Paradise Dam
Lungfish and Aquatic Ecosystem Monitoring
2006-2016
Biennial Summary Report 5 and Final Report

Prepared for Burnett Water Pty Ltd

June 2016, Revised October 2017

Queensland Government

This report has been prepared by Fisheries Queensland for Burnett Water Pty Ltd.

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Paradise Dam

Lungfish and Aquatic Ecosystem Monitoring

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Final Report, Prepared for Burnett Water

August 2017

Fisheries Queensland, Department of Agriculture, Fisheries and Forestry

Summary

This report describes the results of a 10 year monitoring program commissioned by Burnett Water Pty Ltd (BWPL) (now a subsidiary of SunWater Ltd) to fulfil the requirements of a variation of conditions of approval for the Paradise Dam (formerly known as the Burnett River Dam). The conditions of approval were issued pursuant to section 143 of the *Environment Protection and Biodiversity Conservation Act 1999* by the Australian Government's Department of Environment and Heritage (DEH) currently the Department of Environment (DoE) on 8 August 2003.

As per the variation of approval, populations of Queensland lungfish *Neoceratodus forsteri* were monitored at six sites in the vicinity of the Paradise Dam between AMTD 119 km and AMTD 201 km on the Burnett River. Two additional sites were established to compare lungfish populations in the vicinity of the dam with those in other sections of the river, making a total of eight sampling sites. Lungfish were captured by electrofishing, measured, weighed, individually tagged and returned to the water at or near the point of capture. Lungfish spawning activity was monitored at seven locations by sampling eggs to determine the extent and timing of the spawning seasons and to describe suitable lungfish spawning habitat. A three day roving survey was conducted annually within the waters of Paradise Dam to search for suitable spawning habitat or lungfish displaying spawning behaviour. Additional data describing river profiles, habitat in the sampling sites and water quality were also collected. Data from the study were initially collated and analysed by the authors. To improve scientific rigour of the report, the raw data were subsequently provided to the Arthur Rylah Institute for Environmental Research and subject to more detailed independent analyses.

This study confirmed that lungfish remain a common and widespread species in the Burnett River 10 years after the construction of Paradise Dam. A total of 7458 lungfish captures were recorded during the survey including 5601 individual fish. A total of 1967 lungfish eggs were recorded during the study. A sub-sample of 140 individuals was examined to determine their sex and maturity status, including 58 females and 79 males. As in previous lungfish surveys, samples in the current program were dominated by mature lungfish >700 mm in total length with only three individuals <300mm. Slow growth rates observed in lungfish tagged and recaptured during the current survey were also consistent with previous lungfish surveys in the Burnett River and published literature. The condition of lungfish fluctuated within levels observed during previous surveys in the Burnett River. There were no obvious consistent trends in condition of lungfish.

A total of 839 individuals were tagged and recaptured during the current program (winter 2006 to summer 2016). Some lungfish tagged during previous monitoring programs were also recaptured. Recaptures largely occurred in the same location where the fish were originally tagged. No consistent movement trends were observed, however there was evidence that some individuals moved between sites. Nine lungfish tagged in Paradise Dam were subsequently recaptured downstream of the dam wall. These fish are likely to have moved over the wall during flood events that occurred in the study period. Alternatively the fish could have used the downstream fishway on Paradise Dam, which operated sporadically during the survey period. The survey did not yield evidence of a decline in lungfish populations across the study area. Overall Catch Per Unit Effort (CPUE) estimates were comparable with pre-construction lungfish surveys and were confounded by summer flow events downstream of Paradise Dam. CPUE decreased at the two sites within Paradise Dam after the dam filled. However, this outcome most likely reflected the difficulty of electrofishing in very deep water rather than any change in lungfish populations. Likewise, declining CPUE at Claude Wharton Weir

was most likely indicative of lungfish emigrating from the site by ascending a fishway commissioned during the current survey. Population estimates based on mark and recapture records were possible at five of the seven sites. These estimates generally supported CPUE analyses, predicting population declines at Claude Wharton Weir and Gray's Waterhole, but increasing populations at other locations.

There was limited evidence of recruitment into the adult lungfish population during the study period. Some sub-adult lungfish were collected during the first four years of the study, indicating that successful breeding events had occurred at or just prior to the construction of Paradise Dam. The increasing lungfish population downstream of Paradise Dam probably resulted from a redistribution of local lungfish populations during a series of flood events that occurred between 2010 and 2015. These floods led to widespread and repeated overtopping events at weirs and dams within the Burnett River Catchment, including Paradise Dam, Ned Churchward Weir, Claude Wharton Weir and Jones Weir.

Lungfish eggs were located during seven of the 10 survey years and at six of the seven egg sampling sites. The study supported previous reports, which have found that impounded waters rarely provide suitable spawning habitat for Australian lungfish. Patches of suitable spawning habitat were occasionally observed within Paradise Dam. However, there was no evidence of successful spawning events occurring within the dam throughout the study. The majority of viable lungfish eggs were collected downstream of Paradise Dam and Ned Churchward Weir in shallow water amongst submerged and emergent aquatic plants beds in late Winter and Spring. These observations were consistent with a large body of published work on lungfish spawning habitat preferences.

The outcomes of this study and previous lungfish monitoring programs in the Burnett River were used to review any potential impacts of Paradise Dam on local lungfish populations. Conclusions of this review can be summarised as follows;

- The size and structure of lungfish populations in the vicinity of Paradise Dam and at the reference sampling sites remained largely stable throughout the 10 year monitoring program.
- Lungfish condition fluctuated during the monitoring period, but remained within levels recorded during previous surveys in the Burnett River.
- During the monitoring program some lungfish made movements from Paradise Dam to river reaches downstream of the dam wall. It is unclear whether these fish moved over the spillway or utilised the downstream fishway at Paradise Dam. Regardless, the recaptures provide evidence that some individuals can successfully make such movements without suffering long-term injury or death.
- As previously stated, the impounded waters of Paradise Dam are unlikely to represent suitable habitat for successful lungfish spawning and recruitment. There was no evidence of successful spawning events occurring within the dam during the monitoring program.
- The longer-term impacts of spillway flow events on lungfish populations at Paradise Dam remain unresolved. Downstream movements of lungfish recorded during the current study provided an indication that gradual downstream redistribution of lungfish populations may be occurring at Paradise Dam. Data collected at other in-stream barriers (Claude Wharton Weir and North Pine Dam) suggests lungfish condition is likely to deteriorate if they become stranded downstream of such barriers. This result highlights the need to continue operating the fishways at Paradise Dam.

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1 Introduction

On 25 January 2002 the Australian Government's Department of Environment and Heritage (DEH) currently the Department of the Environment (DoE) approved construction and operation of the Paradise Dam (formerly known as the Burnett River Dam) at 131.2km Adopted Middle Thread Distance (AMTD) on the Burnett River.

On 8 August 2003, DEH varied the conditions of the approval pursuant to section 143 of the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). The variation of approval for Burnett River Dam (EPBC 2001/422) included the following conditions (6-9);

6. Burnett Water Pty Ltd must undertake annual aquatic ecosystem monitoring at or about AMTD 119km, AMTD 201km and at least two sites between these points and provide to the Minister five biennial summary reports. This 10-year monitoring program will include measurement of the condition of lungfish and lungfish habitat / macrophytes. Monitoring will commence when the dam becomes operational.
7. Burnett Water Pty Ltd must conduct a review of the impacts of Burnett River Dam on lungfish at the conclusion of the 10-year monitoring program in consultation with the Commonwealth Environment portfolio, to determine whether future monitoring is required.
8. Burnett Water Pty Ltd must make lungfish information and data from research and monitoring activities freely available for inclusion in State and Commonwealth lungfish recovery programs or programs relating to water quality in the Burnett River
9. If aquatic ecosystem monitoring required under paragraph 6 or the review required under paragraph 7 indicates ongoing lungfish population decline at or about AMTD 119km that cannot be attributed to natural periodic fluctuations, then Burnett Water Pty Ltd will initiate appropriate recovery actions. The recovery actions cannot be inconsistent with an adopted Commonwealth Lungfish Recovery Plan.

The current report describes the results of a 10-year lungfish and aquatic ecosystem monitoring program (2006-2016), carried out at six sites between AMTD 119km and AMTD 201km on the Burnett River. Two additional monitoring sites were also established at AMTD 64km and AMTD 242km as reference sampling locations.

The monitoring program included;

- Surveys of lungfish in winter and summer of each year at each location (20 surveys in total)
- Estimates of Catch Per Unit Effort (CPUE) as an index of lungfish abundance
- Tagging and measurements of lungfish to describe the structure of populations (length/frequency), condition factor (CF) and sex ratio
- Movement and growth of any lungfish tagged and subsequently recaptured during the monitoring program
- Population estimates based on mark and recapture events
- Descriptions of habitat in the sampling sites including river channel profiles, substrate types, composition of macrophyte (aquatic plant) communities and,
- Annual surveys of egg numbers and spawning habitat during the known spawning period of lungfish

Based on the outcomes of the 10-year monitoring program, this report also provides a review of the impacts of Paradise Dam on local lungfish populations, as required to fulfil condition 7 in the amended approval notice for the dam. Finally, this report addresses condition 9, by examining whether results of the current monitoring program provided any evidence of ongoing lungfish population decline at or about AMTD 119km that could not be attributed to periodic natural fluctuations.

2 Survey methods

2.1 Sampling locations

Sampling was undertaken in summer and winter each year from 2006-2016 at six sites established in the vicinity of the Paradise Dam between AMTD 119 km and AMTD 201km on the Burnett River (Table 2.1, Fig.2.1). Two of the sampling sites were located downstream of the Paradise Dam wall, two within the impoundment and two upstream of the impoundment (i.e. above Full Supply Level - FSL). The location and number of sampling sites satisfied condition 6 above. Two additional reference sites were also established to provide a mechanism for comparing lungfish populations in the vicinity of the dam with those in other sections of the river (refer Table 2.1). By necessity, the sampling sites were located in areas with suitable conditions for accessing the river and launching boats. In some instances, secondary launch sites were established to allow sampling to continue with minimal interruption during flow events or when water levels were low. Low water levels and flooding restricted the area of available habitat that could be accessed by boat on some occasions. Summary details of the site locations and access points are provided in Table 2.2

Table 2.1 – Summary details of lungfish sampling locations

Number	Site Name	AMTD (km)	Relationship to Paradise Dam
1	Isis	64	Downstream reference
2	Figtree	119	Downstream
3	Paradise Dam	122	Downstream
4	Kalliwa Hut	135	Within
5	Mingo Gorge	158	Within
6	Gray’s Waterhole	183	Upstream
7	Claude Wharton Weir	201	Upstream
8	Mundubbera	242	Upstream reference

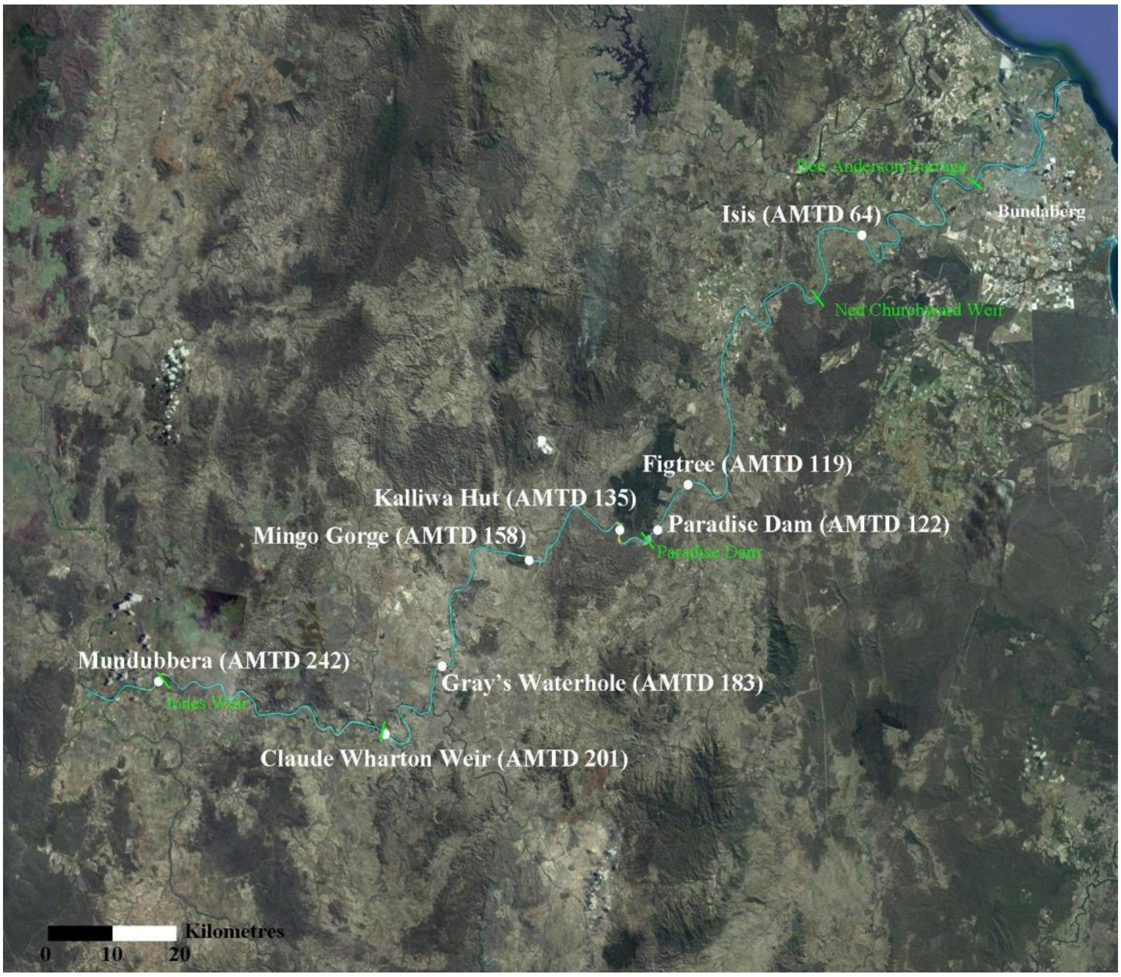


Figure 2.1 – Map of the Burnett River (blue line) indicating the location of the lungfish sampling sites (white dots).

Table 2.2 – Summary details of access points for sampling locations.

Site	Latitude	Longitude	Access notes
1	24 58 236	152 08 986	Access to southern bank via private properties at the end of Pine Creek Rd
2	25 16 785	151 58 006	Access to southern bank via Cherelly Orchard, alternative access via private properties on northern bank.
3	25 17 203	151 57 623	Access to southern bank via dam site
4	25 21 497	151 52 787	Access via Paradise Dam public boat ramp
5	25 23 618	151 44 161	Access via Mingo Crossing Bridge public boat ramp
6	25 31 797	151 40 501	Access to southern bank at boat ramp on private property
7	25 37 089	151 35 921	Access to northern bank via SunWater Claude Wharton Weir downstream access track, alternative access on southern side via public track
8	25 36 793	151 16 207	Access to northern bank at public boat ramp upstream of Jones Weir

2.2 Site descriptions

2.2.1 Site 1, Isis (AMTD 64km)

The Isis sampling site (the downstream reference site) was situated in flowing river reaches downstream of the Ned Churchward Weir. Flow and river height in this area are influenced by water releases from the weir. The primary sampling area was accessed via a private property off Pine Creek Road approximately 10.5 km downstream of the weir. From this point upstream pools and runs were accessed as far as water levels allowed (refer Figure 2.2). In winter 2007, extremely low water levels necessitated use of an alternative access point approximately 5km downstream, at the SunWater Don Beattie Pump Station. A third alternative access point was utilised in summer 2011 due to flood damage at other locations.

Figure 2.2 – Isis sampling area (orange outline) and habitat transects (blue)

2.2.2 Site 2, Figtree (AMTD 119km)

The Figtree site originally comprised two pools located approximately 3km downstream of the Paradise Dam. The pools were accessed via separate access points on private property along Cherelly Orchard Road. Flow and river height in this area are influenced by releases from the Paradise Dam. The downstream pool was rarely accessible. The available area for sampling was determined by water levels over large submerged rocks within both pools. In summer 2009/10, a major flow event blocked vehicular access to this site and delayed sampling. The pool was eventually accessed by launching further upstream and using elevated flows to access the area by boat. From 2013 onwards, the site was accessed from a private property on the northern bank after floods caused extensive damage to banks at the original launch location.

Figure 2.3 – Figtree sampling area (orange outline) and transect (blue)

2.2.3 Site 3, Paradise Dam (AMTD 122km)

This site was located in the tail water pool below Paradise Dam. The pool was accessed with SunWater permission from the dam site. This site was only sampled during the first two surveys. Low water levels and spillway flow events prevented access to the pool during subsequent surveys. This site was dropped from the program in 2007. As stated previously, the omission of this site from the program left 5 sampling sites within the range prescribed by condition 6. This was still sufficient sites to comply with condition 6.

2.2.4 Site 4, Kalliwa Hut (AMTD 135km)

The Kalliwa Hut site was located within the Paradise Dam impoundment adjacent to the former Kalliwa Campground. The site was accessed by boating upstream from the Paradise Dam public boat ramp. Sampling was conducted upstream and downstream from the Kalliwa Hut targeting the shoreline and submerged vegetation within the impoundment (refer Figure 2.4).

Figure 2.4 – Kalliwa Hut sampling area (orange outline) and transects (blue)

2.2.5 Site 5, Mingo Gorge (AMTD 158km)

The Mingo Gorge site was located within the upper reaches of the Paradise Dam impoundment, approximately 1km upstream of the Mingo Crossing Bridge. The original access points were located on private property off the Gayndah / Mt Perry Rd or at the camping area. Subsequently, the site was accessed from the Mingo Crossing Bridge public boat ramp. Sampling effort was concentrated upstream of the launch site in a deep pool and a series of rocky glides within the gorge area (refer Figure 2.5). Heavy infestations of floating aquatic weeds prevented access to this area in winter 2007. In this instance, an alternative sampling location was established at the Mingo Crossing Bridge where the infestation was less dense.

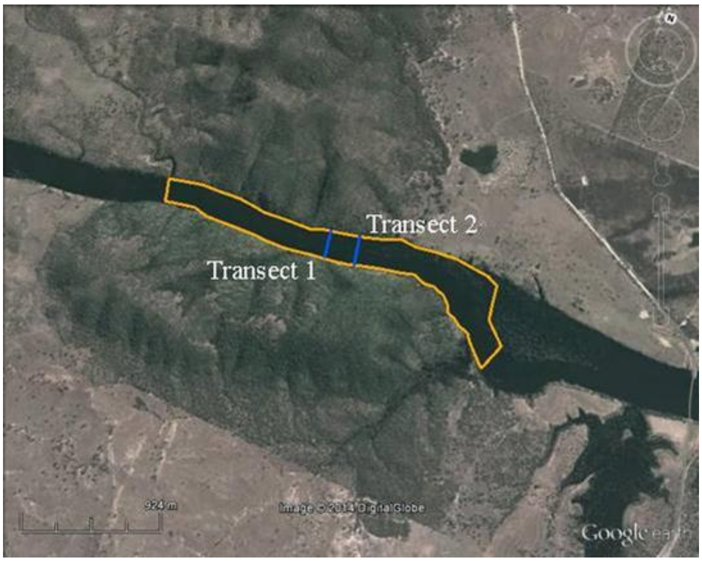


Figure 2.5 – Mingo Gorge sampling area (orange outline) and transects (blue)

2.2.6 Site 6, Gray's Waterhole (AMTD 183km)

Gray's Waterhole is a large permanent pool on the Burnett River at Mt Lawless, approximately 19km downstream of Gayndah. The site was accessed via private property off Gray's Road downstream of a railway crossing across the river. Sampling generally occurred throughout the pool and extended a short distance into a tributary creek (refer Figure 2.6).

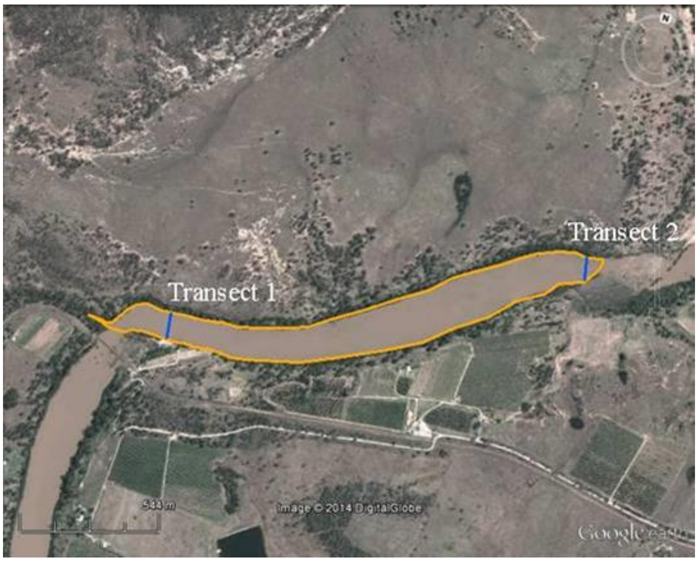


Figure 2.6 – Gray's Waterhole sampling area (orange outline) and transects (blue)

2.2.7 Site 7, Claude Wharton Weir (AMTD 201km)

This site included the tail water pool of Claude Wharton Weir and an adjacent pool downstream. The pools became connected during flow events in 2011. Water flow in the area is influenced by releases from the weir. The original access points were located on the northern bank via tracks off the Burnett Highway or the southern bank on tracks near the weir wall. An alternative access point was established through SunWater' s Claude Wharton downstream access track following flooding in 2011. During the first two years of sampling Claude Wharton Weir did not have an operating fishway. The fishway has been operating intermittently for the last six years (refer Figure 2.7).

