	30/10/02	541	16/05/03	314.4
109595046	28/11/02	385	24/11/03	-

One lungfish took 2.32 days to move out of the fishlock however it is likely to have been affected by one of the 24hr trapping exercises. The trap was placed in the upstream fishlock channel 19 hours after this fish entered the fishlock and was removed 12.75 hours prior to the fish exiting the upstream fishlock channel.

The time records of the first detection of each lungfish at the downstream fishlock channel in March 2003 were compared against the lock cycle phases. Attraction flows coincided with 95.7% of all detections. Including the lungfish that successfully migrated upstream, the lock chamber gate was open during 53% of all first detections at the downstream fishlock channel.

Of the seven lungfish that successfully migrated upstream through the fishlock, five did so on the first day they were detected at the downstream fishlock channel. One lungfish was detected on four consecutive days before migrating upstream and the other was detected at the downstream fishlock channel on two separate days with a 10-day interval between detections.

4.5 Origin of detected lungfish

Of the lungfish detected in the downstream fishlock channel, 22 were originally tagged immediately downstream of the weir and 17 from the two McEvoys sites up to 9km downstream. Two lungfish were originally tagged upstream of the weir, one 25km upstream at Walla gauging weir and the other 36km upstream at Booyal Crossing. Of the four lungfish that were captured and tagged at the top of the fishlock and released downstream, one was detected at the downstream fishlock channel but did not migrate through. Of the seven lungfish that successfully migrated upstream through the fishlock, five were originally tagged directly below the weir and two were tagged downstream at the McEvoys site.

4.6 Recaptures of lungfish

Twenty of the 600 lungfish that were tagged downstream of the weir in October 2002 were recaptured in the same vicinity in November 2002. All recaptured fish were examined for any adverse reaction to the implant procedure but none was obvious. A further seven lungfish that were tagged in October and November 2002 were recaptured in November 2003. Three of the fish had moved 6km upstream below the weir; all other fish were recaptured in the original tagging vicinity.

Lungfish tagged by Brooks and Kind (2002) were identified in this study with 42 individuals recaptured from sites upstream and downstream of Ned Churchward Weir. The majority of lungfish recaptured had not moved a significant distance from the original tagging site after 5 years at liberty. The greatest movement between the original tagging and recapture site was an upstream migration of 81km from the Isis Pump over the Ned Churchward Weir and up to Goodnight Scrub. Two lungfish that were tagged in the impounded area prior to the construction of the weir were recaptured downstream of the weir wall. No recaptured fish were subsequently detected at the fishlock.

5. Discussion

5.1 General discussion

The purpose of this study was to increase knowledge of the use of lock type fishways by lungfish. While assessment of the fishlock by Berghuis, Broadfoot et al. (2000) established that lungfish were able utilise the fishlock to move past the Ned Churchward Weir, questions remained as to whether the fishlock design was entirely suitable for lungfish. The results of current study have reiterated that lungfish can and will use the fishlock. However only it has also demonstrated a discrepancy between the number of lungfish that successfully ascended the fishlock and those that may have been attempting to move past the weir and were unsuccessful.

The results of this study confirm that PIT tag readers are an effective method of assessing the utilisation and behaviour of lungfish at fishlocks. Unfortunately the current study was undertaken over a limited timeframe and has therefore provided only a snapshot of lungfish behaviour at Ned Churchward Weir. To this end the interpretation of the data collected is predominantly speculative, however it is the best available at this time. Monitoring of the passage of PIT tagged lungfish through the Ned Churchward Weir fishlock should be continued for at least another 5 years. Long-term datasets are a more useful tool in evaluating the effects of environmental disruption and seasonal variation, as over time repetitive patterns become easier to discern and interpret.

Whilst lungfish cannot be considered highly migratory, it is apparent that they do have a requirement to migrate. Prior to river regulation, portions of the Burnett River would have been seasonally fragmented and many fish species would have utilised river rises to move between habitats. The greater majority of lungfish habitat is within the highly regulated central and lower Burnett River Catchment. River regulation has further fragmented the remaining habitat by inundating productive spawning habitat (Brooks and Kind 2002). Therefore the maintenance of free passage beyond man-made barriers should be considered an important aspect of maintaining viable lungfish populations.