Figure 2.7 – Claude Wharton Weir sampling area (orange outline) and transects (blue)

2.2.8 Site 8, Mundubbera (AMTD 242km)

The Mundubbera site included the impoundment of Jones Weir, flowing river reaches upstream of the weir and the lower reaches of the Boyne and Auburn Rivers (Figure 2.8). The site was accessed from the public boat ramp upstream of Jones Weir. Water levels in the weir fluctuate widely, limiting access to upstream river sections on some occasions. An alternative launch site was established on private property at the junction of the Burnett and Auburn Rivers to assist with access to these areas. Water levels in this area were extremely low throughout the first two years of the survey.

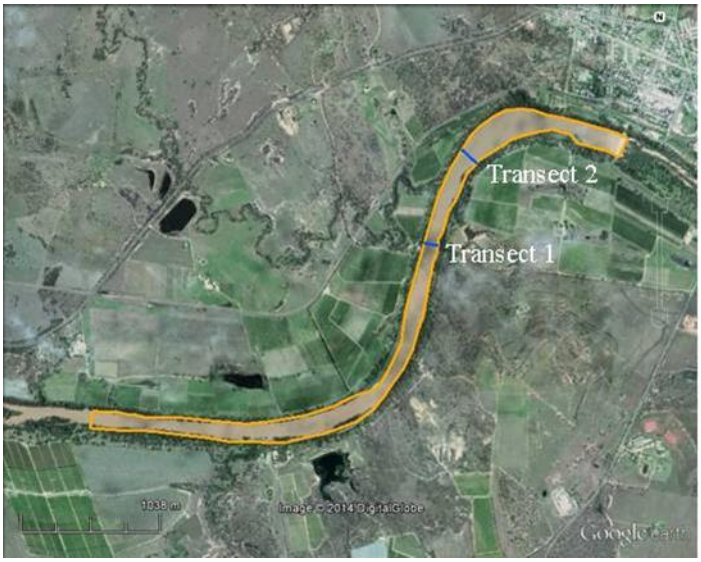


Figure 2.8 – Mundubbera sampling area (orange outline) and transects

2.3 Sampling Protocols

2.3.1 Lungfish sampling program

Each of the sites was sampled for one day during winter and one day during summer every year. This sampling design provided a mechanism for assessment of seasonal variability. Lungfish were collected by targeted electrofishing using a boat-mounted 7.5 Kva electrofishing unit (Smith Root) and pulsed D.C. waveforms. The electrofishing team included a skipper to operate the boat and electrofishing controls and two crew members to collect lungfish using dip nets. Sampling efforts were concentrated around preferred lungfish habitat such as aquatic vegetation and other instream structures, particularly those close to the riverbanks. Lungfish were retained on-board and processed in groups at the end of each fishing session. Electrofishing time (seconds of power on) was recorded following each session to facilitate subsequent calculations of Catch Per Unit Effort (CPUE). CPUE was subsequently expressed in terms of fish/minute and used as an index of lungfish abundance.

Lungfish were examined, measured and tagged in a custom-built vee board mounted on sensor pads connected to digital livestock scales (Tru-Test). Total length (mm) and weight (nearest 100 g) were recorded prior to further examination and tagging. An estimate of relative condition or 'condition factor' (CF) was subsequently calculated from individual length/weight ratios using the formula $CF=W/L^{b}*10000$ where W= weight (g) and L= total length (mm). The constant 'b' was derived from the slope of a regression line fitted through log transformed length and weight data from all individuals that were weighed and measured.

Previous studies of lungfish in the Burnett River and fishway assessments have marked lungfish using various combinations of dart tags, radio tags and passive integrated transponders (PIT tags). Lungfish in the current monitoring program were examined and scanned for evidence of pre-existing tags using procedures described fully in Brooks & Kind (2002). Details of any recaptures from these previous studies were recorded and forwarded to the relevant authors for their records.

Untagged individuals and those bearing only tags used by Brooks & Kind (2002) were marked using individually numbered 23 mm Eco-line PIT tags. These tags are identical to those used by Berghuis & Broadfoot (2004) and are compatible with the fixed PIT tag reader systems at Ned Churchward Weir, Paradise Dam, Claude Wharton Weir and Kirar Weir. Tags were inserted into musculature at the origin of the dorsal fin using custom built needles mounted into a tag applicator.

A sub-sample of the catch was examined to determine details of sex and maturity status. In instances where individuals were running ripe, sex was determined by stripping eggs or milt. In all other cases, details of sex and reproductive status were established by surgical examination procedures described fully in Brooks & Kind (2002). A ruling by the Animal Ethics Committee in February 2010 required the monitoring team to cease invasive surgical procedures unless they could be performed by a registered veterinarian. From that point forward this part of the sampling was restricted to determining sex of lungfish during the annual breeding season by stripping fish in running ripe condition.

Processed lungfish were returned to the water following examination and tagging procedures. Fishing sessions continued until all accessible waters in the site were sampled. The length of time required to successfully gain access to the site and achieve this objective varied and occasionally required that sampling continue into the evening or extend over two days. Low water levels and flooding experienced during the surveys restricted access to some sites on some occasions.

2.3.2 Lungfish habitat and macrophyte monitoring

Water quality parameters (including temperature (Tw), pH, conductivity, dissolved oxygen) were measured at 1m depth intervals to a maximum depth of 10m at each site. Visibility was estimated using a secchi disc.

Depth profiles including details of substrate composition and the distribution of submerged vegetation (macrophytes) were compiled across one or more transects at each site using methods adapted from Duivenvoorden (1997). During the first two years of the program, transect lines were established using a marked 100 m tape stretched between the banks. In instances where the river width exceeded 100 m, marked ropes were attached as necessary. Once transects were established, water depth, substrate type and details of submerged macrophytes were recorded at 2 m intervals. In depths ≤ 3 m a marked pole was used to measure depth to the nearest 100 mm. In deeper sections, depth was estimated using a sounder. Substrate was categorised into rock, silt, sand, gravel or cobble either visually or by using the pole. No substrate details were recorded in depths exceeding 3m. Macrophyte species present and their approximate density (% cover) were recorded from visual census or where a sample could be obtained using the pole. From 2008-2016, the transect lines were retraced using on board GPS navigation equipment, negating the need for marked tapes/ropes.

2.3.3 Spawning surveys

Spawning surveys were undertaken monthly from August to November at 7 sites (Table 2.3, Figure 2.9). Five sampling sites were located in the vicinity of the Paradise Dam, one downstream, three within and one upstream of the impounded area. Two reference sites were also established to compare spawning activity in the vicinity of the dam with other sections of the river (Table 2.3). Egg sampling procedures were based on those described by Brooks (1995) and Brooks & Kind (2002). An additional three-day roving survey was conducted annually in Paradise Dam to identify any potential spawning sites and record details of any suitable spawning habitat that may have developed during the year.

Specifically, eggs were collected at each site using a frame net (800 x 1000 mm) as illustrated in Figure 2.10. On each occasion, the net was pushed through a variety of habitat types in approximately 40 x 2 m ‘shots’. Environmental covariates measured prior to each shot include water depth (mm), substrate type, macrophyte species present, macrophyte height and macrophyte density (% cover).

Table 2.3 – Details of lungfish spawning survey sites

Site Number	Name	AMTD (km)	Relationship to Paradise Dam
1	McEvoy's	69	Downstream reference
2	Figtree	119	Downstream
3	Kalliwa Hut/ Paradise Dam	135	Within
4	Mingo Crossing	154	Within
5	Yenda Benyenda	183	Within
6	Gayndah	199	Upstream
7	Auburn River junction	252	Upstream reference

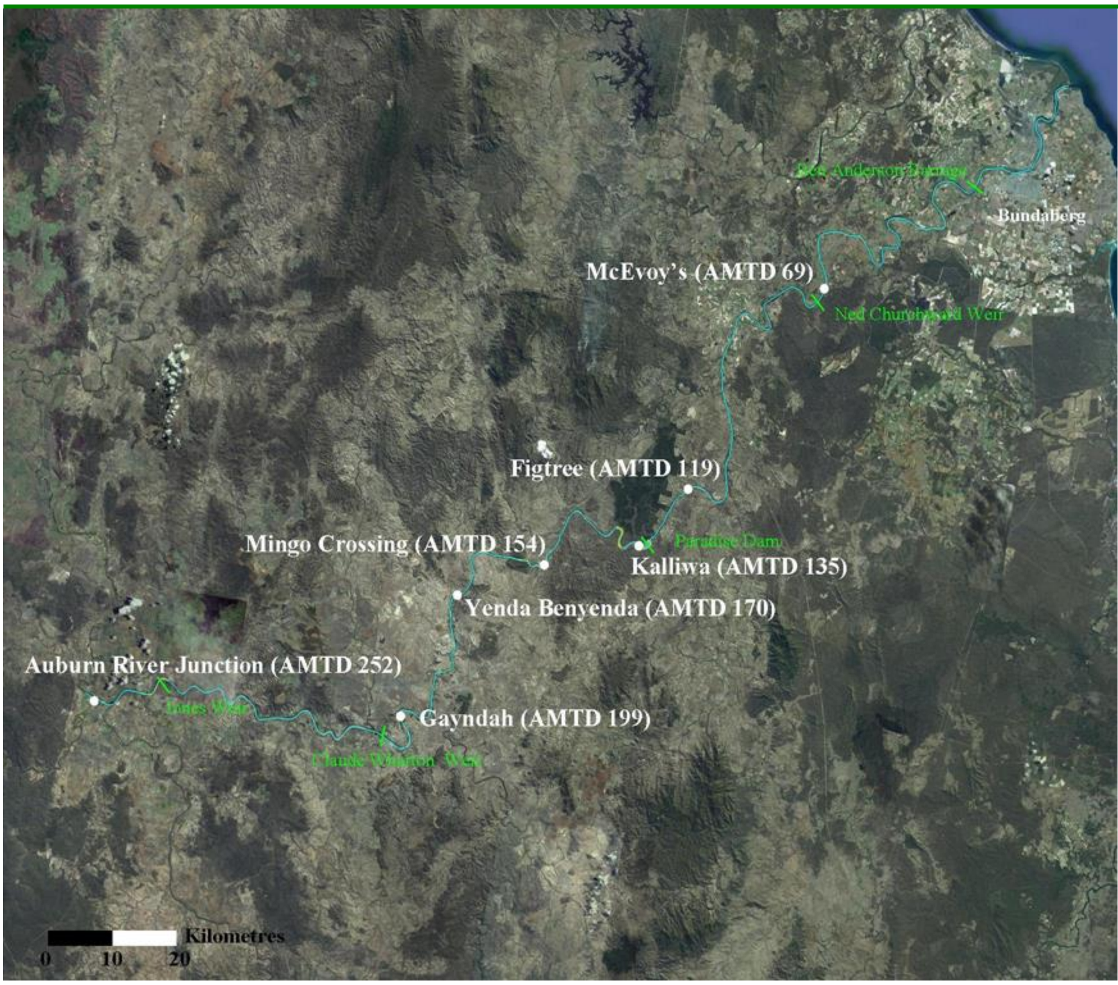


Figure 2.9 – Map of the Burnett River (blue line) indicating the lungfish spawning survey sites (white dots).

Figure 2.10 – Using a push net to collect lungfish eggs

3 Results

3.1 General

Twenty electrofishing surveys were undertaken during the project. Site 3 (downstream of the Paradise Dam spillway) was only accessible during the first two surveys. Low water levels, overtopping events and dam repair works prevented any further access to this area. Likewise, a rocky pool section of the Figtree sampling site was only accessible during the first survey event. Sampling in summer 2010, 2011, 2013 and 2015 was interrupted or delayed by significant flow events, which led to overtopping at Paradise Dam and Ned Churchward Weir. Sampling in Sites 1 and 2 (downstream of these barriers) was undertaken after the flood peak during the summers of 2010 and 2011 in difficult circumstances. Sampling at Site 1 in winter 2007 and summer 2011 was moved 1.5 kilometres downstream of the original site due to a limited access caused by low water levels and flooding events respectively. The summer 2013 survey was undertaken in late April and early May due to major flooding, which occurred in January 2013. The 2015 summer survey was also delayed by flow events and was not finished until early autumn.

A total of 7458 lungfish captures were recorded in the 20 surveys. This total included 5601 individuals that were tagged but not subsequently recaptured during the survey period. Of the remainder, 699 fish were recaptured once, 115 were recaptured twice, 17 were recaptured three times, 5 were recaptured 4 times and one fish was recaptured on five occasions. Records from 57 lungfish caught at Site 3 and 29 fish collected from the small pool at Figtree are included in Table 3.1 & 3.2 below, but excluded from other data analyses. The overall Catch Per Unit Effort (CPUE) was 1.36 fish/minute (electrofishing ‘power on’ time). Details of catch and CPUE for each site during each of the surveys are presented in Tables 3.1 and 3.2.

There was considerable variability in CPUE and the total number of lungfish collected in each sample day. The highest number of lungfish collected in a single day was 238 fish at Figtree in winter of 2015. No lungfish were caught in a sample day on three separate occasions at locations all within Paradise Dam.

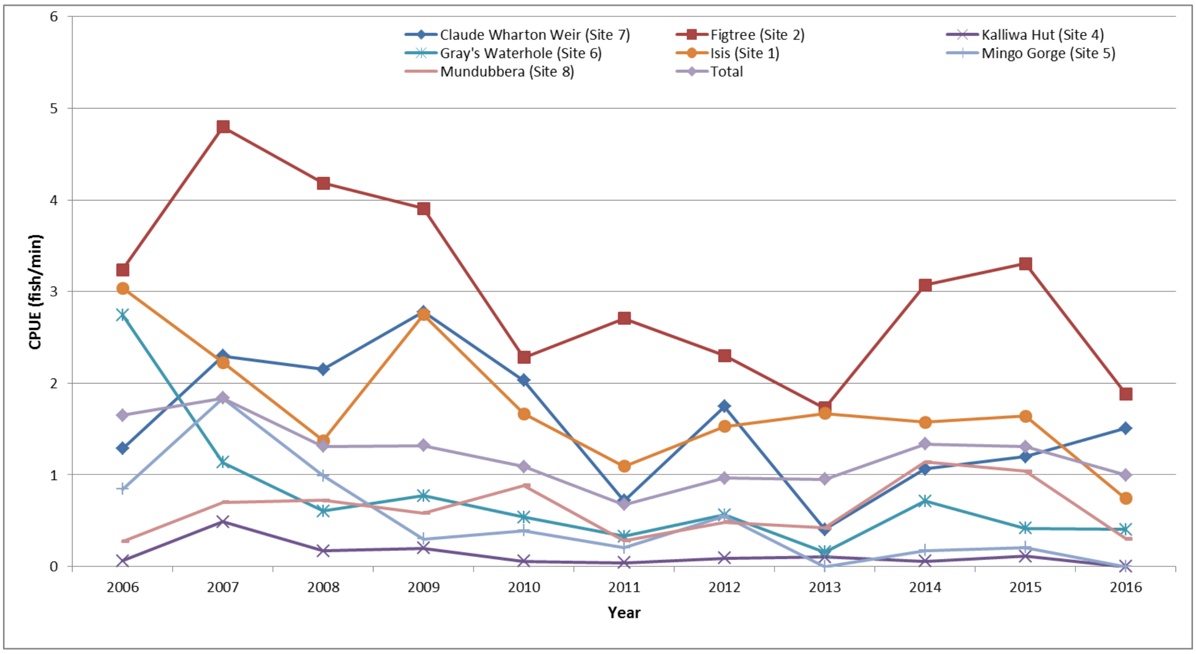


Figure 3.1 – CPUE (lungfish/minute electrofishing) by year

Table 3.1 – Catch details by location (2006 to 2016)

Site	Wint 2006	Sum 2007	Wint 2007	Sum 2008	Wint 2008	Sum 2009	Wint 2009	Sum 2010	Wint 2010	Sum 2011	Wint 2011	Sum 2012	Wint 2012	Sum 2013	Wint 2013	Sum 2014	Wint 2014	Sum 2015	Wint 2015	Sum 2016	Total
1 Isis	92	84	82#	89	115	92	108	68	163	24#	61	70	93	87	100	112	114	82	177	61	**1874**
2 Figtree	148	135	153	99	143	95	117	79	121	72	114	60	139	115	107	171	154	167	238	133	**2560**
3 Paradise Dam	39	18	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**57**
4 Kalliwa Hut	3	16	22	8	5	8	5	1	4	2	1	1	6	3	3	0	1	3	4	0	**96**
5 Mingo Gorge	18	104	92	29	74	18	15	29	20	12	13	11	57	0	0	9	8	1	19	0	**529**
6 Gray's W'hole	49	31	59	43	18	20	46	19	36	22	5	31	24	8	1	17	37	22	13	15	**516**
7 Claude Wharton Weir	39	93	82	110	68	75	62	71	80	53	14	90	71	11	6	13	25	41	16	57	**1077**
8 Mundubbera	9	13	33	30	35	45	22	30	35	17	14	49	44	10	39	50	105	48	104	17	**749**
Total	397	494	523	410	458	354	375	299	459	202	222	312	436	234	256	373	444	367	572	283	**7458**

Sampling was conducted 1.5 kilometres downstream of the original site due to a lack of access to the original site

* No sampling at this site due to a lack of access

Table 3.2 – Catch Per Unit Effort (CPUE) (2006 to 2016)

Site	Wint 06	Sum 07	Wint 07	Sum 08	Wint 08	Sum 09	Wint 09	Sum 10	Wint 10	Sum 11	Wint 11	Sum 12	Wint 12	Sum 13	Wint 13	Sum 14	Wint 14	Sum 15	Wint 15	Sum 16	CPUE 2006-16
1 Isis	3.04	3.03	1.75 #	1.11	1.69	2.69	2.80	1.02	2.27	0.72 #	1.38	1.13	2.07	1.74	1.62	1.44	1.73	0.83	3.00	0.74	**1.79**
2 Figtree	3.27	4.92	4.69	4.02	4.27	3.80	3.99	1.37	4.06	2.04	3.41	1.52	2.95	1.76	1.7	2.87	3.33	2.78	3.81	1.88	**3.01**
3 Paradise Dam	2.98	1.98	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**2.48**
4 Kalliwa Hut	0.06	0.48	0.50	0.20	0.14	0.24	0.16	0.02	0.08	0.05	0.03	0.02	0.2	0.09	0.12	0	0.06	0.09	0.13	0	**0.13**
5 Mingo Gorge	0.84	1.67	2.06	0.54	1.48	0.33	0.27	0.49	0.3	0.18	0.23	0.17	0.97	0	0	0.15	0.22	0.03	0.31	0	**0.51**
6 Gray's W'hole	2.75	0.69	1.72	0.87	0.35	0.45	1.13	0.35	0.74	0.56	0.12	0.49	0.7	0.28	0.04	0.43	1.01	0.49	0.33	0.40	**0.69**
7 Claude Wharton Weir	1.28	2.39	2.19	2.50	1.75	3.23	2.38	1.67	2.51	0.99	0.35	1.65	1.88	0.54	0.28	0.71	1.45	1.80	0.65	1.51	**1.59**
8 Mundubbera	0.27	0.42	0.95	0.54	1.03	0.66	0.47	1.07	0.77	0.3	0.27	0.36	0.78	0.17	0.68	0.88	1.32	0.67	1.40	0.30	**0.67**
Total																					**1.36**

Sampling was conducted 1.5 kilometres downstream of the original site due to a lack of access to the original site

* No sampling at this site due to a lack of access

CPUE was generally highest in the early years of the program, when the Burnett Catchment was experiencing ongoing drought. Sampling locations within the dam (Site 4, Kalliwa and Site 5, Mingo), were still flowing reaches in early stages of the survey, but were progressively inundated as the dam filled. Regression analyses (by Generalized Linear Models), and using CPUE as the response variate confirmed that CPUE varied between sites and between years (Table 3.3). A seasonal effect was also evident at all the sites with higher catch rates observed during winter surveys than summer (Table 3.3). However, there was no evidence of a significant pattern of change in CPUE over time within the individual sites (Figure 3.1, Table 3.3).