5.2 Lungfish migration

Brooks and Kind (2002) suggested a relationship between lungfish migration and river flow with individual fish actively migrating downstream following major river flows often with a partial or complete return upstream. Data from the current study provides further evidence of this relationship. Two lungfish that were originally tagged upstream of the weir made large-scale downstream migrations moving 25km and 36km respectively. It was likely that these fish travelled over the top of the weir following flood flows in February 2003 and were attempting to return upstream when detected at the fishlock in April and May 2003. However, neither of these fish actually migrated upstream through the fishlock. The current study also demonstrated the upstream migration of a proportion of lungfish tagged downstream of the weir. However, it is impossible to tell where these fish originated from prior to being tagged. It may be that these fish had already migrated downstream prior to being tagged and were detected as they attempted to return upstream. The migration of individual fish in both directions is equally likely, such a strategy would increase the opportunity to colonise new spawning and feeding habitat.

5.3 Lungfish migration and river flow

The majority of lungfish detections occurred between March and May, a period that coincided with low-level flood events and sustained outlet works release flows. Comparison of the detection of lungfish in this study with the capture of lungfish migrating through the fishlock by Berghuis, Broadfoot et. al. (2000) provided some interesting behavioural insights. During the assessment of the fishway, lungfish migrated upstream through the fishlock at irregular intervals from late winter until late autumn. However minor flood flows occurred throughout this period in 2000 and lungfish were recorded using the fishlock following the peak of each flow. In the current study no major releases occurred from the start of June to the end of October 2003 and no detections of lungfish occurred between mid-July and October.

Despite the failure of both this study and Berghuis, Broadfoot et. al, (2000) to find any statistical correlation between lungfish migration and river flow it is likely that one does exist. The first post-winter detection of lungfish occurred in November 2003 when high volume irrigation releases resumed. Although Berghuis, Broadfoot et. al, (2000) did not consider the rock-bar downstream of Ned Churchward Weir to be a major barrier for most fish species. The results of the current study suggest that it may prevent large fish such as lungfish from accessing the weir on low flows. However, it is also possible that lungfish migrate upstream following the peak of the flood flows, when water velocities are reduced and river levels are higher. The further study of lungfish migration over a longer term and a variety of conditions will assist in determining whether triggers to migration are seasonal or flow related.

5.4 Distances migrated and home range

Of the 389 lungfish tagged at the McEvoys sites, 17 (4.4%) migrated upstream and were detected at the fishlock. Interestingly, Brooks and Kind (2002) also found that only a small percentage of lungfish actively migrated away from their “home range” but that lungfish populations downstream of Ned Churchward Weir were far more mobile than fish from the other sites. The recapture of lungfish in the current study further support this finding with the majority of tagged lungfish recaptured within the vicinity of the original tagging site.

It is yet to be established why certain lungfish migrate considerable distances both upstream and downstream and others do not. However, similar individualistic migratory behaviour has previously been documented in other fish species and is considered to assist in maintaining genetic homogeneity within populations (Adkinson 1995). Genetic studies undertaken on lungfish populations in Burnett and Mary Catchments indicate that the lungfish already has low genetic diversity (Frentiu, Ovenden et al. 2001) so the effect of blocking such migrations may have a serious long-term impact.

5.5 Size classes of lungfish migrating

Although only 4.6% of the lungfish tagged below Ned Churchward Weir were detected at the fishlock they appeared to be representative of the tagged population. In this study, 80% of lungfish were larger than 850mm in length, a similar result to that found by Brooks and Kind (2002). The average threshold for sexual maturity of lungfish is 767.2mm for males and 834.4mm for females (Brooks and Kind 2002). Interestingly the current study has demonstrated that immature individuals also migrate, with a 385mm long lungfish moving through the fishlock. Given this result it is unlikely that lungfish are migrating upstream solely to find spawning habitat. It is more likely that a percentage of individuals migrate both up and downstream facultatively in search of suitable feeding and over wintering habitat.