Table 3.3 – Results of regression analyses of CPUE (2006 to 2016)

	d.f.	m.s.	v.r.	F prob
Year	10	1.84	4.53	<0.001
Site	6	19.61	48.34	<0.001
Season	1	2.66	6.56	0.014
Year*Site	57	0.41	1.02	0.476
Year*Season	8	0.24	0.58	0.786
Site*Season	6	0.79	1.95	0.092
Residual	48	0.41		
Total	136	1.39		

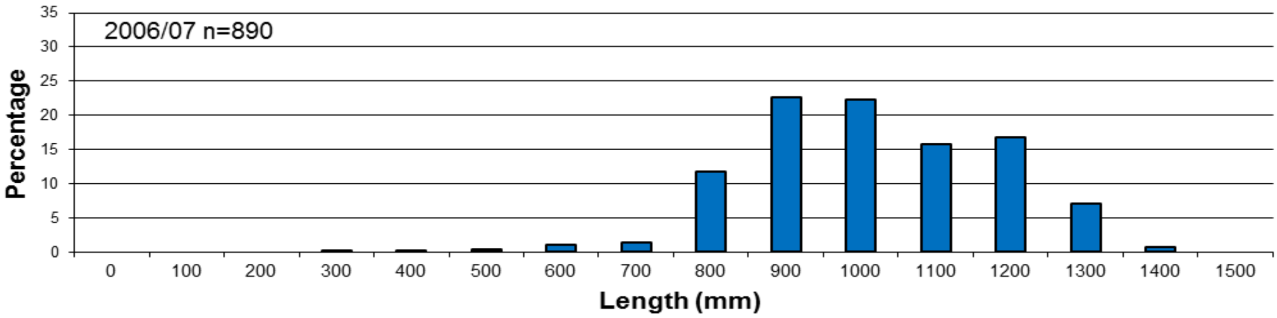
3.2 Population structure

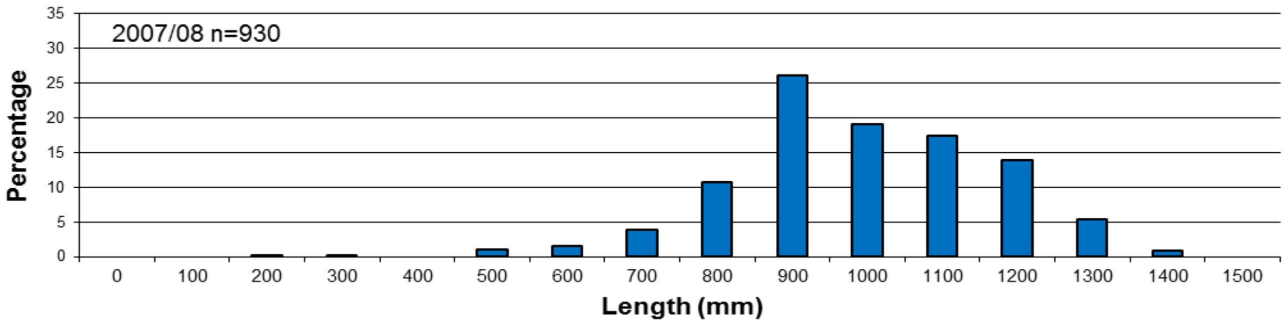
3.2.1 Length Frequency

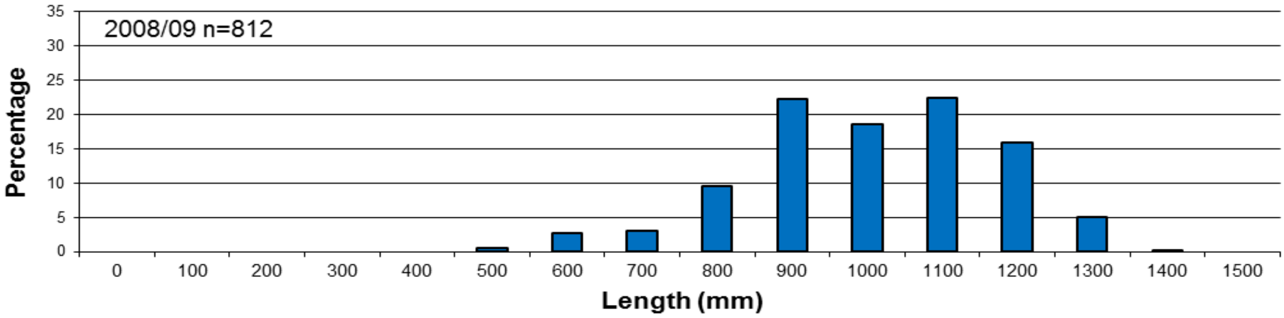
The total length (TL) of lungfish varied from 170-1390mm (Table 3.4). This compares well with data from the Paradise Dam baseline survey where Kind et. al. (2005) reported a length range of 148-1395mm. Brooks and Kind (2002) reported a size range of 345-1420mm in samples collected between 1997 and 2000. Mean TL after ten years of sampling was 985 ± 157 mm, compared to 946mm reported by Kind et. al. (2005) and 906mm reported by Brooks and Kind (2002). Length-frequency histograms using data from all sites for each year are presented in Figure 3.2. Samples were dominated by adult fish with only four fish <300mm and 122 fish <600mm. This means that approximately 98% of all individuals collected during the surveys are likely to be sexually mature adults. Length-frequency histograms provide some evidence of an increase in the number of individuals in the size range of 500-700mm over the first four years of sampling and a decrease in the last six years of sampling (Fig.3.2). The age curve presented by Brooks and Kind (2002) predicts that these fish would be approximately 7-12 years old and may indicate evidence of successful breeding and recruitment events that occurred at the time of or prior to the construction of Paradise Dam. Complete length and weight data were available from 7052 individuals. The length/weight relationship for these lungfish collected is presented in Figure 3.3.

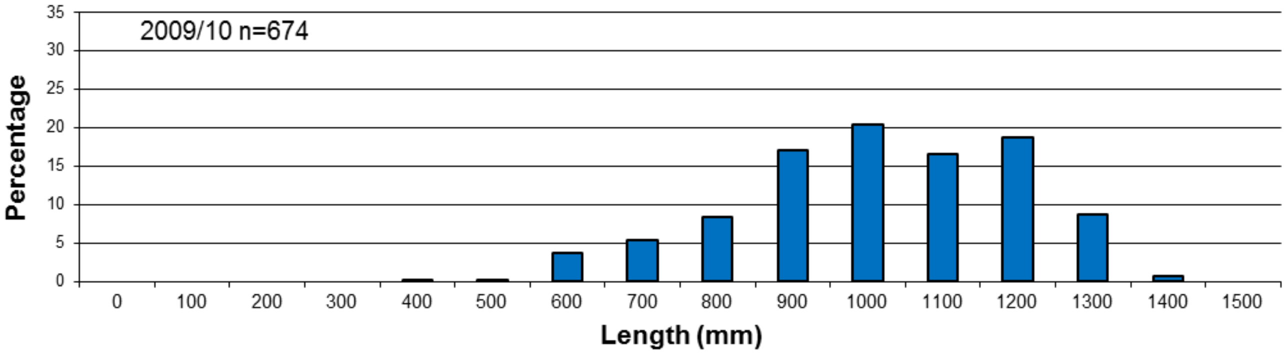
Table 3.4 – Summary statistics for lungfish total length (mm) by site (2006 to 2016)

Site No.	Site	Length range (mm)	Mean length (mm)	S.D.
1	Isis	240-1360	990	163
2	Figtree	170-1375	972	154
3	Paradise Dam	770-1278	1077	115
4	Kalliwa Hut	770-1275	1013	122
5	Mingo Gorge	640-1310	998	142
6	Gray's Waterhole	750-1390	1090	126
7	Claude Wharton Weir	410-1330	926	167
8	Mundubbera	270-1330	1012	133






2008/09 n=812
Percentage
Length (mm)
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500


2009/10 n=674
Percentage
Length (mm)
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30
25
20
15
10
5
0
0
100
200
300
400
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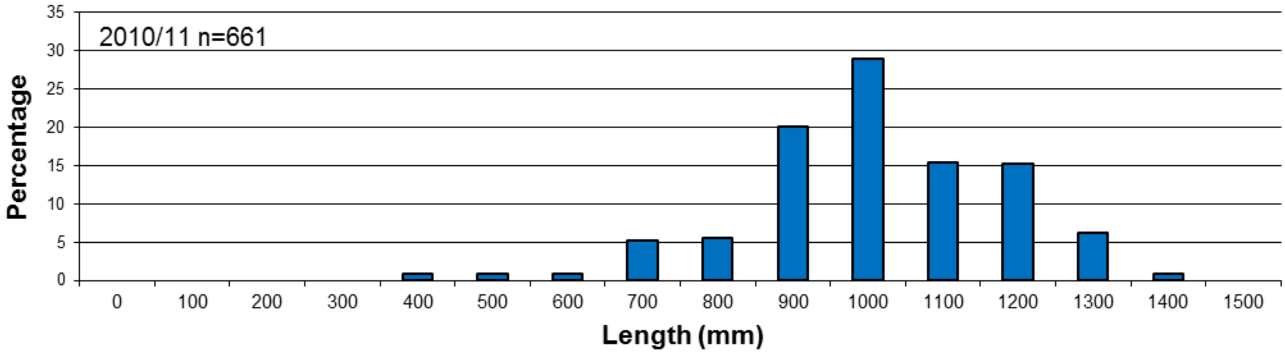
1000
1100
1200
1300
1400
1500


2010/11 n=661
Percentage
Length (mm)
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30
25
20
15
10
5
0
0
100
200
300
400
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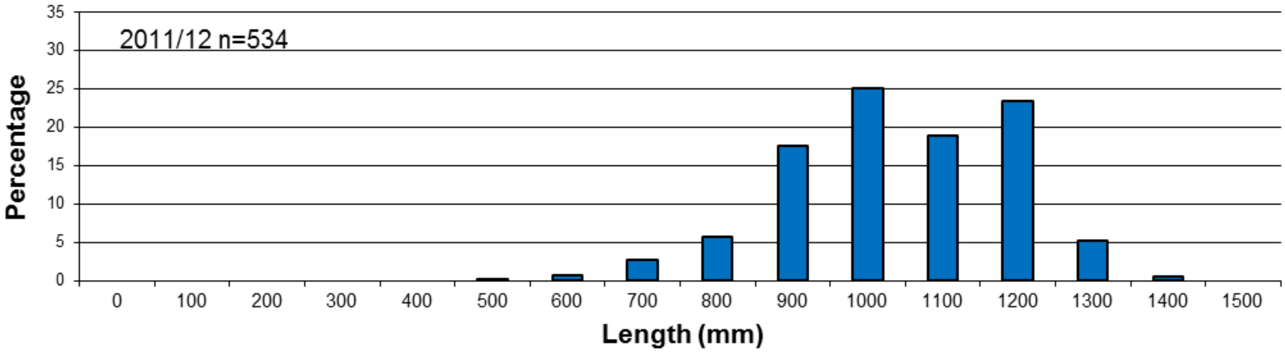
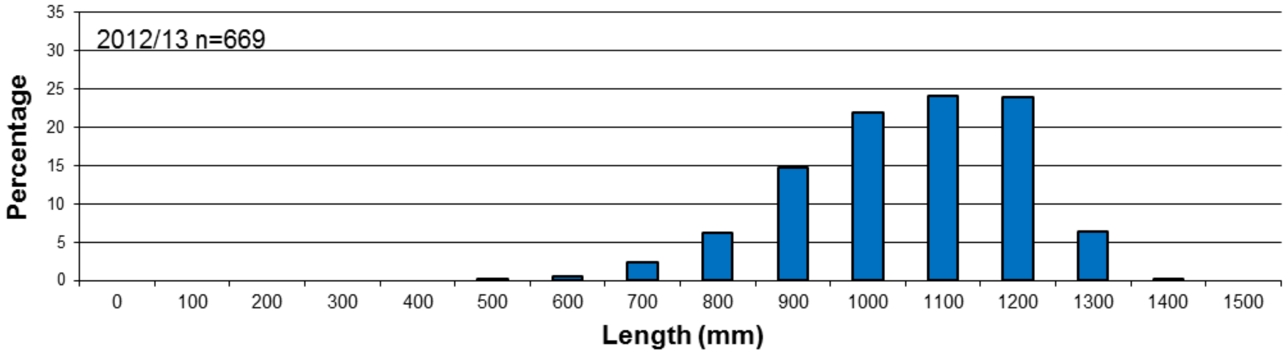
600
700
800
900
1000
1100
1200
1300
1400
1500


2011/12 n=534
Percentage
35
30
25
20
15
10
5
0
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
Length (mm)


2012/13 n=669
Percentage
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25
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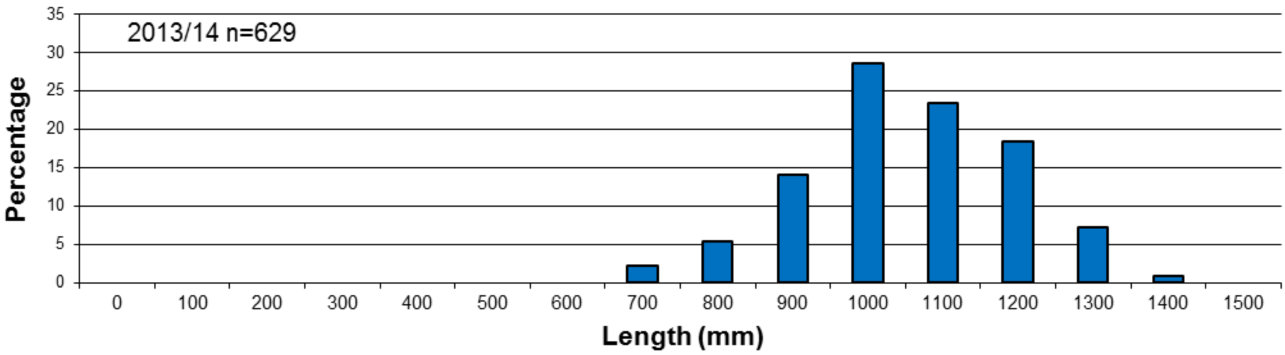
15
10
5
0
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
Length (mm)


2013/14 n=629
Percentage
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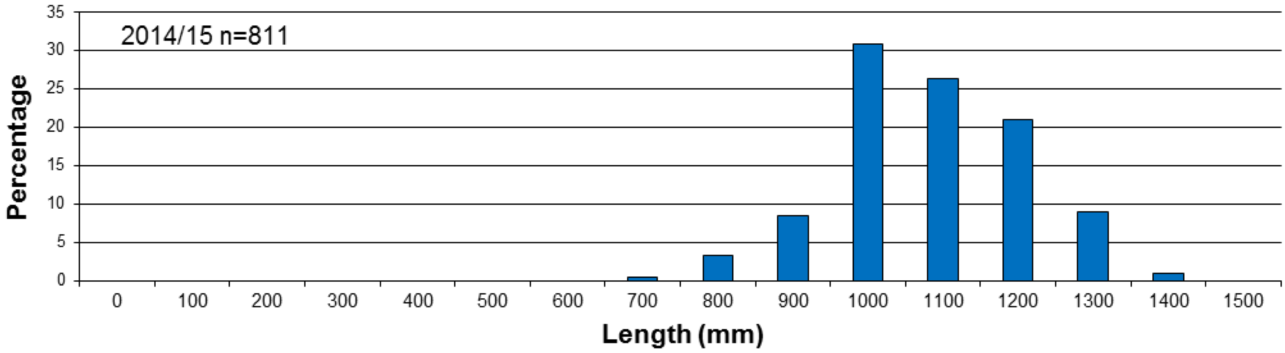
30
25
20
15
10
5
0
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
Length (mm)



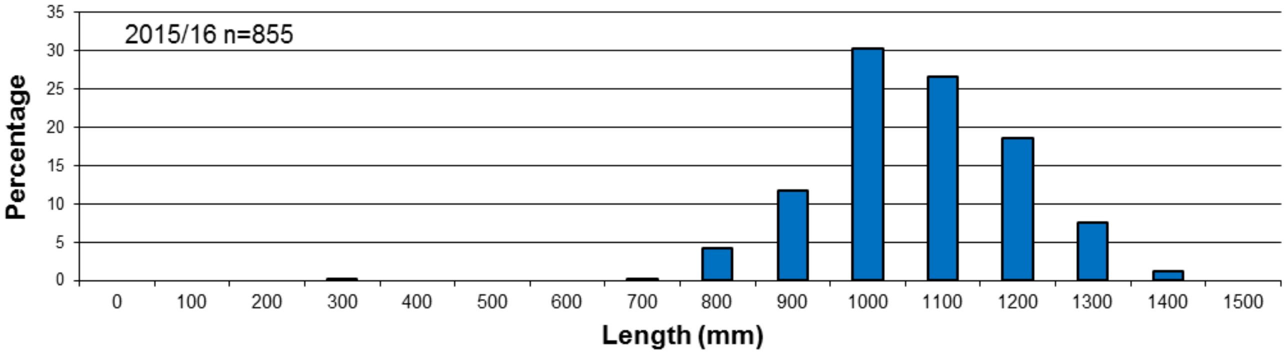


Figure 3.2 – Length-frequency histograms for each year (2006 to 2016) at all sites

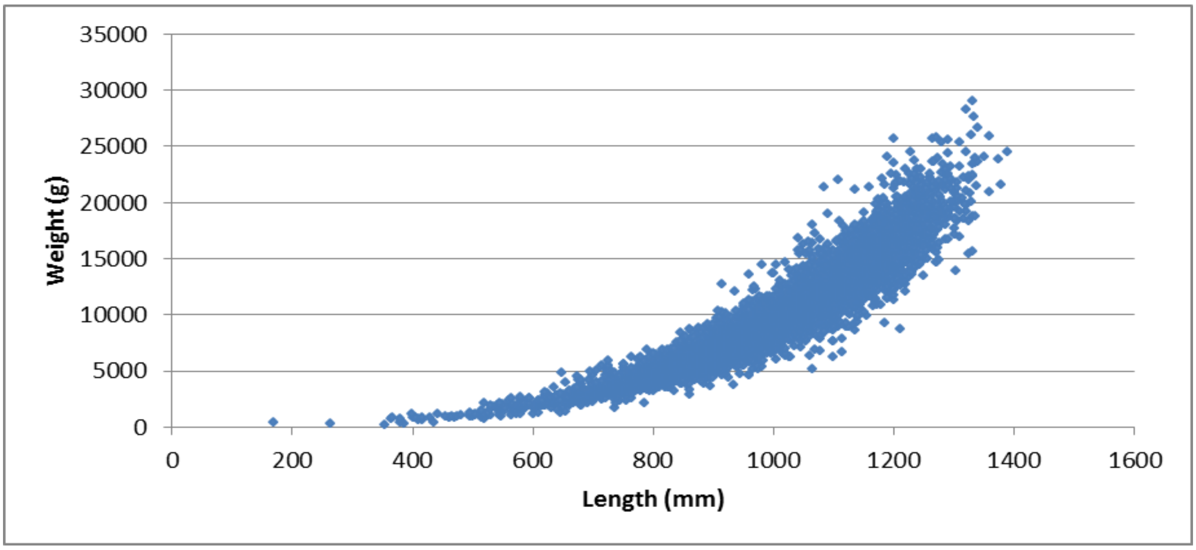


Figure 3.3 – Length/weight relationship for all lungfish (2006 to 2016) where length and weight details were complete (n=7052).

3.2.2 Recaptures, movement and growth

There were 1011 recapture events where lungfish were tagged and subsequently recaptured during the current study. Nine of these events involved a fish being tagged, released and then recaptured later in the same day. Some lungfish that had already been tagged in previous studies (e.g. Brooks and Kind 2002, Kind et. al. 2005, DEEDI 2012 a,b) were also recaptured during the current study. These records were collated but are not further analysed in the current report.

Of 6438 individuals tagged during the study, 5601 (87%) were not subsequently recaptured. The remainder were recaptured between one and five times. The recapture rates varied widely at individual sampling sites between 2.6% at Mingo Gorge (Site 5) and 22.2% at Figtree (Site 2) (Table 3.5). Excluding instances where fish were tagged and recaptured on the same day, ~3% of recaptures indicated movement >1km. All other recaptures occurred close to or at the same location where the fish had originally been tagged. One fish tagged downstream of Ned Churchward Weir was subsequently recaptured 170km upstream in Jones Weir at Mundubbera. To achieve this movement the fish would have needed to traverse Ned Churchward Weir, Paradise Dam, Claude Wharton Weir and Jones Weir. Alternatively, it may have been physically relocated.

Two fish tagged downstream of Paradise Dam (at Figtree, Site 2) were recaptured in the upper reaches of the dam at Mingo Gorge raising the possibility they utilised the upstream fishway at the dam. However, further investigation of these records revealed that the fish were part of a group of 15 lungfish physically relocated from Figtree and released into Paradise Dam by the former Fisheries Queensland Fishway Team. The fish were fitted with telemetry devices and released into the dam to investigate operation of the downstream fishway, and whether they would try and return to their home range downstream of the dam (see DEEDI 2012 a,b).

Nine fish tagged in Paradise Dam were subsequently recaptured downstream of the dam at Figtree (Site 2). These fish were tagged between August 2007 and August 2009 and recaptured in a period spanning August 2011 to March 2016. The fish may have moved downstream by successfully utilising the downstream fishway at Paradise Dam. This fishway operated from February 2009 to December 2010 before being damaged by floodwaters. Following repairs, the fishway resumed operation in February 2015. Alternatively, the fish may have moved over the spillway of Paradise Dam during a series of overtopping events that occurred during the study.

Four fish tagged downstream of Claude Wharton Weir (Site 7) were subsequently recaptured upstream of Jones Weir (Site 8), a distance of ~41km. Upstream movement over Jones Weir can only have occurred during overtopping events as the fishway at the weir is inoperative. The fish most likely ascended Claude Wharton Weir by successfully using the fishway on that weir.

Two recaptures revealed upstream movements (~18km) from Gray's Waterhole (Site 6) to the base of Claude Wharton Weir (Site 7). Another recapture highlighted a different fish moving from Claude Wharton Weir downstream into Gray's Waterhole. The remaining recaptures highlighted relatively short movements (<5km) generally within individual sampling locations. Mean growth rate from the recapture data was 8.75mm per year (Figure 3.4). This is consistent with slow growth observed in previous lungfish monitoring programs (see Brooks and Kind 2002).

Table 3.5 – Summary of lungfish recaptures (2006 to 2016)

Site No.	Site	Recaptures	Recapture rate (%)	Mean growth (mm/year)	Mean time at liberty (days)
1	Isis	164	9.2	9.09	1098
2	Figtree	569	22.2	8.4	931
3	Paradise Dam	7	12.3	29	205
4	Kalliwa Hut	3	3.1	28.7	1443
5	Mingo Gorge	14	2.6	3.1	504
6	Gray's Waterhole	56	10.8	4.4	749
7	Claude Wharton Weir	110	9.9	8.14	786
8	Mundubbera	79	10.7	11.98	1090
	Total	1002	13.6	8.75	940

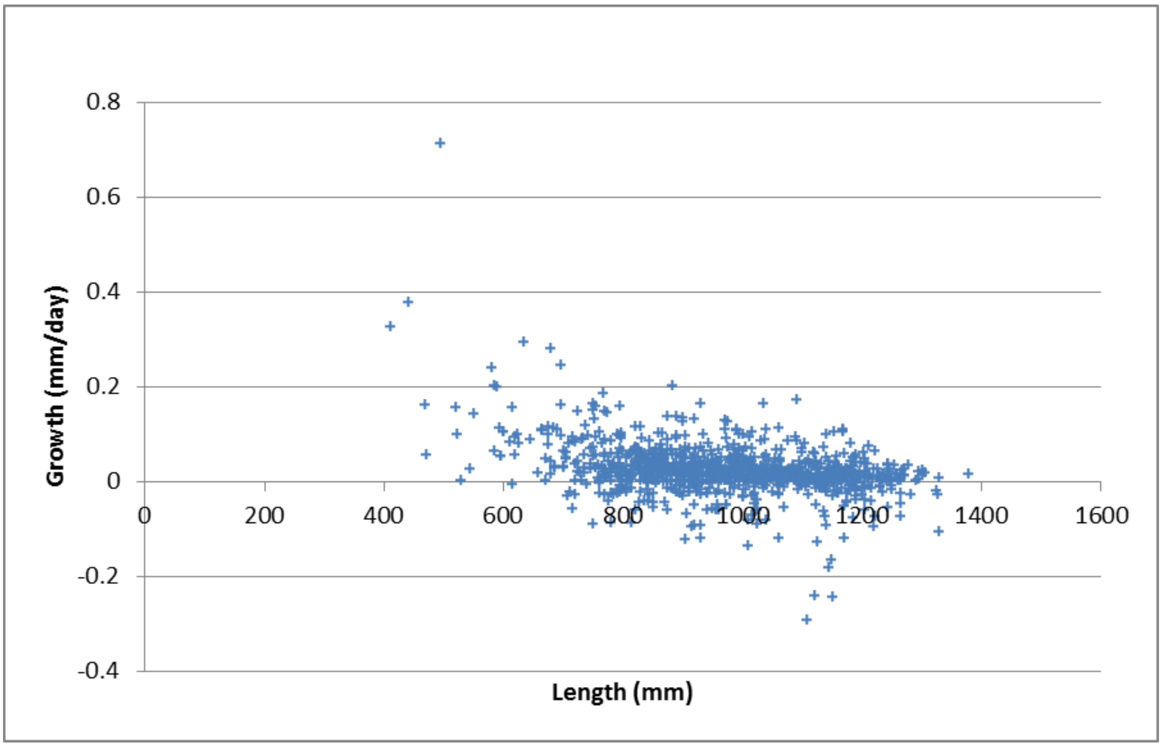


Figure 3.4 – Growth rate of recaptured lungfish (2006 to 2016)

3.2.3 Condition factor and sex ratio

A malfunction in the digital scale system meant that no weight data were gathered during the summer 07/08 survey. Condition factor (CF) estimates for individual fish based on length/weight ratios described earlier varied from 0.0455 to 0.2011 (Table 3.6). Mean CF for the eight sampling sites varied from 0.0878 at Claude Wharton Weir to 0.1108 at Kalliwa (Figure 3.5).

Table 3.6 – Summary statistics for lungfish condition factor by site (2006 to 2016)

Site No.	Site	Number	Condition factor range	Mean condition factor	S.D.
1	Isis	1786	0.0476-0.2011	0.1007	0.0133
2	Figtree	2465	0.0644-0.1922	0.1046	0.0130
3	Paradise Dam	57	0.0863-0.1565	0.1049	0.0133
4	Kalliwa Hut	87	0.0815-0.1797	0.1108	0.0172
5	Mingo Gorge	502	0.0552-0.1589	0.0994	0.0134
6	Gray's W'hole	473	0.0667-0.1765	0.1046	0.0132
7	Claude Wharton Weir	960	0.0455-0.1534	0.0878	0.0154
8	Mundubbera	716	0.0514-0.1546	0.0990	0.0123

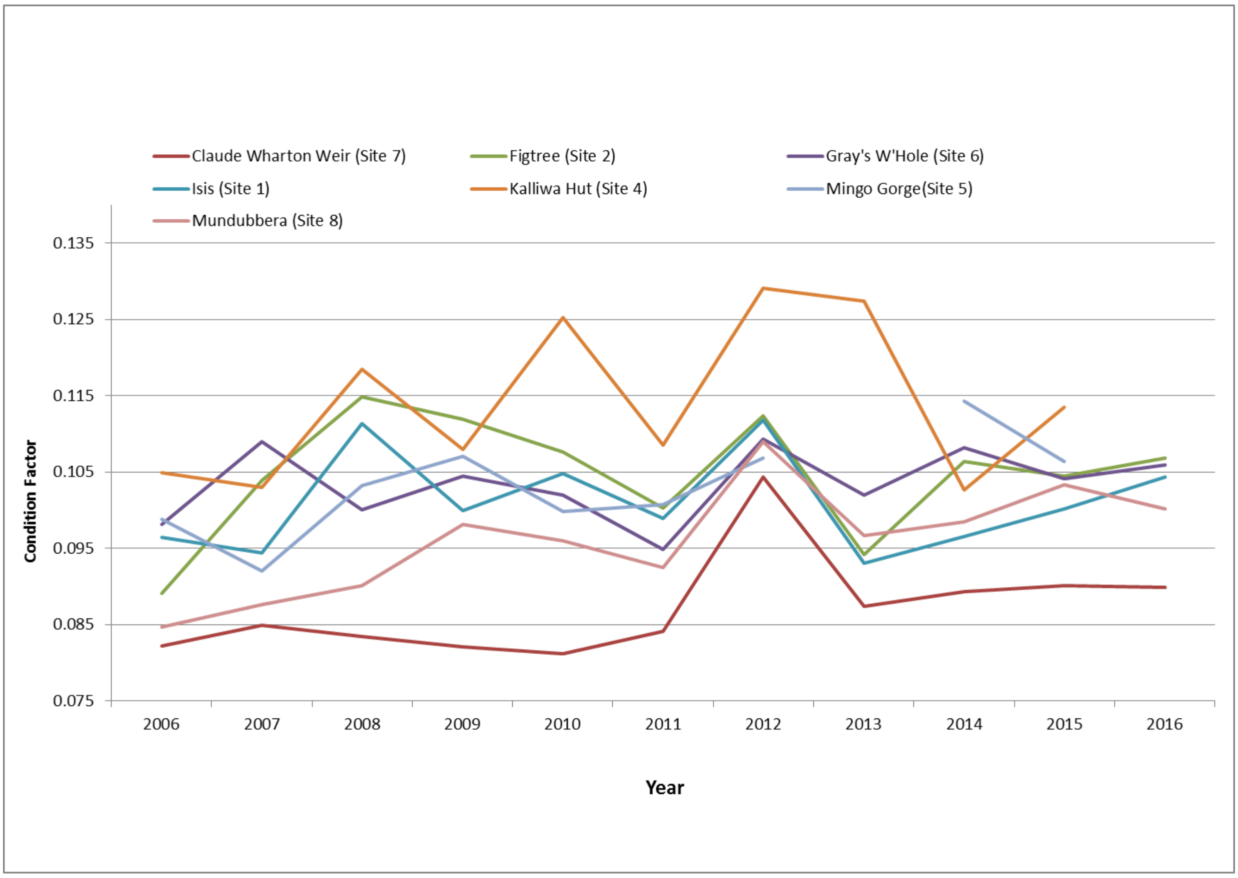


Figure 3.5 – Mean Condition Factor of all lungfish by Site (2006 to 2016)

Condition factor provides an index of wellbeing and can be indicative of relative food availability or density of conspecifics in different sections of the habitat. Mean condition factors in this study (0.088-0.111) compared well with values presented in Brooks and Kind (2002), who reported mean condition of 0.101 in a sample of 2361 lungfish collected from 1997-2000. Condition factor at Claude Wharton

Weir (Site 7) was consistently lower than other locations, but improved following commissioning of the fishway on the weir in 2009 (Fig. 3.5).

Assessment of sex ratio in lungfish populations was included in the current study as an alternative indicator of changes that may be occurring in local lungfish populations. However, in 2010 an Animal Ethics Committee ruling determined that invasive procedures to examine lungfish gonads should only be conducted by a registered veterinarian. Following this decision, sex could only be determined when fish in running ripe condition were collected. (Running ripe means that lungfish eggs or sperm were clearly visible during measuring procedures).

A total of 264 fish including 63 females and 198 males were examined to determine their sex and maturity status. (Three fish were not sexed). Details of recorded sex and maturity status are presented in Table 3.7

Table 3.7– Sex and maturity status of lungfish sub-sample

	Number	Length range(mm)
Mature males	194	696-1318
Mature females	52	740-1260
Immature females	7	630-780
First spawning females	4	660-719
Males (maturity uncertain)	4	635-740
Sex undetermined	3	660-755
Total	**264**	

3.3 Population Estimates

Mark and recapture records provided an opportunity to estimate lungfish population size at some sites for comparison with trends in CPUE. Because all sections of the river were not sampled equally, no attempt was made to estimate the size of the entire population in the survey area. Sufficient data were available to attempt population estimates using a basic model at Isis, Figtree, Gray's Waterhole and Claude Wharton Weir. Table 3.8 provides a summary of lungfish tagged and recaptured at these sites.

Table 3.8. – Summary of lungfish tagged and recaptured in each survey at Isis, Figtree, Gray's Waterhole and Claude Wharton Weir sampling sites

Survey	Isis (Site 1)		Figtree (Site 2)		Gray's W'hole (Site 6)		Claude Wharton Weir (Site 7)	
	Tagged	Recapture	Tagged	Recapture	Tagged	Recapture	Tagged	Recapture
1	92	0	118	0	49	0	39	0
2	81	3	117	16	28	3	89	4
3	82	0	125	17	52	7	74	8
4	87	2	94	6	40	3	106	5
5	115	0	109	34	18	0	62	6
6	89	5	76	19	13	7	69	6
7	102	6	84	33	42	4	57	5
8	64	4	64	16	17	2	56	15
9	152	11	93	28	26	10	73	7
10	23	1	61	11	19	3	47	6
11	53	8	94	20	4	1	12	2
12	60	10	51	9	31	0	83	7
13	78	15	105	36	21	3	60	11
14	79	8	98	17	8	0	8	3
15	86	14	80	27	0	1	6	0
16	97	15	133	39	15	2	12	1
17	103	11	107	47	32	5	17	8
18	70	12	113	57	18	4	36	5
19	146	31	146	93	13	0	13	3
20	52	9	88	45	14	1	50	7

Insufficient recapture data were available to attempt similar analyses at the other locations.

The population estimates were (initially) calculated using the Chapman variation of the Lincoln-Peterson mark-and-recapture method as follows;

$N=((M+1)(C+1))/(R+1)-1$,

Variance of $N=((M+1)(C+1)(M-R)(C-R))/((R+1)(R+1)(R+2))$,

Standard error= $\sqrt{(\text{Variance of } N)}$,

Where,

N = population estimate

M = number of lungfish tagged from previous sample/s

C = total number of lungfish caught including recaptures in current sample

R = number of lungfish recaptures in current sample

The method assumes the population is closed (i.e. minimal immigration or emigration occurs), all lungfish are equally likely to be captured in each sampling event, capture and tagging do not affect catchability or, each sample is random and tags are not lost between sampling events.

Population estimates are presented in Figure 3.6 for the duration of the study. However, the reliability of the estimates improved over time as the number of recapture events built up. Estimates at all four locations were considered to be generally acceptable from survey 6 onwards (summer 2009). However, the estimates for Claude Wharton varied widely and had higher standard error throughout the survey. The estimated number of lungfish in the sampling site at Isis (approximately 10 000 individuals) was considerably higher than in locations further upstream.

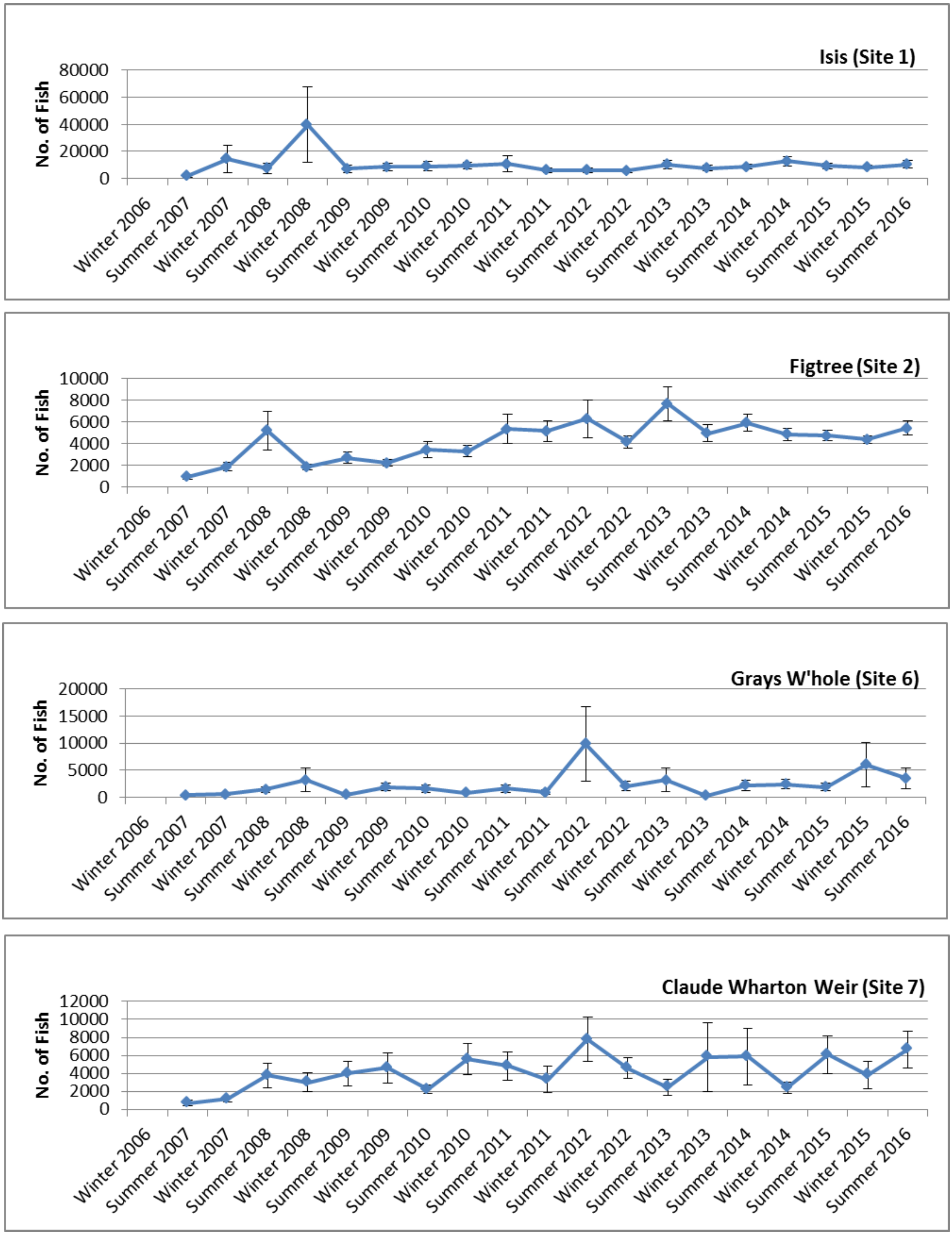


Figure 3.6 – Population estimates from mark and recapture. Vertical bars indicate standard error. Y axis scale varies between sites

The population estimates for Isis (downstream of Ned Churchward Weir) remained relatively stable at around 10 000 individuals from summer 2009 onwards apart from one survey in winter 2008 when a large sample was collected (115 fish) with no recaptures. Likewise the summer 2011 survey yielded 23 fish with only one recapture, which increased the population estimate and the level of error (Fig. 3.6). At Figtree (downstream of Paradise Dam), population estimates indicated a gradual increase over time, particularly following the 2010 flood when the estimate moved from approximately 3000 fish to around 5000. After this period levels fluctuated but remained relatively stable at the higher level (Fig.3.6). Standard error estimates for this location were smaller than at other sites and relatively consistent throughout the survey. Population estimates at Gray’s waterhole were relatively stable at approximately 2000 individuals apart from two surveys (Summer 2012, Winter 2015) when the estimates and error were higher. Population estimates at Claude Wharton Weir were variable and had consistently higher levels of error than the other locations. There were several potential confounding factors at this site, which may have influenced the outcomes. These factors including flood effects, the location of the site (at the dam wall) and operation of the fishway are examined in the discussion section.

3.4 Additional analyses and Independent Review of CPUE and Mark/Recapture

The monitoring program used boat-mounted electrofishing to sample lungfish populations and Catch Per Unit Effort (CPUE) expressed in terms of fish / minute of electrofishing as the key index of lungfish abundance. Because lungfish were tagged before release, subsequent recapture records allowed for estimates of population size to be calculated at some of the sampling sites. These capture and analysis techniques are widely utilised in freshwater fisheries management to monitor population changes in fish stocks. However, there are several factors that can influence catchability in electrofishing surveys, which in turn may confound the relationship between CPUE and fish abundance. Likewise, population estimates generated from mark and recapture are underpinned by key assumptions, which should be considered when analysing and interpreting results of mark/recapture studies.

To improve the voracity of initial analyses presented in sections 3.1 to 3.3 above, raw data from the lungfish surveys were sent to experienced biometricians at the Arthur Rylah Insitute for Environmental Research (ARI) and subject to independent analyses. Terms of Reference for the review included;

- Conducting exploratory analyses of the data set to elucidate the survey design, highlight any outliers in the data and consider potential correlation between environmental covariates in the survey
- Repeating the analysis of trends in CPUE using data standardised against environmental covariates rather than the raw CPUE data
- Revising population estimates from the mark/recapture data using techniques appropriate to minimise potential confounding effects from violations of the mark/recapture assumptions.

Results from this analyses were provided to Sunwater separately and are considered in the discussion and conclusion sections of this report.

3.5 Lungfish habitat and macrophyte monitoring

River depth profiles, sediment types, macrophyte species present, water quality parameters and physical site characteristics are provided for each site below. These measurements represent a 'snap shot' description of habitat conditions within the sites at the time of lungfish sampling. Data is presented graphically for the last two years and first years of monitoring to demonstrate changes in river depth profiles over the 10 years of monitoring. Flooding events in 2013, 2011 and 2010 significantly changed the depth profiles and habitat of most sites.

3.5.1 Site 1 – Downstream reference (Isis)

Habitat in this site comprises a series of shallow pools and glides. Depth profiles increase gradually from the southern bank to a maximum of around 3 metres. The average depth and average width remained consistent throughout the first seven years of monitoring. However, major flooding in 2013 significantly changed the river depth profiles (Figure 3.8). Large amounts of sand were deposited which reduced the average and maximum depths (Table 3.9). The height of the exposed sand banks on the southern bank deposited from the 2011 flow events were reduced by the 2013 flood. The northern bank has a steeper overall profile compared to the southern bank and is characterized by overhanging riparian vegetation and submerged woody debris. The substrate is dominated by coarse river sand, with a top layer of fine silt and occasional rocky outcrops. Macrophyte species and density has been significantly reduced since the major flow events. No macrophytes were recorded along the transects post 2013 floods. A small patch of Ribbonweed (*Vallisneria nana*) was the only macrophyte recorded along the transects in 2012. Prior to the flow events the southern river margin was dominated by Water Lilies (*Nymphoides sp*.), Water Hyacinth (*Eichhornia crassipes*), Water Primrose (*Ludwigia peploides*) and Water Couch (Paspalum sp.). Patches of Ribbonweed (*Vallisneria nana*) also occurred in the open river channel at depths between 75-1850mm. The northern bank is generally steep and supports far less substrate-rooted macrophytes. Other plant species recorded during monitoring included *Hymenachne* sp, Foxtail (*Ceratophyllum demersum*), Ferny Azolla (*Azolla pinnata*) and various filamentous algae species. The density of aquatic plants and the plant community in this area fluctuates seasonally and in relation to flow conditions.