5.6 Lungfish behaviour at the fishlock

Although only a small percentage of the lungfish detected successfully migrated upstream through the fishlock it is interesting to note that behaviour at the downstream fishlock channel was similar whether successful or not. Five of the seven lungfish that migrated through the fishlock did so on the same day they were first detected, indicating a strong migratory impetus. However, the majority of the fish that did not migrate upstream through the fishlock were similarly only detected in the downstream channel on a single day. Radio-tagged lungfish located below Ned Churchward Weir by Brooks and Kind (2002) displayed similar behaviour with fish moving upstream approaching the weir and fishlock for a short time before returning downstream. It is therefore likely that the majority of fish detected in the current study also moved back downstream after spending a short amount of time at the weir, a result which has implications for the future design of mechanical fishways.

The recapture of lungfish that had migrated up to the weir from downstream sites but were not detected indicates that not all lungfish approach the fishlock. It is possible that entrance and approach conditions in the fishlock are not effective at attracting lungfish with more than one contributing factor likely. A recent assessment of fishway performance on the Parana River in South America questioned whether the restriction of fish to a small percentage of channel was adequate, particularly when compared with that previously available for migratory fish (Oldani and Baigun 2002). In arid countries such as Australia this is particularly relevant. At base flows river channels are narrow but during flood flows the channels often expand to a width of several hundred metres forcing migrating fish to cross often turbulent channels to find a single fishway entrance.

Behavioural aspects should also be considered when attempting to speculate why lungfish fail to pass through a fishlock. In general upstream migrating fish are attracted to flowing water, at a natural barrier the flow is continuous and fish are able to scan the open water below the barrier to find the best place to pass. At Ned Churchward Weir, migrating fish are being encouraged to enter the fishlock under unnatural conditions and this may be affecting behaviour. A study of pike-perch (*Stizostedion lucioperca*) in Austria found that despite being highly migratory and physically able to ascend, these large fish actively avoided the small channel provided at fishway entrances (Schmutz, Giefing et al. 1998).

At Ned Churchward Weir the fishlock entrance is separated from the spillway by a wing wall and flow patterns below the weir differ from those in front of the fishlock entrance. Furthermore, fish are expected to enter into a concrete chamber and wait up to 40 minutes until the lock chamber gate closes before being lifted up to the level of the headwater. Attraction flows through the fishlock are discontinuous within phases of the same cycle so fish are unlikely to remain in the vicinity for any length of time.

The majority of lungfish detections occurred during low-level spillway flows and high-level outlet release flows and large numbers of lungfish were observed congregating below the weir during spillway flow conditions. It is therefore likely that during the higher-level spillway flows lungfish were attracted away from the fishlock entrance. Although the volume of water released by the fishlock has never been quantified, SunWater has estimated that it uses approximately 12 ML^{-day} despite being designed to release up to 1 cumec (86.4 ML^{-day}). In comparison to the volume of water released through the outlet works and over the spillway during river flow events the 12 ML^{-day} released by the fishlock is likely to be insignificant. Overseas, auxiliary attraction flows are provided through the fishway entrance to reduce the effect of competing attraction flows (Clay 1995), this may also be advantageous for Australian fishways.

At Ned Churchward Weir, four of the lungfish that successfully migrated upstream did so within a single fishlock cycle and exited immediately after the upstream fishlock chamber gate opened. However one lungfish took over five hours and another more than two days to exit. Although passage was prevented for a portion of the two days the fish entered the downstream fishlock chamber 17 hours prior to the trap being placed in the upstream fishlock channel and so had ample opportunity to exit. Due to the limited operation of the PIT tag readers in the fishlock chamber a fish had to be detected at both the upstream and the downstream antenna before it could be determined whether it had entered the fishlock chamber. It is likely that many of the fish that were detected at the downstream fishlock channel entered the fishlock chamber. The comparison of detections and fishlock operation showed that for more than fifty percent of the detections the fishlock chamber gate was open and an attraction flow was being provided. However once inside the fishlock chamber there is nothing to prevent fish from exiting again unless the fishlock chamber gate closes.