Table 3.9– Physical characteristics of Site 1 (Isis)

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Max depth (m)	3.6	4.6	3.5	4.3	4.2	3.8	3.1	3.17	3.3
Mean depth (m)	1.71	19.26	13.51	2.16	2.18	2.26	1.60	1.19	1.22
Mean width (m)	52	56	51.5	59.5	60	55	55.5	51	52

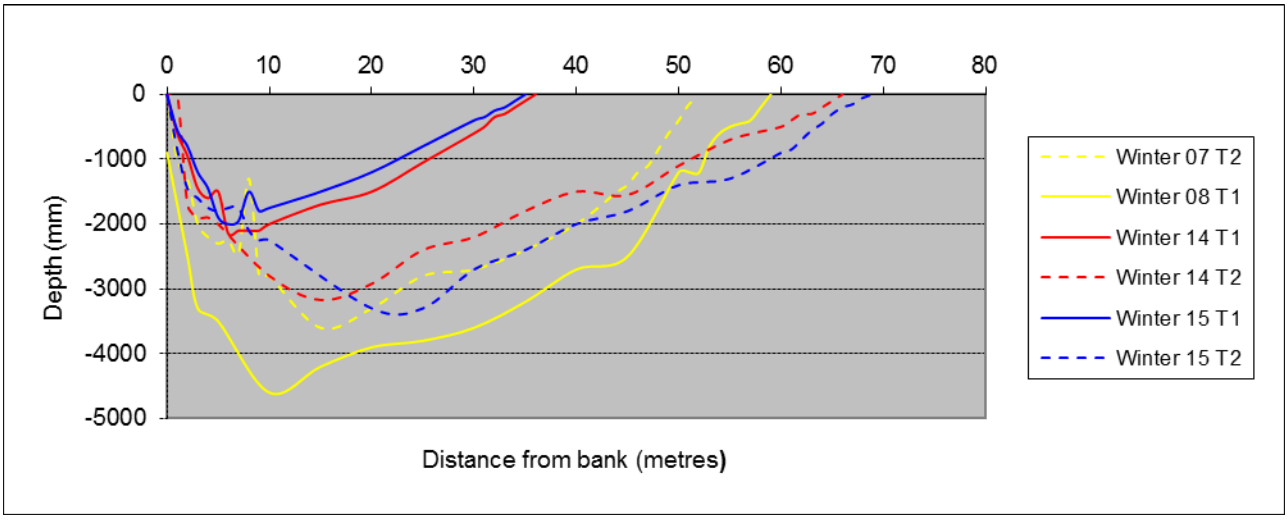


Figure 3.8 – Depth profiles of Site 1 (Isis)

3.5.2 Site 2 – Downstream (Figtree)

Habitat in this site comprises shallow pools connected by a short riffle/run sequence. Depth profiles highlight that the entire area is shallow (Figure 3.9). Mean depth barely exceeds 1 metre and the maximum depth recorded in the transect analysis was under 2.5 metres (Table 3.10). The transects were moved, from the lower pool near the Figtree Gauging Station in 2006/07 and 2007/08 to the upper large pool for subsequent surveys, because of access problems associated with the lower pool. The average depth and average width increased slightly following the flow events in summer 2010 and 2013. The 2013 flood event scoured out sediment on the southern river bank margin at the bottom of the pool and prevented access to the site from the southern bank. Access to the site is now obtained from the northern bank via a private property. The upper pool's southern and northern banks exhibit a considerable amount of overhanging riparian vegetation. The dominant substrate at this site is coarse river sand, overlaid with a layer of fine silt along the banks. Submerged and emergent rocks are also a feature of the survey area and rock has only been recorded along the transect lines since the scouring of the bottom layer in 2010 and 2013. No macrophytes were recorded along the transect lines in 2013, 2011 and 2010. Ribbonweed (*Vallisneria nana*), Curly Pondweed (*Potamogeton crispus*) and Water Hyssop (*Bacopa monniera*) were recorded along the transect line in 2012, but these macrophytes were scoured in the 2013 flood. A similar suite of macrophytes were again recorded in 2014 with the addition of Water Milfoil (*Myriophyllum sp.),* and again removed by flooding prior to the 2015 sampling during which only a small patch of sparse Ribbonweed was recorded. Before the big flow events the site was heavily vegetated and dominated by Water Lilies (*Nymphoides sp.*) along the river margins, particularly the northern bank. Extensive mixed patches of Ribbonweed, Hydrilla (*Hydrilla verticillata*) and filamentous algae also occurred across the river in depths from 150-1900mm. Other species observed in the area included Foxtail (*Ceratophyllum demersum*), Ferny Azolla (*Azolla pinnata*) and Para Grass (*Urochloa mutica*).

Table 3.10 – Physical characteristics of Site 2 (Figtree)

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Max depth (m)	2.35	1.9	1.9	2.1	2.3	2.3	2.1	1.95	2
Mean depth (m)	1.19	0.94	0.95	1.42	1.46	1.57	1.46	0.93	0.96
Mean width (m)	41	99	99	111	119	109	125	121	119

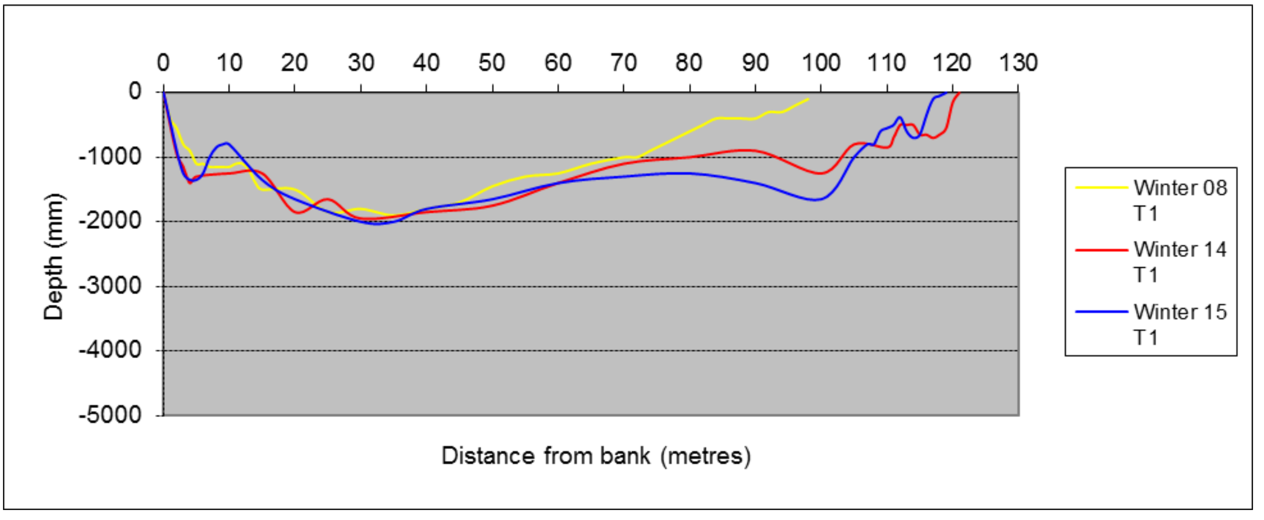


Figure 3.9 – Depth profiles of Site 2 (Figtree)

3.5.3 Site 3 – Downstream (Paradise Dam)

This site was only sampled during the first year of monitoring. Few lungfish were caught at this site and due to ongoing access problems the decision was made to not utilise this site on a regular basis and therefore no habitat data was recorded for this site.

3.5.4 Site 4 – Within (Kalliwa Hut)

This site is within the Paradise Dam impoundment and depth fluctuates with inflows and releases from the dam. The average width of the sampling area has increased from approximately 240 metres to over 530 metres and the average depth has increased from 6 metres to 18 metres over the 10 years of monitoring (Table 3.11 and Figure 3.10). Depth profiles demonstrate rapidly increasing depth to a maximum thus far of approximately 35 metres in the mid-channel (Figure 3.10). Both banks are characterised by large inundated trees and patches of other submerged vegetation, often extending more than 100m from the bank. The vegetation is in various states of decay reflecting variable water levels in the dam over time. Occasional shallow bays and steep rock bars have been formed by inundation of sections above the crest of the former river bank. Substrate along the river margins is predominantly coarse sand and silt, however substrate types could not be determined at most points due to depth. Apart from flooded patches of terrestrial grass, no submerged aquatic plants were recorded along the transect lines in the first six years of monitoring. A small patch of Water Hyssop (*Bacopa monniera*) was recorded on the transects in 2011 and again in 2014. Water Milfoil

(Myriophyllum sp.), Water Hyssop (*Bacopa monniera*) and Ribbonweed (*Vallisneria nana*) were recorded along the transects in 2012. There were no macrophytes recorded along the transects in 2013. Water Hyssop and sparse patches of short (10mm) Ribbonweed were observed during roving surveys, with more extensive beds observed in one shallow bay prior to the 2013 flooding events. The noxious floating plant, Salvinia (*Salvinia molesta*) and Ferny Azolla (*Azolla pinnata*) has been observed during all years of monitoring except 2013.

Table 3.11– Physical characteristics of Site 4 (Kalliwa Hut)

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Max depth (m)	13	28.8	30.5	33.3	33.4	34.7	31.8	28.6	33.1
Mean depth (m)	6.16	14.1	12.89	16.69	16.08	16.71	17.94	14.76	13.74
Mean width (m)	241	421	485.5	525	533.5	510	535.5	406.5	532.5

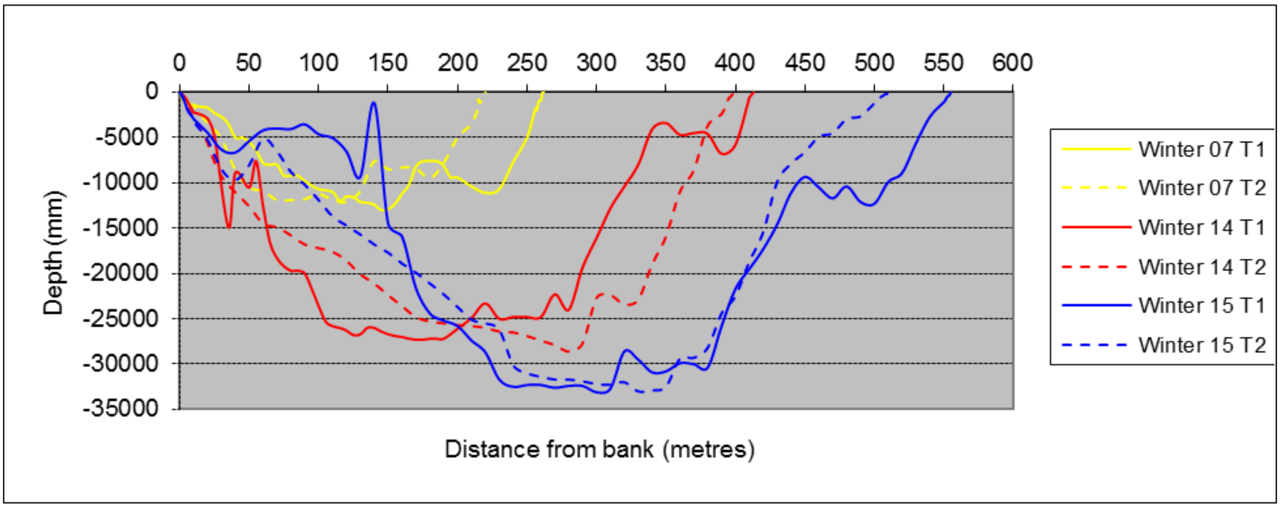


Figure 3.10 – Depth profiles of Site 4 (Kalliwa Hut)

3.5.5 Site 5 – Within (Mingo Gorge)

Mingo Gorge is located in the upper reaches of the Paradise Dam impoundment and is subject to variable water levels with inflows. The site has changed during the ten years of monitoring due to the filling of Paradise Dam. The average depth has increased from approximately 4 metres to 12 metres and the average width of the site has also increased from 70 metres to 240 metres (Table 3.12). The site has changed from a series of rocky pools, glides and riffles to a large permanent water body. The southern bank has remained steep due to the gorge, but now has increased to over 10 m deep within a few metres of the bank and is comprised of flooded riparian vegetation (Figure 3.11). The northern bank now has a gentle slope for the first 130 metres and is comprised of flooded vegetation and submerged and semi-submerged riparian vegetation which is it varying stages of decay. The survey site has had varying levels of Salvinia (*Salvinia molesta*) infestations which have not been recorded along the transect lines in the last six years of monitoring. Apart from filamentous algae growing along the margins, transect sampling only detected submerged aquatic plants during the 2014 monitoring, when some very sparse Ribbonweed (*Vallisneria nana*), Water Hyssop (*Bacopa monniera*) and algae were recorded on the northern bank. Small patches of Ribbonweed (*Vallisneria nana*), Water Hyssop (*Bacopa monniera*) and Water Lilies (*Nymphoides sp.*) were observed growing on sandy patches between the rocks in the first two years of monitoring and sparsely along the northern bank edges in the first six years of monitoring. Substrate in the site is heavily dominated by rock, particularly in the upper reaches of the gorge area which has become submerged in recent years. The substrate on the northern bank consists mainly of soil that has become submerged.

Table 3.12– Physical characteristics of Site 5 (Mingo Gorge)

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Max depth (m)	5.22	19.5	21.9	24.5	25.6	25.6	23.6	19.2	24.8
Mean depth (m)	2.07	6.93	9.51	11.52	12.74	12.79	10.57	5.87	9.14
Mean width (m)	53	218	230.5	249	252	249	236	212	249.5

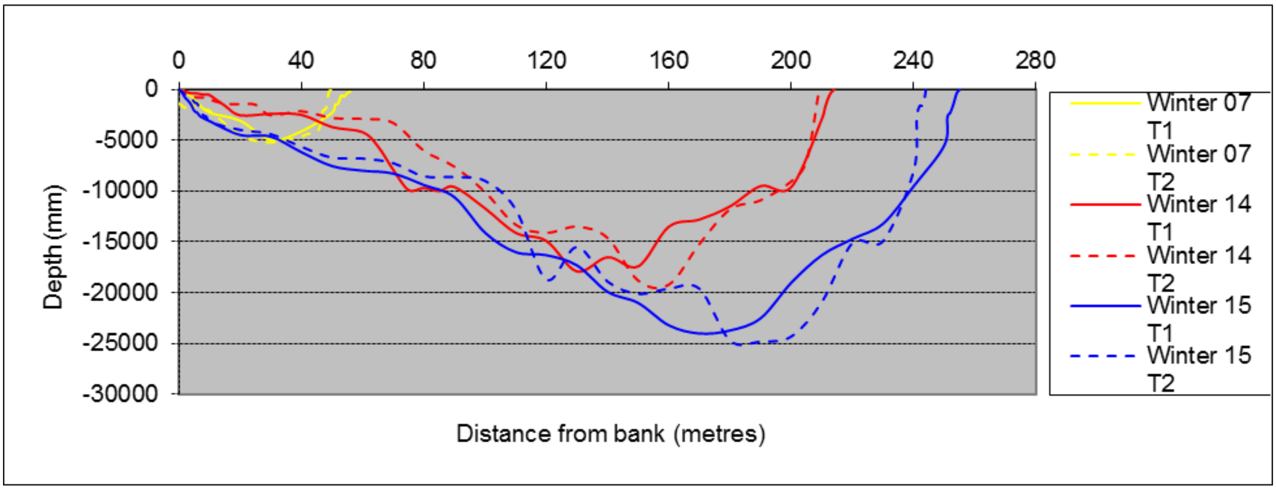


Figure 3.11 – Depth profiles of Site 5 (Mingo Gorge)

3.5.6 Site 6 – Upstream (Gray's Waterhole)

Habitat in this location is almost entirely a single permanent deep pool reaching depths up to 13 metres. The average depth and average width of this site remained consistent throughout the first seven years of monitoring. Flooding events in summer 2013 scoured the southern bank and increased the maximum and average depth (Table 3.13). The large sand deposits of the 2011 flow events were also removed by the 2013 flood. The profile of the southern bank has also changed to a steeper drop off that reaches a depth of over 5 metres within 2 metres of the bank (Figure 3.12). Both northern and southern banks are steep and heavily lined with overhanging riparian vegetation. There are occasional patches of submerged woody debris and some large submerged rock bars. The survey area also includes a relatively shallow tributary stream at the upstream extremity of the site. This tributary is heavily laden with silt. The only submerged macrophytes recorded during transect sampling at this site were rootlets of trees (mostly *Callistemon sp.*) growing along the river banks. Some small patches of Ribbonweed (*Vallisneria nana*) and Hydrilla (*Hydrilla verticillata*) were observed in the upper reaches of the pool. Some patches of Para Grass (*Urochloa mutica*) also occur in areas where the bank profile slopes more gently. Substrate in the site is a combination of sand and rocks, although substrate type could not be determined at the majority of the transect points due to the depth of the pool.

Table 3.13– Physical characteristics of Site 6 (Gray's Waterhole)

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Max depth (m)	8.5	9.8	9.8	8.9	10	10.1	12.8	12.6	12.7
Mean depth (m)	2.84	3.36	3.29	4.46	4.46	5.71	6.09	4.32	3.84
Mean width (m)	96	94	94	97	95.5	95	102.5	103	104.5

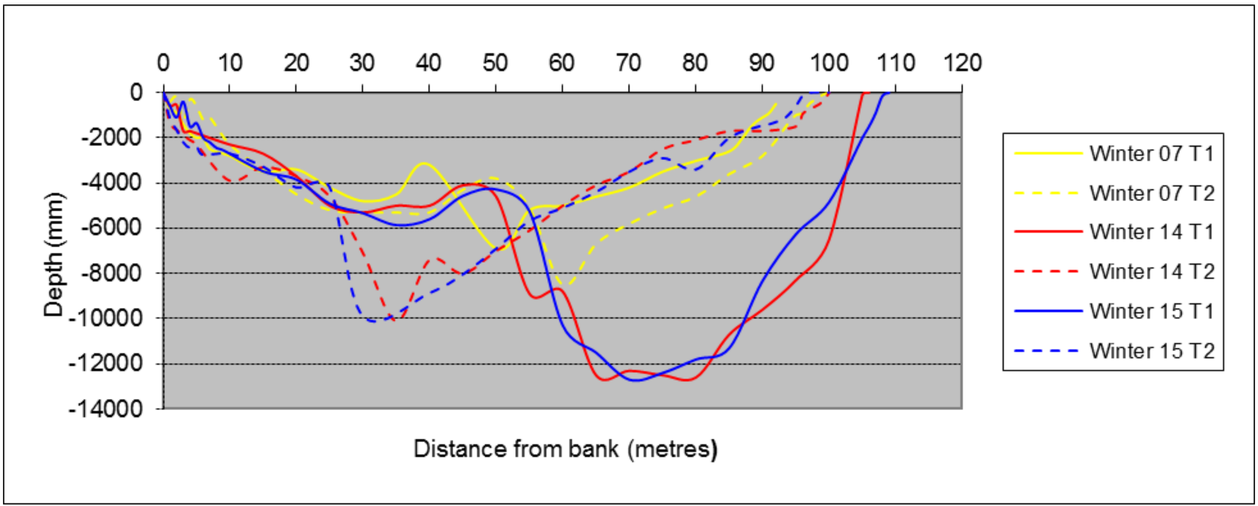


Figure 3.12 – Depth profiles of Site 6 (Gray's Waterhole)

3.5.7 Site 7 – Upstream (Claude Wharton Weir)

This site comprises a series of shallow pool, glide and riffle sections influenced by operation of the Claude Wharton Weir and flooding events. Depth profile analysis highlights the pool-glide-riffle sequence, with one transect in a considerably more shallow section than the other (Figure 3.13). While some overhanging riparian vegetation is present, the banks have been degraded by recent flooding events. The 2011 flow events scoured out the pools and connected the two pools directly below the Claude Wharton Weir. The 2013 flood event deposited large amounts of sand in the downstream section of the site which changed the depth profiles further. The deposited sand reduced the average width and overall size of the sampling site (Table 3.14). There are patches of Para Grass (*Urochloa mutica*) in cleared edges along both banks. Some submerged woody debris is present on one transect and is sparsely distributed throughout the remainder of the site. Para Grass (*Urochloa mutica*) and Slender Knotweed (*Persicaria decipiens*) were the only macrophyte species detected on the transect lines, although small patches of Ribbonweed (*Vallisneria nana*), filamentous algae and other species have been observed in the riffle zones. Substrate varies from gravel / rock in the riffle areas to sand and gravel in the glides and pools. Heavy silt loads were observed in slow flowing sections, resulting in the sites typical turbid water.

Table 3.14 – Physical characteristics of Site 7 (Claude Wharton Weir)

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Max depth (m)	3.1	3	2.95	3.3	5	5.1	4.8	3.7	4.4
Mean depth (m)	1.2	1.58	1.38	1.50	2.55	2.95	2.39	1.06	1.32
Mean width (m)	60	57.5	57.5	59.5	82	82	44.33	66	68

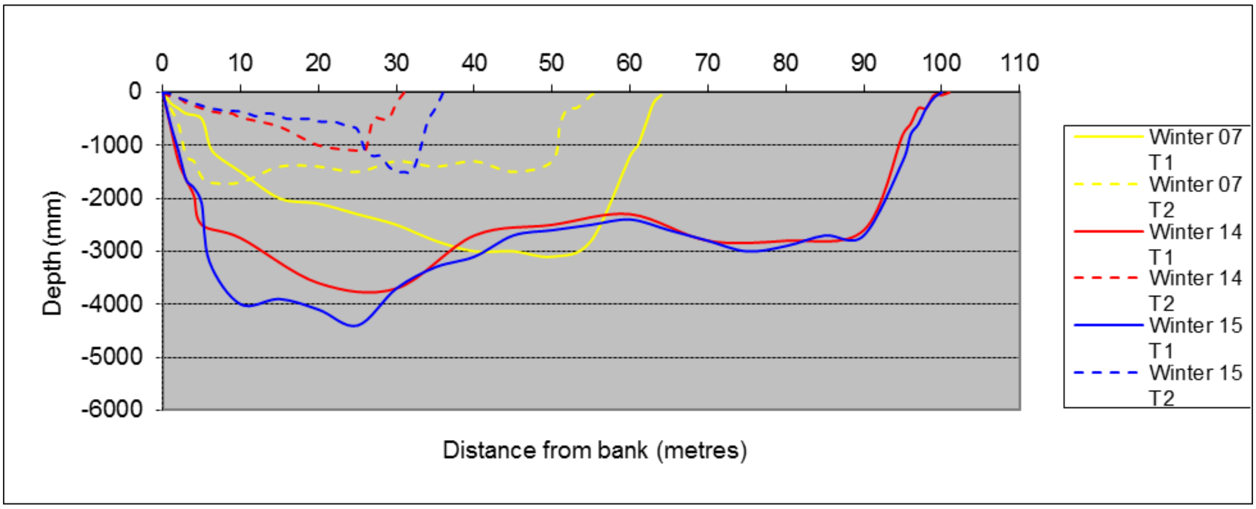


Figure 3.13 – Depth profiles of Site 7 (Claude Wharton Weir)

3.5.8 Site 8 – Upstream (Mundubbera)

This site is predominantly weir pool habitat with some runs and glides in the upper reaches. Lower reaches of the Boyne River have glide/riffle sequences. Depth profiles highlight the broad and shallow nature of the weir pool, with depth averaging approximately 4 metres despite average channel width of up to 148 metres (Figure 3.14). Average depth and average channel width slightly increased during 2012 to 2014 after the 2011 and 2013 floods (Table 3.15). The maximum depth also increased by almost 4 metres between the 2006/7 and 2013/14 surveys, reflecting slight scouring from the recent flow events and filling of the weir pool. The depth profiles demonstrate that there were no significant changes to the river profiles from the 2013 flood (Figure 3.14), but rather varying water levels. Ribbonweed (*Vallisneria nana*), Hydrilla (*Hydrilla verticillata*) and Curly Pondweed (*Potamogeton crispus*) were recorded along the transect lines in 2014 and 2015. There were extensive water lily beds in shallow sections of the weir pool during much of the sampling. Para Grass (*Urochloa mutica*) is also widespread in the lower reaches of the pool. Mixed beds of Ribbonweed (*Vallisneria nana*), Hydrilla (*Hydrilla verticillata*) and filamentous algae were frequently observed in upper reaches of the site and at confluences of the river and tributary streams. The pool has a considerable amount of inundated trees and other submerged woody debris. Substrate in the site is dominated by sand, frequently topped by heavy layers of silt.

Table 3.15 – Physical characteristics of Site 8 (Mundubbera)

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Max depth (m)	3.3	5	6.15	6.26	8.45	7.8	8.2	8.34	8.2
Mean depth (m)	1.67	2.57	2.59	3.79	4.15	4.34	4.34	2.94	2.66
Mean width (m)	103	124.5	131.5	145.5	145.5	144	147.5	141	148

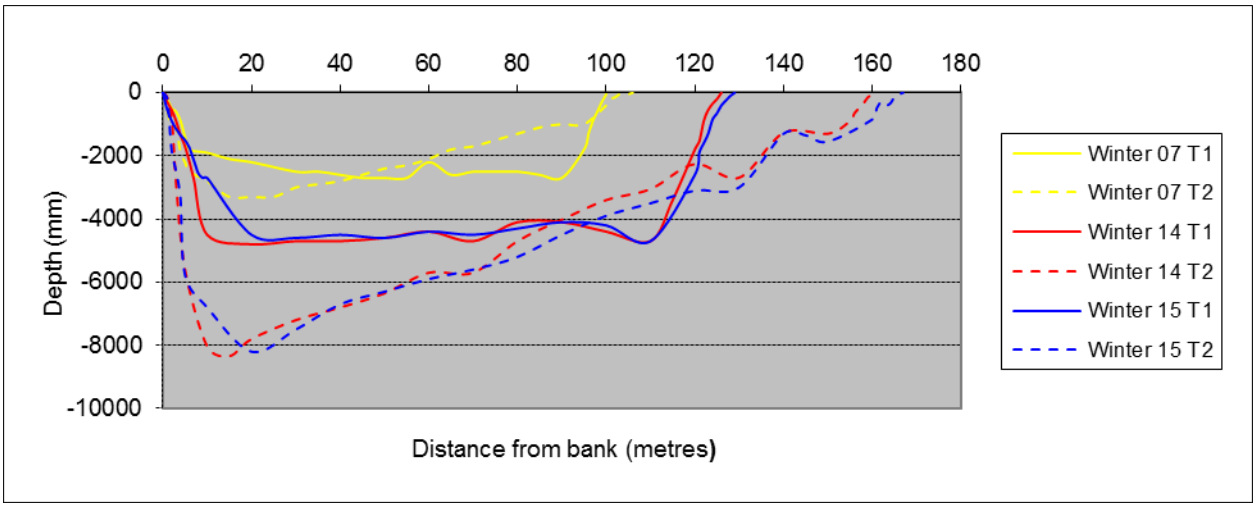


Figure 3.14 – Depth profiles of Site 8 (Mundubbera)

3.6 Spawning surveys

Lungfish eggs were located in each of the first four years of spawning surveys between August and November. No lungfish eggs were collected in the 2010, 2011 or 2015 spawning surveys. Eggs were collected in 2012, 2013 and 2014. During the survey period, some evidence of spawning activity was confirmed at six of the seven sites (Table 3.16, Figure 3.15). No eggs were collected from Spawning Site 3 (Kalliwa Hut/Paradise Dam boat ramp) within the impoundment. This site was shifted closer to the wall (near the boat ramp) when access to the original site was blocked during 2008 due to rising water levels. A total of 1967 lungfish eggs were collected from 11320 push net shots. Lungfish egg(s) were present in 372 (3.29%) of all push net shots. A total of 655 eggs were collected in 2006, 115 in 2007, 508 in 2008, 74 in 2009, 0 in 2010, 0 in 2011, 311 in 2012, 3 in 2013, 301 in 2014 and none in 2015.

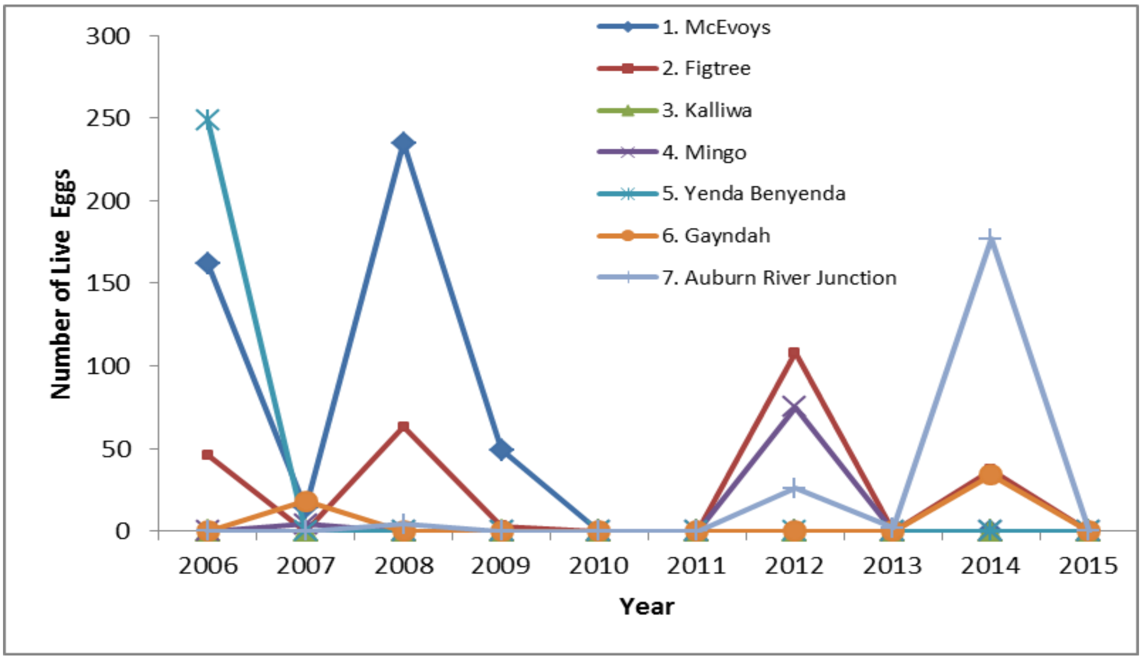


Figure 3.15 – Lungfish egg numbers observed by site and season

In total, 662 eggs (33.6%) have been either infertile or dead. The proportion of live eggs varied between years, from a high of 82% in 2014 to a low of 31% in 2007. Viable lungfish eggs were collected at three of the seven designated sampling sites in 2006, 2007, 2008, 2012 and 2014, two sites during 2009 and a single site in 2013. As previously reported, fish in running ripe condition have been collected during adult lungfish monitoring at Gray's Waterhole (Site 6), Figtree (Site 2), Isis (Site 1), Mundubbera (Site 8) and Kalliwa (Site 4), confirming spawning activity independently of the egg sampling. Approximately 250 running ripe condition lungfish were collected during adult lungfish monitoring, providing further evidence of spawning activity despite no eggs being collected for some of those years.

Table 3.16 – Summary of lungfish eggs collected at seven sampling sites during spawning seasons between 2006 and 2016.

	2006			2007			2008			2009			2010	2011	2012			2013			2014			2015	**Total**
	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	Total	Total	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	Total	
1. McEvoy's	162	144	306	14	66	80	235	189	424	49	22	71	0	0	0	0	0	0	0	0	0	0	0	0	**881**
2. Figtree	46	10	56	0	0	0	63	9	72	3	0	3	0	0	108	88	196	0	0	0	37	10	47	0	**373**
3. Kalliwa Hut	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
4. Mingo Crossing	0	0	0	4	9	13	0	0	0	0	0	0	0	0	75	10	85	0	0	0	0	0	0	0	**98**
5. Yenda Benyenda	249	44	293	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**293**
6. Gayndah	0	0	0	18	4	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	13	47	0	**69**
7. Auburn River Junction	0	0	0	0	0	0	4	8	12	0	0	0	0	0	26	5	31	2	1	0	177	30	207	0	**253**
Total	**457**	**198**	**655**	**36**	**79**	**115**	**302**	**206**	**508**	**52**	**22**	**74**	**0**	**0**	**209**	**103**	**311**	**2**	**1**	**3**	**248**	**53**	**301**	**0**	**1967**

Approximately 45% of all lungfish eggs in the surveys were collected from the downstream reference site (Spawning Site 1), in reaches below Ned Churchward Weir. However, the proportion of live eggs at this site varied greatly from 52% in 2006 to 17.5% in 2007, improving slightly to 55% in 2008 and further to 69% in 2009. The initial decrease in proportion of live eggs coincided with a noticeable decrease in habitat quality as a result of poor quality water being released from Ned Churchward Weir. This improved slightly with increased water releases from Ned Churchward Weir in 2008. The proportion of live eggs in 2009 are not truly indicative of the quality of the spawning habitat during that season as no eggs were found until an increase in releases flooded the emergent vegetation where subsequently all the eggs were found. No eggs have been recorded at this site since. This was to be expected due to the absence of suitable habitat. Similarly, 46 viable eggs (82%) were located in reaches downstream of the Paradise Dam (Spawning Site 2) in 2006, none in 2007, 63 (87%) in 2008, only 3 (100%) in 2009, 108 (55%) in 2012 and 37 (79%) in 2014.

Approximately 14.9% (293 eggs) of the entire sample (1967 eggs in ten years) were collected from Yenda Benyenda (Spawning Site 5), during the 2006 survey. At that stage, the site was not inundated and resembled a flowing river reach. Again, all of these eggs were collected during 2006 and no further eggs have been located at this site since the area was inundated by inflows to the dam. No lungfish eggs or evidence of spawning activity had been recorded at Kalliwa Hut/Paradise Dam Boat Ramp (Spawning Site 3), within the Paradise Dam impoundment, either by push net sampling or more extensive roving surveys until 2015. A few small patches of macrophytes were observed in minor tributaries flowing into the dam between 2006 and 2008 and some sparse patches of macrophytes were beginning to establish in late 2009. Extensive patches of Water Hyssop (*Bacopa monniera*) were observed fringing the water’s edge in various bays throughout Paradise Dam in the 2012 roving survey. During the 2014 and 2015 spawning seasons macrophyte beds dominated by Red Watermilfoil *(Myriophyllum verrucosum*) were observed, but no spawning was recorded in these despite four running ripe fish being captured during the winter 2015 lungfish survey. These fish were captured around a single clump of Para grass (*Brachiaria mutica*) growing from a submerged tree stump in 2.0 m of water. No similar habitat was located during the roving survey.

Viable eggs were located at Mingo Crossing (Spawning Site 4) in the upper reaches of the Paradise Dam during September 2007, but again no spawning activity was observed at this site until 2012 when complex beds of macrophytes established. These beds comprised of Red Watermilfoil (*Myriophyllum verrucosum*), Ribbon weed (*Vallisneria gigantea*), Curly pond weed (*Potamogeton crispus*), Water Primrose (*Ludwigia peploides*) and Water Hyssop (*Bacopa monniera*) on the fringes. During 2012, 85 eggs were collected at this site with 75 (88%) of these eggs viable. The majority of eggs at this site were found at depths less then 400mm.

Lungfish spawning behaviour has been consistent with previous descriptions provided by Brooks (1995) and Brooks & Kind (2002). Lungfish spawning has occurred at temperatures between 17.7 and 30.5^{0}C and lungfish eggs were located at depths ranging from 20 to 1350mm (Figure 3.17). Approximately 86% of all eggs were located in depths less than 500mm and more than 99% of all lungfish eggs were collected from shots where macrophyte density exceeded 50% (Figure 3.16).+

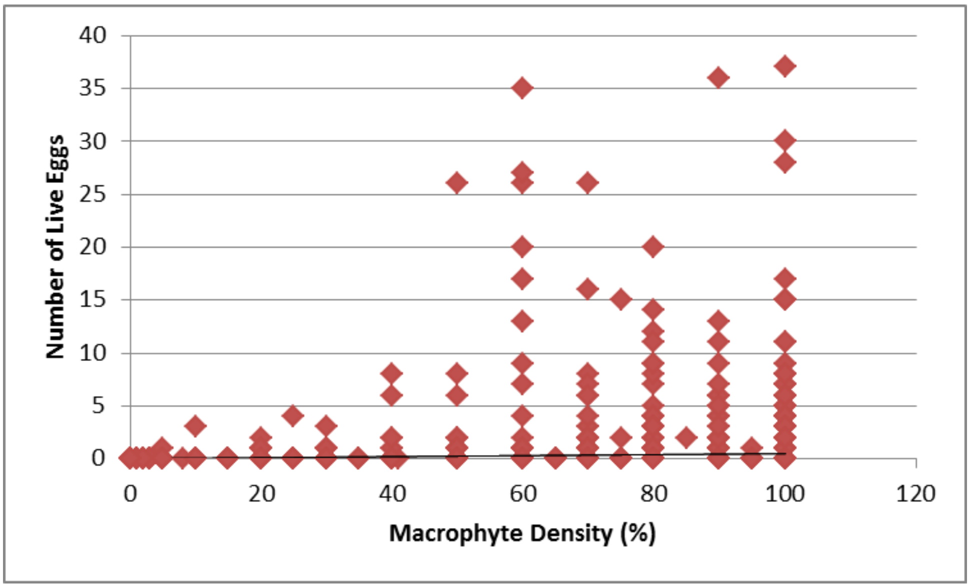


Figure 3.16 – Number of lungfish eggs in relation to macrophyte density

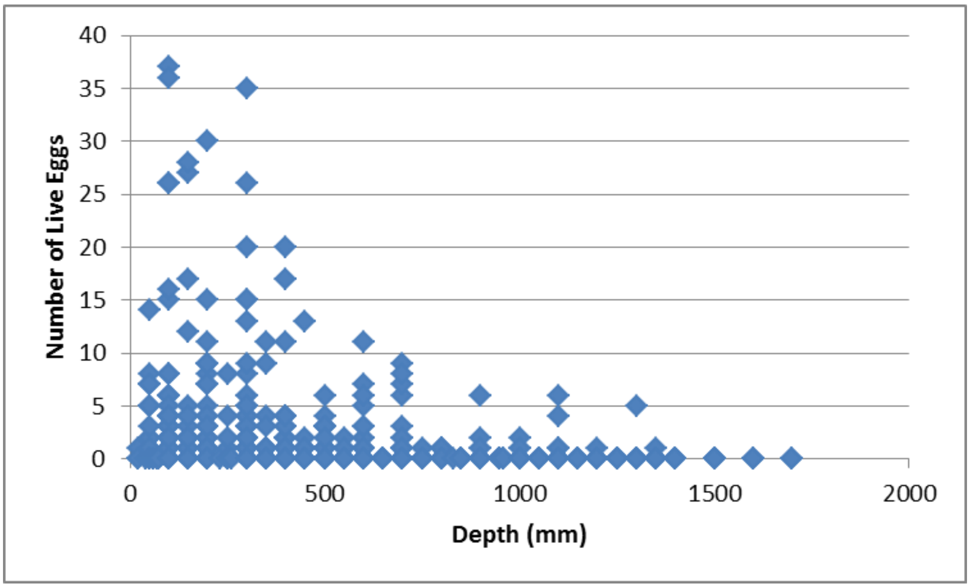


Figure 3.17 – Lungfish egg numbers observed by depth

A total of 398 push net shots were made through habitat where macrophyte density exceeded 50% and lungfish eggs were present. These samples yielded 99% of all eggs collected in the survey. In most of these samples, the quadrat formed by the push net shot contained a mixed plant community. Ribbonweed (*Vallisneria gigantea*) was present in 69% of samples where eggs were found and macrophyte density > 50%. Other macrophyte species including Water Primrose (*Ludwigia peploides*), Hydrilla (*Hydrilla verticillata*) and filamentous algae were also commonly associated with successful sample shots. Other macrophyte species associated with egg laying sites included Water Couch (Paspalum sp.), Curly pond weed (Potamogeton crispus), Red Watermilfoil (*Myriophyllum verrucosum*), Slender Knotweed (*Persicaria decipiens*), Foxtail (*Ceratophyllum demersum*) and Water Hyssop (*Bacopa monniera*). Only a small proportion of eggs were located amongst the rootlets of terrestrial grasses protruding into the water.

4 Discussion

This report described results from a monitoring program required to fulfil revised conditions of approval for the Paradise Dam under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999.* The approval included the following conditions;

6. Burnett Water Pty Ltd must undertake annual aquatic ecosystem monitoring at or about AMTD 119km, AMTD 201km and at least two sites between these points and provide to the minister five biennial summary reports. This 10-year monitoring program will include measurement of the condition of lungfish and lungfish habitat / macrophytes. Monitoring will commence when the dam becomes operational.
7. Burnett Water Pty Ltd must conduct a review of the impacts of Burnett river Dam on lungfish at the conclusion of the 10-year monitoring program in consultation with the Commonwealth Environment portfolio, to determine whether future monitoring is required
8. Burnett Water Pty Ltd must make lungfish information and data from research and monitoring activities freely available for inclusion in Sate and Commonwealth lungfish recovery programs or programs relating to water quality in the Burnett River
9. If aquatic ecosystem monitoring required under paragraph 6 or the review required under paragraph 7 indicates ongoing lungfish population decline at or about AMTD 119km that cannot be attributed to natural periodic fluctuations, then Burnett Water Pty Ltd will initiate appropriate recovery actions. The recovery actions cannot be inconsistent with an adopted Commonwealth Lungfish Recovery Plan.