Additionally the attraction flow temporarily ceases just prior the fishlock chamber gate opening so fish are likely to leave the downstream fishlock channel. On fishways which cater for passage in one direction only cones and screens can be used to retain fish once they have entered (Larinier, Travade et al. 2002). However at Ned Churchward Weir the fishlock must cater for downstream migration so mechanical screens must not prevent downstream migrating fish from exiting.

A major criticism of fishlocks elsewhere has been that fish may fail to exit in the time provided and remain in the fishlock chamber (Clay 1995) and this may also be the case for lungfish at Ned Churchward Weir. It is possible that lungfish may become disoriented as the fishlock chamber fills and fail to find the exit and are remaining in the chamber until it fills again or exit through the downstream fishlock chamber gate.

5.7 Optimising of the operation and design of mechanical fishways for the passage of lungfish

The design of mechanically operated fishways varies widely, however the importance of factors such as entrance conditions and effective fish attraction remain the same. Fishways should continue to be designed to cater for the entire migratory fish community and any improvements made to cater for the passage of lungfish should not be to the detriment of other fish species.

Although the fishlock is capable of providing passage for lungfish, the results of this study indicate that the current design and operation is less than optimal. The major alterations relate to improving the attraction of fish to the fishlock entrance, the retention of fish between phases of the fishlock cycle and conditions that facilitate the efficient removal of fish at the end of each cycle.

The following is a list of recommendations that may improve the passage of lungfish through fishlocks and fishlifts:

- Provision of continuous attraction flow at both the upstream and the downstream fishlock channels with minimal variation in flow intensity between cycle phases.
- Vary the operation of the fishlock to suit the full range of conditions such as incrementally increasing fishway attraction flows during outlet release and spillway flows.
- Attract fish away from the spillway by releasing through the outlet works when flows over the spillway are within the capacity of the outlet works.
- Devise mechanical means to retain lungfish once they have entered the fishlock channels, without compromising the ability to provide for downstream passage.
- Investigate mechanical means to encourage lungfish to exit as quickly as possible once the lock chamber is full.
- Design entrances that assist lungfish to move away from spillway and outlet flows and into the fishway.
- Investigate the benefits of faster fishway cycling during peak migration periods such as during flood flows.

5.8 Further development and application of PIT tag reading technology

The improvement in fish passage resulting from the recommendations listed above could be assessed using both trapping and PIT tag technologies. As has been demonstrated in this study PIT tag readers are a useful way to identify fish behaviour at fishways, however they also have application in riverine situations. In this study improvements were made using new developments in PIT tag reading technology. For example, antenna size was expanded to a level where fish could be detected in shallow riffle areas and over the full width of the low-flow river channel. At Ned Churchward Weir, antennas were installed at the downstream rock-bar however due mainly to problems with flood damage no useful data was collected. The re-design of the system to be more robust to environmental damage is possible and the benefits would be numerous. Remote automatic reading stations could be installed throughout the catchment providing long-term data not only for migrating fish but also for other aquatic fauna such as turtles and platypus. The detection of aquatic fauna at remote reading stations would provide a reference point of the location of a individual at a certain point which could be compared to recapture data or with detections at other stations.

The PIT tag reading system used in this study was custom built by QFS for installation at Ned Churchward Weir and was the first to be installed on a fishlock in Australia. Problems with electrical interference from componentry used to operate the fishlock reduced the number of functioning readers, which in turn reduced our ability to detect small-scale movements of lungfish within the fishlock. However these problems are not insurmountable and during the course of this project possible solutions were sought and identified. However, it was not within the timeline or budget of this project to implement them. Details in Appendix A provide technical background and suggested solutions to address many of the problems encountered in this study. The development of an “off the shelf” system would improve the durability and in the long term reduce the costs of PIT tag reading systems. Commercial tracking systems using PIT tag technology have been developed for the livestock and meat processing industry and it may be possible to utilise these companies to further develop PIT tag reading systems.

The reader system installed at Ned Churchward Weir requires the manual upload of data from a laptop computer on site. The risk associated with this method is that equipment failure can go unnoticed for substantial amounts of time resulting in loss of potentially valuable data. The remote upload of data using existing data transfer technology would reduce the risk of data loss and provide other benefits. For example, fish migration data could be posted on to websites as a public relations tool. Appendix A below provides specific detail on possible improvements to the current system used at Ned Churchward Weir.