The key design requirements for the monitoring program are presented in Table 4.1 below.

Table 4.1 – Requirements of monitoring program

Requirement	Outcome
Undertake a 10 year monitoring program (Condition 6)	Monitoring was undertaken twice annually from 2006-2016
Monitoring to occur between AMTD 119km and 201km and at least two sites between these points (Condition 6)	Monitoring occurred twice annually at seven locations between AMTD 64km and AMTD 242km. One additional location was dropped from the program due to difficulties with access. Lungfish spawning activity was assessed annually at 11 locations between AMTD 68km and AMTD 252km including a roving survey within Paradise Dam.
Monitoring to include measurement of lungfish condition, lungfish habitat and macrophytes (Condition 6)	Monitoring comprised sampling of adult lungfish (including tagging, measuring & weighing), assessment of habitat, water quality and sampling of lungfish eggs
Monitoring to commence when the dam becomes operational (Condition 6)	Paradise Dam was completed in November 2005. Monitoring commenced in February 2006

Table 4.1 demonstrates that the monitoring program clearly fulfilled the minimum design requirements of approval condition 6. .

The primary purposes of the monitoring program were to determine;

- whether there is evidence of ongoing declines in lungfish populations at or about AMTD 119km (downstream of Paradise Dam), which cannot be attributed to periodic natural fluctuations (and therefore is any further action required under Condition 9)
- whether Paradise Dam is likely to be impacting on local lungfish populations (as required by approval Condition 7)

To assess whether there is evidence of ongoing declines in lungfish populations at or about AMTD 119km, three key questions will be addressed in subsequent sections of the discussion. These are;

1. Did CPUE indices or population estimates from mark/recapture data provide evidence of ongoing population decline during the monitoring program?
2. Is there evidence of change in the structure of lungfish populations?
3. Is there any evidence of an ongoing decline in spawning activity (i.e. the number of lungfish eggs and/or mortality rate of eggs) during the monitoring program?

4.1 Estimates of lungfish abundance

4.1.1 Catch Per Unit Effort

The monitoring program used boat-mounted electrofishing to sample lungfish populations and Catch Per Unit Effort (CPUE) expressed in terms of fish / minute of electrofishing as the key index of lungfish abundance. Because lungfish were tagged before release, subsequent recapture records allowed for estimates of population size to be calculated at five of the sampling sites. These capture and analysis techniques are widely utilised in freshwater fisheries management to monitor population changes in fish stocks. However, there are several factors that can influence catchability in electrofishing surveys, which in turn may confound the relationship between CPUE and fish abundance. Likewise, population estimates generated from mark and recapture are underpinned by key assumptions, which should be considered when interpreting results of mark/recapture studies.

All the samples collected in the current monitoring program were collected from the same river reaches, using the same electrofishing equipment and a three-person crew. Sampling was only conducted in daylight hours and a sample was collected in summer and winter at each site each year with some variability in timing due to flow events. To this extent, the sampling error was controlled as far as possible. However, the results need to be considered in the context of other factors, which may have confounded the CPUE estimates. These factors are considered individually in the following sections.

Environmental variability.

During the first three years of the program, the entire Burnett Catchment was subject to ongoing drought. Throughout this period sampling locations within the dam resembled pre-dam conditions, with relatively shallow water and some inflow. Low water levels in the dam also meant that the downstream fishway remained inoperable until February 2009. During this period no lungfish could have moved from locations upstream of the dam to locations downstream of the dam.

As the study progressed, Paradise Dam filled and reached full capacity in March 2010. Progressive inundation of the two sampling locations within the dam (Mingo and Kalliwa) significantly altered the physical nature of the habitat at these sites. At Kalliwa Hut, the width of the river increased from approximately 200m in 2007 to over 500m in 2015. More significantly, during the same period depth increased from 15m to over 30m. The same trend was evident in the upper reaches of the dam at Mingo where depth increased from 5m to 25m as the dam progressively filled.

In December 2010 widespread rain in the Burnett Catchment culminated in a major flood event. The Burnett River at Bundaberg reached its highest flood peak since 1942. Two years later, in January 2013 the remnants of Tropical Cyclone Oswald caused widespread and severe flooding throughout the Burnett River Catchment. On 29 January 2013, the Burnett River at Bundaberg peaked at a record high level (9.53m). These two major floods were followed by minor flooding again in 2015.

Successive flood events in the period from 2010-2015 resulted in frequent overtopping events at Jones Weir, Claude Wharton Weir, Paradise Dam and Ned Churchward Weir. A separate study conducted during this period (DEEDI 2012a,b) documented large numbers of fish, including lungfish moving downstream over the spillway of Paradise Dam during the 2010 flow events. This observation is consistent with recapture data from the current program where nine lungfish tagged in the dam were recaptured downstream. Presumably, lungfish moved over the other barriers during flow events as well, resulting in some redistribution of lungfish populations in the river.

The filling of Paradise Dam and flow events that occurred during the program confounded CPUE estimates at some locations, most notably those situated within Paradise Dam. The flow events disrupted the sampling program, causing delays and preventing access to normal boat launching points on some occasions. Summer samples in 2010, 2011, 2013 and 2015 were all delayed beyond February, with the 2013 survey continuing into May. In 2010 and 2011, summer surveys downstream of Paradise Dam and Ned Churchward Weir were conducted in very difficult circumstances, with strong flow continuing in the river and flood debris creating navigation hazards for the boat. More significantly, the floods caused widespread and significant physical damage to the riparian zone and instream fish habitat at all the sampling locations.

In sampling sites located within Paradise Dam, (Mingo and Kalliwa Hut), CPUE declined rapidly as the dam filled. By 2010 when the dam reached full capacity, boat-mounted electrofishing was essentially ineffective as a sampling technique at those locations. Only 28 lungfish were captured in 12 surveys days at Kalliwa Hut after the dam reached full capacity. All of these fish were captured in shallow water along the perimeter of the dam. The sampling location upstream of Mingo Crossing filled more slowly and reasonable numbers of lungfish were collected in the upper reaches of that location until 2012. However, only 38 lungfish were collected in the last 8 surveys conducted at Mingo, including 15 in one day. Many of these fish were captured in upper reaches of the sampling site where depths were <5m. From these results we suggest that boat-mounted electrofishing is not an effective sampling technique for sampling lungfish in deep sections of Paradise Dam and the samples collected at Mingo and Kalliwa after the dam filled are not indicative of the size of the lungfish population in the dam. Boat-mounted electrofishing during daylight hours was the only sampling technique used to collect lungfish in this monitoring program. No samples were collected during the night, when more lungfish would possibly have been more actively feeding in shallow areas around the perimeter of the dam. We suggest that this technique be considered if any future monitoring of lungfish populations occurs in Paradise Dam. A compromise survey design may be to target sampling in the upper reaches of the dam rather than the deepest sections.

In a previous study by Brooks and Kind (2002), gill nets were used in combination with electrofishing. However, their results confirmed that nets yield far fewer lungfish than electrofishing and require significant sampling time to deploy and retrieve. The use of nets to collect lungfish also raises concerns regarding animal welfare as they often remove large numbers of scales exposing patches of skin to damage and infection. On the basis of results provided by Brooks and Kind (2002) and water quality data recorded in the current study, we recommend that deep water netting should not be considered as an alternative lungfish sampling technique in Paradise Dam. Low oxygen levels observed at depths >6m suggest that there would be unacceptable risks of lungfish mortalities once fish started to struggle in nets set at these depths. We are unable to recommend a humane sampling technique that would provide reliable ongoing estimates of lungfish population size within deeper sections of Paradise Dam.

At all other locations in the study, boat-mounted electrofishing provided a reliable method of safely and quickly collecting samples of adult lungfish. Independent analyses of the data demonstrated that environmental variability confounded CPUE estimates to some extent, particularly the flood events from 2010-2015. Analysis of standardised CPUE data confirmed this result at the Figtree sampling site where elevated summer flows reduced catchability of lungfish and had a statistically significant effect on CPUE estimates.

Fishing efficiency

As mentioned previously, the same electrofishing equipment and electrofishing team structure (one skipper, two net operators) was used throughout the survey. However two different boats were used and there was some turnover of personnel across the length of the survey period. The original outboard powered electrofishing boat was replaced early in the survey by a new boat fitted with an inboard jet motor. This vessel was more manoeuvrable than the original one and may have confounded CPUE to some extent. However, it is unlikely that this change would have compromised the CPUE in any measurable amount.

Only one operator (the boat skipper) participated in all of the twenty surveys. Across the 10 years of the program there was some turnover of net operators. It is sensible to predict that the skipper almost certainly became more skilled at locating and electrofishing lungfish during the 10 year program. However, the influence of netting experience is less clear and probably not possible to isolate.

Lungfish behaviour

Analyses of CPUE confirmed that a consistent seasonal effect was evident in CPUE at all the sampling locations. Catch rates were generally higher in winter than summer, particularly at sampling locations downstream of Paradise Dam and Ned Churchward Weir. A similar pattern was also evident at Gray’s Waterhole. We suggest that this pattern can be partly attributed to lungfish aggregating in these locations during the winter/spring pre-spawning period. Lungfish courtship and spawning behaviour was observed on numerous occasions during the winter surveys and running ripe fish were collected in some of the samples. Lungfish courtship and spawning behaviour occurs in relatively shallow sections of the river, making these fish more susceptible to electrofishing.

When the current monitoring program commenced in 2006, the fishway at Claude Wharton Weir was not operating. Baseline surveys for Paradise Dam (Kind et. al. 2005) noted that lungfish collected downstream of Claude Wharton Weir were in noticeably poorer condition than fish from the other sampling sites. In the current survey, analyses of standardised CPUE confirmed that CPUE declined significantly as the survey progressed. This decline was most notable after the fishway commenced operating. During the same period, mean condition of lungfish collected below the weir began to improve. This supports other internal technical reports, which recorded lungfish moving upstream through the fishway. Later in the survey, CPUE at Claude Wharton increased again and mean condition of the fish again decreased, after the fishway was rendered inoperable due to flood damage.

In addition to behavioural patterns described above, it is also likely that lungfish became more adept at avoiding the electrofishing boat as the survey progressed. Previous experience with radio-tagged lungfish in the Mary and Burnett Rivers (see Kind 2002) suggests that individuals move away from the boat as it approaches. This is consistent with anecdotal observations from the current monitoring program, where lungfish were often observed retreating into deep water as the boat was being launched and during pre-fishing tests of the motor and generator.

Trends in CPUE

Overall CPUE from the 10-year sampling period in the current study was 1.36 (fish/minute). A one-year pre-construction survey at similar locations (Kind et. al. 2005) reported higher overall CPUE of 1.99. The CPUE value reported by Kind et. al. (2005) represents results from a single year of sampling when the Burnett River Catchment was experiencing widespread drought. During this survey water levels were low and visibility was high at most of the sampling locations. Similar conditions continued into early years of the current study. CPUE in 2006/7 was 1.88, 2007/8 was 1.69 and 2008/9 was 1.58. Following this period, Paradise Dam started to experience significant inflows and mean CPUE declined as water depth increased in sites located within the dam.

In a survey conducted from 1997-2000 at a different sub-set of locations, Brooks and Kind (2002) reported much lower overall CPUE (0.70).The CPUE reported by Brooks and Kind (2002) was undertaken at sites extending from AMTD 37.5km to AMTD 321km and included three different sampling techniques. The current survey was undertaken between AMTD 64km and AMTD 242km. However, even corrected for technique and including only locations within the current survey area, data from Brooks and Kind (2002) yield an overall CPUE of 0.71. Three sampling locations used in the current survey were also included in the previous 4-year survey by Brooks and Kind (2002). A summary of CPUE in these locations is presented in Table 4.2 below.

Table 4.2 – Comparison of CPUE at three locations between current study and Brooks and Kind (2002)

Study period	Isis	Gray's Waterhole	Mundubbera
1997-2002	0.80	0.61	0.44
2006-2016	1.79	0.69	0.67

This comparison indicates that CPUE in the current study at Isis (downstream of Ned Churchward Weir) was more than double the CPUE reported by Brooks and Kind (2002) in the same area. Mean CPUE in the current study at Gray's Waterhole and Jones Weir at Mundubbera were also higher than those reported by Brooks and Kind (2002).

Independent analysis of standardised CPUE data confirmed that statistically significant declines in CPUE occurred in the Paradise Dam impoundment at Kalliwa Hut (Site 4), Mingo Gorge (Site 5) and downstream of the Claude Wharton Weir (Site 7). We conclude that declining CPUE Paradise Dam was largely an artefact of reduced catchability due to the inefficiency of electrofishing as a sampling method in deep water, a view shared by the independent reviewers. At Claude Wharton Weir, we suggest that declining lungfish numbers resulted at least partially from fish successfully ascended the fishway and migrating out of the sampling site. At all other sites standardised CPUE estimates fluctuated according to prevailing conditions and lungfish behavioural patterns without any long-term trends becoming evident. The highest mean CPUE estimates were observed at the three locations downstream of instream barriers (Claude Wharton, Figtree and Isis). These locations were all characterised by flowing, relatively shallow water where lungfish are susceptible to electrofishing. These areas also represented the best spawning habitats in the study areas. The result is also likely to be representative of a redistribution of lungfish populations in the river as fish move over the instream barriers during flood events and accumulate in pools downstream of the barriers.

4.1.2 Population estimates from mark and recapture

Mark and recapture methods were used in this study for a number of reasons. Recapture data were used to describe growth and movements of fish tagged during the study. More importantly they provided an alternative technique to detect changes in population size.

Population estimates derived from mark and recapture have a number of underlying assumptions including;

1. Mortality rate is the same for marked and unmarked fish
2. Marked and unmarked fish are equally vulnerable to recapture
3. Tags are retained throughout the study and can be recognised on recapture
4. Marked fish mix equally with unmarked fish
5. There is negligible immigration or emigration during the study period

In the current study, trends in population were only assessed over time within each sampling location and there was no attempt to estimate the total number of lungfish in the whole study area. Reliable population estimates based on mark-recapture events were generated in five locations where sufficient recaptures were collected. These were Isis (downstream of Ned Churchward Weir) and Figtree (downstream of Paradise Dam), Gray’s Waterhole (upstream of Paradise Dam), below Claude Wharton Weir and in Jones Weir at Mundubberra. In Kalliwa and Mingo Gorge, the recapture rate was considered to be too low and/or too variable to adequately model population estimates.

There is little evidence from this study or previous lungfish monitoring programs to indicate that mortality rate would vary between marked and unmarked lungfish. For example, Kind (2002), Kind et. al. (2005) and DEEDI (2012 a,b) all reported results from long-term lungfish radio-telemetry studies. In all of these studies, mortality rate was negligible and fish continued to behave normally over long periods (telemetry records up to 996 days). In the current study, recaptures were collected from fish tagged as far back as 1997 and multiple recaptures of the same individual were common. This evidence provides a strong case that the assumption of equal mortality was met. Kind et. al. (2005) reported high levels of PIT tag retention from lungfish “double tagged” with external and internal tags. The same trend is evident in the current study, where there were no recorded instances of a PIT tag not being present on a recaptured fish bearing an external tag. The inference here is that internal PIT tags were reliably retained throughout the study and that the assumption of tag retention was also met. Likewise, there was little evidence that marked fish did not mix equally with unmarked fish. Marked and unmarked fish were consistently captured in the same locations throughout the study, often at the same time. The relevant consideration here is whether previously tagged lungfish were more able to avoid electrofishing (as previously discussed). The physical characteristics of some sampling sites were more conducive to escape than others. For instance, Gray’s Waterhole is a steep sided, deep pool where fish could easily retreat to deep water to avoid electrofishing. In contrast

Figtree is a long, shallow pool where fish are susceptible to electrofishing throughout the site. However, large numbers of multiple recaptures suggest previously tagged fish were equally catchable as untagged fish.

The assumption of negligible emigration or immigration is difficult to achieve in a long-term monitoring program within an open river system and unlikely to have been met in this study. This was the main driver for commissioning independent analyses of the mark/recapture data using more sophisticated modelling techniques. However, in the current study, approximately 97% of all recaptures occurred in the same location as the original tagging event. This observation is consistent with Brooks and Kind (2002) who reported movements <1km in 56% of recaptured lungfish and a modal movement of zero. One individual was recaptured five times in the same location. Telemetry studies (Kind 2002, Brooks and Kind 2002, DEEDI 2012 a,b) have demonstrated that some lungfish can be highly mobile within impounded waters. However, these studies also reported highly restricted movements in flowing river reaches.

Mark and recapture events in the current study demonstrated that some fish traversed Paradise Dam during flow events. This issue was also highlighted by DEEDI (2012 a,b) who noted lungfish and other species moving over the dam wall during flood events. This immigration may have confounded mark recapture outcomes at Figtree. Likewise, fish movements over the walls of Claude Wharton Weir and Ned Churchward Weir probably confounded the results at these locations to some extent. However, operation of the fishways at these locations, (which operated intermittently during the study period) also led to some lungfish emigrating upstream. Kind et. al. (2005) noted that lungfish collected at the base of Claude Wharton Weir were in poorer condition (had lower condition factor) that at other locations. This trend continued in the current study until a fishlock was installed at Claude Wharton Weir in April 2008. A subsequent monitoring program conducted between March 2008 and February 2010 (DAF 2013) recorded large numbers of fish including 144 lungfish successfully moving upstream through the lock. The same study also recorded 13 tagged lungfish, which moved upstream through the fishway before moving back over the weir crest in a subsequent flow. During this period in the current monitoring program condition factor estimates from lungfish captured downstream of Claude Wharton Weir improved while the fishway was operable, but began to fall again when the fishway was damaged by flooding in 2012. These observations are consistent with lungfish emigrating upstream from the site via the fishway and being replaced by other fish moving over the weir crest during flow events.

Independent analyses of mark/recapture data provided further evidence of a decline in the size of the lungfish population downstream of Claude Wharton Weir. As previously discussed, this is likely to have been at least partially a result of lungfish successfully emigrating upstream via the fishway, which became operable part way through the current study. Likewise, these analyses identified a decline in lungfish numbers at Gray's Waterhole, which recovered somewhat in the latter years of the study. This result mirrored CPUE analyses at Gray's Waterhole where, despite no overall significant decline in CPUE, yearly CPUE estimates decreased from 2006 to 2012 and then levelled off. This result is more difficult to interpret and is likely to have been influenced by changes in flow, spawning behaviours and the deep, steep-sided nature of the waterhole.

At Site 1 (Isis) and Site 2 (Figtree), the mark/recapture analyses predicted that lungfish populations were stable or increasing. These sites were in reaches downstream of Ned Churchward Weir and Paradise Dam respectively. Catchability at Site 1(Isis) was much lower than Site 2 (Figtree), which resulted in a higher overall population estimate at Isis. This result may have been related to the extent of temporary migration in and out of the respective sampling areas. However, the movement data do not provide compelling evidence to explore this possibility. Inferred population growth at both locations was probably more related to immigration during flow events than to actual recruitment.

4.2 Lungfish population structure and spawning success

The size range of lungfish sampled during the current study (170-1390mm) was comparable with previous monitoring programs in the Burnett River, including Brooks and Kind (2002) and Kind et. al. (2005). Likewise, the samples were dominated by mature individuals, with only 5.6% of the sample <600mm. Whether or not this outcome is a sampling artefact or a true representation of the lungfish population structure is debatable. Kind and Brooks (2003) used the same sampling methods to collect more than 28 000 native fish (36 species) from the Burnett River. Samples in this study were dominated by small-bodied fish, which were easily detected and collected using boat-mounted electrofishing. These samples also included small freshwater catfish, which are similar in appearance to juvenile lungfish. Brooks (1995) was also able to collect lungfish <600mm using electrofishing techniques. These observations suggest that low numbers of small lungfish are unlikely to result from sampling bias. The more likely scenario is that successful lungfish spawning and recruitment events occur periodically at intervals, as proposed by Kemp (1984). Length-frequency histograms from the current study highlighted that a large proportion of individuals in the size range of 500-700mm were collected during the first four years of the study (2006-2010). The age curve presented by Brooks and Kind (2002) predicts that these fish would be approximately 7-12 years old, indicating that the last successful breeding and recruitment events probably occurred at the time of or prior to the construction of Paradise Dam.

The number of lungfish eggs and location of spawning events fluctuated widely during the study period. Some spawning was recorded in seven of the ten years during the study. However, no eggs were located in 2010, 2011 or 2015. A large proportion of eggs collected during the survey came from locations downstream of barriers, most notably Ned Churchward Weir. Eggs were generally located during late winter and spring, in shallow water amongst dense stands of submerged and emergent aquatic plants. These observations are consistent with the large body of published scientific evidence describing habitat preferences for lungfish spawning.