6. Conclusion

Two major outcomes were achieved by this study and both are of equal importance, It has been demonstrated that the current fishlock is unlikely to be providing optimal passage for lungfish. However, basic improvements in fishlock design and operation are likely to improve the suitability of the design for the passage of lungfish. Secondly the potential that PIT tag reading technology has in improving the knowledge of the passage of fish through man-made barriers has been shown. However, short-term studies are often affected by influences such as environmental variation within seasons and should therefore be considered as a snapshot of the time rather than a representation of the catchment. Many of the major fish passage facilities overseas have routine monitoring programs in place and as a result resource managers are able to predict and manipulate flows to suit environmental and consumptive requirements. If a similar approach was adopted on Queensland rivers then comparable benefits may result.

Burnett Water Pty Ltd has made a commitment to the installation of PIT tag readers at two structures upstream of Ned Churchward Weir, the Burnett River Dam and Eidsvold Weir. It is therefore recommended that the PIT tag reading system at Ned Churchward Weir be maintained over the longer term and that further monitoring and tagging of lungfish be undertaken within the vicinity of the weir. Should the proposed raising of Ned Churchward Weir proceed or if any of the suggested modifications to the design and operation of the fishlock are undertaken the reader system can be used to monitor the passage of lungfish.

7. Acknowledgements

We are grateful to Peter Jackson and Claire Peterken for their input into this study and their efforts in and continued support of fish passage in Queensland. We also wish to thank Shane Piltz, Steve Brooks, Peter Kind and Andy Rohlf for their extensive and cheerful assistance in the field and assistance with project logistics. Steve, Peter and Claire also provided pertinent comments on a draft version of this report.

Management, operations and technical staff from SunWater Corporation, provided much appreciated assistance by providing facilities to operate and store equipment, data collection and with the installation of the equipment used in this study. In particular we would like to thank Gary Smith, Des Charles, Milton Pukallus and Phil Byrne.

Andrew McDougall of the Department of Natural Resources Mines and Energy assisted in the collection of lungfish recapture data.

The development of the PIT tag reading system used in this study benefited greatly from the input and assistance of Alex Haro from the United States Department of the Interior and Vince Tranquilli of the Oregon Department of Fisheries and Wildlife.

The Queensland Department of State Development funded this study under the "Burnett Program of Actions".

8. References

Adkinson, M. D. (1995). "Population differentiation in Pacific salmon: local adaptation, genetic drift or the environment?" Canadian Journal of Fisheries and Aquatic Sciences(52): 2762-2777.

Barbin-Zydelwiski, G., A. Haro, et al. (2001). "Performance of stationary and portable passive transponder detection systems for monitoring of fish movements." Journal of Fish Biology **58**: 1471-1475.

Berghuis, A. P. and C. D. Broadfoot (in press). Reducing delays to fish spawning migrations at barriers with fishways., Queensland Fisheries Service, Bundaberg. Report to Agriculture Fisheries and Forestry, Australia.

Berghuis, A. P., C. D. Broadfoot, et al. (2000). Assessment of the Walla Weir Fishlock, Burnett River, Queensland Fisheries Service, Report to SunWater.**:** 50 pp.

Brizga, S. O., A. H. Arthington, et al. (2000). Burnett Basin WAMP: Current Environmental Conditions and Impacts of Existing Water Resource Development, Volume 1. Brisbane, for the Department of Natural Resources**:** 108 pp.

Brooks, S. G. and P. K. Kind (2002). Ecology and demography of the Queensland lungfish (*Neoceratodus forsteri*) in the Burnett river, Queensland. Brisbane, Queensland Government, Department of Primary Industries.

Clay, C. H. (1995). Design of Fishways and Other Fish Facilities. Florida, Lewis Publishers.

Frentiu, F. D., J. R. Ovenden, et al. (2001). "Australian lungfish (*Neoceratodus forsteri:* Dipnoi) have low genetic variation at allozyme mitochondrial DNA loci: a conservation alert." Conservation Genetics **2**: 63-67.

Larinier, M., F. Travade, et al. (2002). Fishways: biological basis, design criteria and monitoring.

Lucas, M. C. and E. Baras (2000). "Methods for studying spatial behaviour of freshwater fishes in the natural environment." Fish and Fisheries **1**(4): 283-316.

Oldani, N. O. and C. R. M. Baigun (2002). "Performance of a fishway system in a major South American dam on the Parana river (Argentina-Paraguay)." River Research and Applications **18**: 171-183.

Schmutz, S., C. Giefing, et al. (1998). "The efficiency of a nature-like bypass channel for pike-perch (Stizostedion lucioperca) in the Marchfeldkanalsystem." Hydrobiologia **371/372**: 355-360.

Sinclair-Knight-Merz. (1998). Burnett River catchment study, Catchment Overview, for the Queensland Department of Natural Resources.**:** 92 pp.

Stuart, I. G. and A. P. Berghuis (2002). "Upstream passage of fish through a vertical-slot fishway in an Australian subtropical river." Fisheries Management and Ecology **9**: 111-122.

Appendix A

Electrical interference

The electronic equipment installed at fishlocks emits a large amount of interference at or near **124-134 kHz**. This interference emanates from either switch-mode power supplies or PLCs in the control rooms. This interference is then easily conducted through mains power lines throughout the weir.

Prevention

Filtering of electronic equipment and/or selection of equipment that does not interfere with PIT equipment. i.e. Does not operate or emit signals around the Low Frequency (**124 -134.2 kHz**). Mostly caused by switch-mode power supplies, PLCs, and electric motors.

PLC fishway hydraulic data acquisition

The system at existing fishlocks only provides fishway hydraulic data for short periods and it is difficult to interrogate the data. There is a need for this data to be easily accessible so that fish passage information provided by the readers can be correlated with the operation of the fishway. i.e. Timing of valve and gate operation.

The current Citec data needs to be logged into a file that can be later interrogated on a second by second basis.

Installation and cable runs

Control room – A computer/data logger would need to be housed in or near the control room.
Cable runs from the control room to the fishlock (control box) would be required to house communications cabling (a 100mm conduit would suffice.

Control Box - a weatherproof control box suitable to house the PIT readers needs to be installed at the top of the fishlock. Communications cables would terminate into this box. This control box needs to be supplied with a separate 240VAC mains line so that backup power supplies (eg. UPS) can run the system in power outages).

Twin-Axial cable runs – cable runs from the control box to each antenna position are required (cable nominal diameter 8.4mm each). Conduit would need to be installed in these areas of cable distribution. Refer to diagram.

A computer with backup power and other communications technology will be required to run the system. This equipment needs to be in a protected environment in or near the fishlock control room.

Appendix B

Summary table of all fish tagged and detected at the fishlock

The number of fish PIT tagged downstream of the Ned Churchward weir and detected at the fishlock between 01/01/03 to 28/12/03, including upstream passage success rates and passage times for each species.

Species	No. tagged	Fishlock Entrance	Fishlock Exit Channel	Upstream Passage success	Passage Time (hours:minutes:seconds)		
					Min	Median	Max
Australian bass	8	3	0	-	-	-	-
banded grunter	51	29	7	24%	0:22:22	0:29:11	0:40:32
blue catfish	129	53	27	51%	0:12:21	0:36:53	7 days 18:16:35
bony herring	2	0	0	-	-	-	-
bullrout	1	0	0	-	-	-	-
freshwater catfish	64	17	12	71%	0:19:53	0:30:47	0:40:02
golden perch	46	23	10	43%	0:11:14	0:19:03	0:31:51
goldfish	1	0	0	-	-	-	-
Hyrtl's tandan	12	2	0	-	-	-	-
long-finned eel	35	22	19	86%	0:12:31	0:31:18	7:45:50
Queensland lungfish	917	41	7	17%	0:18:02	0:16:30	2 days 7:40:48
spangled perch	7	1	0	-	-	-	-
striped mullet	346	16	4	25%	0:0:21:19	0:0:19:40	7 days 15:12:16
yellow-fin bream	2	0	0	-	-	-	-
Total	**1621**	**207**	**86**	**42%**	**0:11:14**	**0:29:11**	**7 days 18:16:35**