Lungfish eggs were only located within the impounded waters of Paradise Dam on one occasion despite considerable sampling effort. These were recorded at Mingo Crossing during Winter/Spring of 2012, where some suitable macrophytes had become established in a localised area. Some eggs were collected in the upper reaches prior to the dam reaching full capacity and four running ripe fish were located in the dam on another occasion. Small patches of potential spawning habitat were also observed periodically during the survey. However, the overall conclusion here is consistent with other studies (e.g. Brooks and Kind 2002) that impounded waters are largely unsuitable habitat for lungfish breeding.

Spawning events observed during this study are not directly indicative of successful recruitment. Indeed, observations made during the study confirmed that many of the eggs batches were either inundated or exposed before they were fully developed. Recruitment from these spawning events may only become apparent 7-12 years after the eggs were laid, extending beyond the current survey period. Apart from some apparent recruitment early in the study, there was little evidence to suggest that the structure of local lungfish populations changed during the current survey period. This is despite the extreme environmental fluctuations observed in the study period.

Analyses of sex ratio was included in the original survey design for this monitoring program, to provide another indicator of potential changes that may have occurred in local lungfish populations over time. Following the Animal Ethics Committee ruling in 2010 to prohibit internal gonad examination, this measure was essentially rendered ineffective. While records continued to be made when fish in running ripe condition were collected, this occurred too infrequently to provide a reliable ongoing estimate of sex ratio.

5 Conclusions

This results of this study confirmed that adult lungfish remain common and widespread throughout the survey area, 10 years after the Paradise Dam became operational in 2006. There was no evidence of ongoing decline or change in the structure of local lungfish populations downstream of Paradise Dam or in the control sites. Overall Catch Per Unit Effort in the current study was comparable or higher than CPUE estimates reported by previous lungfish monitoring programs using the same techniques in similar locations within the Burnett River.

Lungfish became progressively more difficult to catch in Paradise Dam as the dam filled and reached full capacity. Boat electrofishing was rendered largely ineffective as a sampling technique once the dam filled, creating an impoundment up to 30m deep. This observation was confirmed by rapid declines in CPUE estimates at sampling sites within the impoundment. The inefficiency of electrofishing in deep water meant that it was not possible to estimate the size of the lungfish population within Paradise Dam using mark and recapture data. Given the significant animal welfare risks associated with netting lungfish in deep water, it is difficult to recommend a more suitable technique for sampling lungfish in the dam. If any future lungfish monitoring occurs, the best compromise may be to sample upper reaches of the dam and conduct surveys during the night when lungfish are more active.

Mark/recapture data collected in the current study confirmed that some lungfish successfully emigrated from Paradise Dam and moved into river reaches further downstream. These individuals either used the downstream fishway or moved over the crest of the dam of the dam during spillway flow events. Visual observations confirmed that some lungfish did move over the wall during spillway flow events. A previous assessment of the downstream fishway at Paradise Dam (DEEDI 2012a), reported that some lungfish suffered injuries or were killed attempting such movements. While the results presented here confirm that some individuals also survive, neither study was designed to estimate what the net impact of these movements would be on the overall size of local lungfish populations. Regardless, it is likely that such movements have resulted in a net downstream re-distribution of local lungfish populations.

In the two sampling sites downstream of Paradise Dam (Site 1, Isis and Site 2, Figtree) mark/recapture models inferred that lungfish populations were stable or even increasing. Analyses of raw CPUE data at Site 2, Figtree suggested that CPUE declined during summer surveys over time, but that no similar pattern was evident in the winter surveys. When the CPUE data were standardised against environmental covariates, summer flow events reduced catchability and confounded the CPUE relationship at this site. This result is consistent with observations provided by the field team who commented on difficulties accessing and surveying this site when significant flow events were occurring. The prediction that lungfish populations were stable or increasing downstream of Paradise Dam is also consistent with the earlier inference that flow events are resulting in a progressive downstream re-distribution of local lungfish populations.

There were varied outcomes in sampling sites located upstream of Paradise Dam. At Site 7, Claude Wharton Weir, CPUE and mark/recapture models both indicated that lungfish numbers decreased during the survey period. This sampling location was situated immediately downstream of Claude Wharton Weir, which had a fishway retrofitted during the current survey. A separate assessment of the fishway (DAFF, 2013) highlighted lungfish successfully ascending this fishway. These emigration events probably contributed strongly to the decrease in lungfish number in the sampling site. Mark / recapture records also highlighted some instances of lungfish emigrating from this site in a downstream direction and some immigration into the site. A Site 6, Grays Waterhole, there was no consistent trend in CPUE. However, mark / recapture data suggested that the population was declining over time. There are no obvious explanations for this outcome.

There was limited evidence of recruitment into the adult lungfish populations after the first four years of the study. Evidence of fish recruiting into the adult population during the early years of this study indicated that the last successful spawning events in the Burnett River probably occurred just prior to or during construction of the Paradise Dam. This observation is consistent with authors such as Kemp (1984) and Kind (2011) who have suggested that long periods between successful recruitment events may be normal for lungfish. However, this outcome does little to resolve longstanding concern over the paucity of juvenile lungfish found during similar monitoring programs and collection efforts spanning back to the 1800s.

Lungfish eggs were located in the study area during seven of the 10 survey years. The location and number of eggs varied from year to year. However, the majority of eggs were located downstream of Ned Churchward Weir and Paradise Dam in shallow water amongst dense aquatic plant beds in late Winter and Spring. This result is consistent with a large body of published work describing lungfish spawning habitat preferences. Some lungfish eggs were collected from the upper reaches of Paradise Dam while the dam was still filling, and once after Paradise Dam reached full capacity. No further eggs were located despite considerable search effort. Four lungfish in breeding condition were sampled in the dam on one occasion. These observations support previous studies, which have concluded that suitable lungfish breeding habitat rarely arises in impounded waters.

Observations and mark and recapture records confirmed that some lungfish moved downstream past the wall of Paradise Dam during the monitoring program. These fish may have successfully negotiated the downstream fishway at the dam, which operated for a total of (approximately) two years during the 10-year monitoring program. A more likely explanation is that these fish moved over the spillway of the dam sometime during a series of overtopping events, which occurred in the second half of the monitoring program. Subsequent recaptures of lungfish downstream of the dam wall, confirmed that some individuals at least are able to survive this movement. Presumably lungfish also descended over other barriers during the study, resulting in some mortality and re-distribution of local lungfish populations.

Condition 7 of the variation of approval for Paradise Dam required a review to be conducted of the impacts of the dam on local lungfish populations. Based on the outcomes of the current monitoring program, these impacts may be summarised as follows

1. There was little change in the size or structure of lungfish populations during the 10 year period following construction of Paradise Dam. Lungfish remained a widespread and common species in all the sampling sites throughout the program.
2. The condition of lungfish observed during the monitoring program fluctuated within limits observed in previous lungfish monitoring programs in the Burnett River.
3. The impounded waters of Paradise Dam appear unlikely to represent suitable habitat for successful lungfish spawning and recruitment. This conclusion is consistent with a previous study in the impoundment formed by Ned Churchward Weir (Brooks and Kind 2002).

4. Fishway monitoring programs described in DEEDI (2012 a,b) documented mortalities and injuries suffered by lungfish moving over the spillway of the dam during periods of overtopping. Some lungfish in the current study made movements from within the dam to river reaches downstream of the dam wall. It is unclear whether these fish moved over the spillway or utilised the downstream fishway at Paradise Dam. Regardless, the recaptures provide evidence that some individuals can make such movements without suffering long-term injury or death.

5. However, downstream movements during such flow events may be leading to a gradual accumulation of lungfish in river reaches downstream of the dam wall. If this is the case, the condition of any fish unable to move back upstream is likely to deteriorate over time. As discussed previously, lungfish downstream of Claude Wharton Weir exhibited poor condition prior to installation of the fishlock on that barrier. Likewise, lungfish stranded downstream of North Pine Dam on the North Pine River (where there is no fishway device) also exhibit poor condition relative to individuals collected within the dam (DAF unpublished data 2007). Given these observations, it is important that the fishway at Paradise Dam continues to operate so that displaced fish can make return upstream movements.

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7 Water quality measurements

7.1 Summary of water quality data for 2006 to 2008.

(NR=not recorded due to equipment malfunction) (Tw= water temperature)

Site 1 - Isis

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	16.7	23.7	17.6	24.9	9.84	0.45	2.4	NR	7.74	6.95	8.23	7.4	740	542	495	134.2
2	16.4	22.8	17.0	23.4	11.06	0.35	2.2	NR	7.85	6.76	7.74	7.3	700	551	490	163.7
3	16.3	22.6	16.5	23.1	13.96	0.31	2.4	NR	7.85	6.7	7.51	7.12	674	545	495	165.5
4				22.9				NR				7.04				166.6
Visibility	Winter 06 2600mm				Summer 07 300 mm				Winter 07 1500mm				Summer 08 600mm			

Site 2 - Figtree

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1		26				5.65				8.1				477		
2		25.5				2.55				7.85				488		
3																
Visibility	Winter 06 1000mm				Summer 07 900mm				Winter 07				Summer 08			

Site 3 – Paradise Dam

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	19.8	23.2			10.19	7.63			8.13	8.35			464	543		
2	19.5				10.34				8.07				459			
Visibility	Winter 06 1000mm				Summer 07 1200mm											

Site 4 - Kalliwa

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	17.3	26.1	23	22.7	11.63	10.1	8.9		7.54	8.36	7.88	7.69	455	509	485	264
2	17.1	25.1	22.8	22.4	11.72	7.8	9.1		7.21	8.64	7.92	7.47	461	510	490	272
3	17	24.8	22	22.3	11.55	4.65	9.35		7.23	8.26	7.89	7.32	463	508	490	274
4	15.8	24.2	21.7	22.3	2.94	0.32	9.25		6.89	7.25	7.97	7.21	466	486	490	271
5	15.6	23.1		22.2	1.22	0.25			6.42	7.22		7.09	467	521		274
6	15.4	22.2		22.1	1.01	0.25			6.19	6.94		6.92	471	547		306
7	15.3	20.6		22.2	2.77	0.25			4.93	5.86		6.89	473	572		305
8	15.3	19.1			3.78	0.31			4.84	6.41			473	596		
9	15.3				4.4				4.61				473			
Visibility	Winter 06 1000mm				Summer 07 900mm				Winter 07 5000mm				Summer 08 1000mm			

Site 5 - Mingo Gorge

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1		25.2	22.3	24.6		6.65	9.55			8.2	8.28	7.39		581	611	301
2		24.6	22	23.2		5.04	9.9			7.88	8.23	7.22		579	603	296
3		21.4	20.2	22.6		3.07	9.6			7.31	8.04	7.16		562	604	296
4		22.5	18.2	22.1		0.21	7.4			7.06	7.75	7.08		414	606	301
5		21.3		21.9		0.15				6.8		7.03		329		304
6		20.8		21.8		0.15				6.65		7		279		304
7		20.2		21.7		0.15				6.6		6.94		240		305
8		20.2				0.12				6.57				237		
Visibility	Winter 06				Summer 07 400mm				Winter 07 1400mm				Summer 08 150mm			

Site 6 - Gray's Waterhole

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	17.5	25.8	16.5	23.9	12.36		11.05		7.73	8.05	8.34	7.27	597	706	785	
2	17	25.8	15.9	23.9	10.74		8.9		6.92	7.39	8.1	7.26	592	681	784	
3	16.1	25.7	15.2	24	8.08		6.85		6.96	7.31	7.93	7.24	597	673	787	
4	15.7	25.7	15	24	5.56		5.8		6.61	7.22	7.8	7.22	601	689	785	
5	15.5	25	14.8	23.9	4.8		4.5		6.32	6.89	7.8	7.2	603	693	785	
6	15.3	25	14.6		4.16		2.85		5.93	6.94	7.47		603	696	781	
7	15.1		14.2		3.43		1.4		5.21		7.42		605		777	
8	15		14.1		2.76		1.35		5.02		7.4		608		780	
Visibility	Winter 06 1500mm				Summer 07 800mm				Winter 07 400mm				Summer 08 200mm			

Site 7 – Claude Wharton Weir.

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	19.4		17.4		13.4		9.9		7.8		8.16		743		864	
2	17.2				11.45				7.57				740			
3	15.9								6.83				747			
Visibility	Winter 06 1000mm				Summer 07				Winter 07				Summer 08			

Site 8 - Mundubbera

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1		24.1	16.2	22.4		0.99	7.5	1.7		4.87	7.28	6.75		224	456	202
2		23.5	15.5	21.9		0.45	5.6	1.8		5.14	7.21	6.75		223	452	195.2
3		23.4		21.8		0.32		1.85		5.05		6.71		223		198.8
4				21.7				1.95				6.73				200.1
Visibility	Winter 06				Summer 07 300mm				Winter 07 300mm				Summer 08 100mm			

7.2 Summary of water quality data for 2008-2010.

(NR=not recorded due to equipment malfunction) (Tw= water temperature)

Site 1 - Isis

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	08/09		09/10		08/09		09/10		08/09		09/10		08/09		09/10	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	17.5	31.3	20.4	24	7.82	6.3	4.69	5.91	8.7	7.96	9.24	6.9	431	521	660	224
2	17	30.8	19.7	23.9	7.68	5.11	4.1	5.87	8.5	7.81	9.02	7.01	428	520	660	224
3	16.9	29.4	18.9	23.9	7.6	4.24	4.41	5.87	8.38	7.64	9.36	7.02	428	516	673	225
4	16.4			23.9	7.6			5.8	8.26			7.03	430			225
Visibility	Winter 08 700mm				Summer 09 700mm				Winter 09 1500mm				Summer 10 200mm			

Site 2 - Figtree

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	08/09		09/10		08/09		09/10		08/09		09/10		08/09		09/10	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	16.4	28	15.3	24.2	7.77	2.75	4.8	6.26	8.5	7.47	7.82	7.32	529	425	470	194.9
2	16.3	28	15.3	24.1	7.65	2.41	3.77	6.26	8.35	7.34	7.7	7.27	530	445	472	196
3				24.1				6.24				7.16				198
Visibility	Winter 08 800mm				Summer 09 1300mm				Winter 09 1700mm				Summer 10 150mm			

Site 4 - Kalliwa

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	08/09		09/10		08/09		09/10		08/09		09/10		08/09		09/10	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	17.8	29.9	19.7	29	4.3	6.02	4.7	7.7	7.96	8.4	8	8.4	352	378	428	444
2	17.7	28.9	19	28.6	4.23	4.7	4.57	7.55	7.89	8.25	7.82	8.4	354	375	425	450
3	17.5	28.5	18.6	28	3.91	4.38	4.11	7.4	7.82	7.89	7.71	8.36	351	375	431	454
4	17.6	28.2	18.2	26.9	3.73	4.04	3.1	7.03	7.75	7.63	7.61	8.2	351	377	431	450
5	17.5	28	18.1	26.2	3.65	3.18	3.17	6.03	7.71	7.51	7.45	7.8	351	375	432	453
6	17.5	27.8	18	26.2	3.55	2.79	2.69	5.8	7.68	7.41	7.33	7.84	349	366	435	458
7	17.5	27.7	17.7	25.1	3.41	1.65	1.28	2.5	7.66	7.23	7.14	7.23	351	365	433	461
8	17.4	27.2	17.6	24.6	3.35	1.18	1	0.6	7.7	7.2	7.07	7.08	352	370	433	459
9		27		22.4		0.9		0		7.16		6.9		372		511
Visibility	Winter 08 1300mm				Summer 09 1100mm				Winter 09 1300mm				Summer 10 1000mm			

Site 5 - Mingo Gorge

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	08/09		09/10		08/09		09/10		08/09		09/10		08/09		09/10	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	17.8	29.5	18.3	30.4	7.21	6.17	6.8	7.21	7.62	8.1	7.48	8.6	361	384	440	521
2	17.1	29.3	17.7	29.5	5.76	4.84	4	7.01	7.55	7.97	7.47	8.54	364	384	445	501
3	16.6	29.2	17.6	28.7	4.58	4.95	4.15	6.1	7.49	7.86	7.39	8.3	366	384	457	501
4	16.2	28.5	17.5	28.5	4.3	3.92	3.98	5.64	7.39	7.72	7.36	8.13	370	370	450	506
5	16	28.3	17.5	28.2	4.26	2.56	3.9	4.27	7.32	7.51	7.31	7.79	368	359	445	534
6	15.9	28.1	17.5	28.1	4.42	1.88	3.95	3.19	7.2	7.43	7.27	6.87	375	346	445	563
7	15.9	28	17.5	27.8	5.53	1.41	3.79	3.51	7.24	7.32	7.25	6.72	378	330	445	582
8	15.9	27.9	17.4	27.1	4.95	1.27	3.68	0.6	7.23	7.24	7.21	6.65	378	331	446	595
9		27.7	17.4	22.6		1.06	3.57	0.25		7.15	7.18	6.5		329	443	519
Visibility	Winter 08 1000mm				Summer 09 600mm				Winter 09 1400mm				Summer 10 1100mm			

Site 6 - Gray's Waterhole

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	08/09		09/10		08/09		09/10		08/09		09/10		08/09		09/10	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	17.5	31.7	17	28	8.3	4.47	5.77	6.77	7.02	8.73	7.8	7.57	506	467	495	510
2	15.6	31.2	16.8	27.8	8	3.84	4.28	6.36	7	7.85	7.76	7.76	480	472	496	514
3	15.3	30	16.5	27.6	7.48	3.48	4.18	6.19	6.95	7.69	7.68	7.74	483	476	494	518
4	15.2	28.8	16.2	27.4	7.37	2.82	3.9	5.84	6.85	7.6	7.53	7.69	494	475	499	518
5	15.1	28.2	16.1	27.2	7.28	2.2	3.53	5.26	6.7	7.46	7.52	7.62	497	470	498	520
6	15.1	28	16	26.9	7.26	1.66	3.48	4.8	6.6	7.6	7.5	7.55	497	470	498	519
7	15	27.9	15.9	26.6	7.24	1.35	3.28	4.37	6.5	7.28	7.44	7.48	500	470	504	523
8	15	27.9	15.9	26.4	7.24	1.1	3.06	3.5	6.45		7.41	7.42	502	473	504	529
9			15.9	26.3			2.96	3.4			7.38	7.35			503	529
Visibility	Winter 08 200mm				Summer 09 150mm				Winter 09 900mm				Summer 10 1000mm			

Site 7 – Claude Wharton Weir.

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	19.4		17.4		13.4		9.9		7.8		8.16		743		864	
2	17.2				11.45				7.57				740			
3	15.9								6.83				747			
Visibility	Winter 06 1000mm				Summer 07				Winter 07				Summer 08			

Site 8 - Mundubbera

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	06/07		07/08		06/07		07/08		06/07		07/08		06/07		07/08	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1		24.1	16.2	22.4		0.99	7.5	1.7		4.87	7.28	6.75		224	456	202
2		23.5	15.5	21.9		0.45	5.6	1.8		5.14	7.21	6.75		223	452	195.2
3		23.4		21.8		0.32		1.85		5.05		6.71		223		198.8
4				21.7				1.95				6.73				200.1
Visibility	Winter 06				Summer 07 300mm				Winter 07 300mm				Summer 08 100mm			

7.3 Summary of water quality data for 2010-2012.

(NR=not recorded due to equipment malfunction) (Tw= water temperature)

Site 1 - Isis

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	10/11		11/12		10/11		11/12		10/11		11/12		10/11		11/12	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	18	28.1	18.3	28.3	8.3	6.94	7.61		8.42	8.03	8.42	7.59	327	435	705	683
2	17.2	28.2	17.6	28.1	8.2	6.22	7.55		8.23	7.96	8.37	7.62	327	434	714	685
3	16.8	28.2	17.2	28	8.1	5.67	7.45		8.1	7.93	8.33	7.63	329	435	715	687
4	16.6		17		8		7.37		8.01		8.3		340		715	
Visibility	Winter 10 600mm				Summer 11 400mm				Winter 11 1900mm				Summer 12 900mm			

Site 2 - Figtree

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	10/11		11/12		10/11		11/12		10/11		11/12		10/11		11/12	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	19	28.7	17.6	26.6	8.5	8.43	8.52		6.19	8.43	8.5	7.84	283	458	672	748
2	18.3	28.4	17.3	26.4	8.4	8.4	8.51		6.06	840	8.54	7.89	282	459	674	748
3		28.3	16.8	26.4		5.43	8.52			8.35	8.5	7.94		460	681	740
Visibility	Winter 10 600mm				Summer 11 400mm				Winter 11 1900mm				Summer 12 900mm			

Site 4 - Kalliwa

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	10/11		11/12		10/11		11/12		10/11		11/12		10/11		11/12	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	18.3	29.9	16.4	26.8	7.8	9.96	9.72		8.05	8.66	8.6	6.84	278	469	650	720
2	16.9	29.9	16.4	26.6	6.2	9.05	9.34		7.97	8.58	8.64	7.15	270	466	650	724
3	16.2	27.5	16	26.6	4.8	6.62	8.6		7.81	7.99	8.56	7.3	278	481	647	727
4	15.8	27.3	15.8	26.6	3.6	4.61	8.23		8.33	7.73	8.48	7.53	278	505	648	730
5	15.6	27.1	15.5	26.6	2.9	3.56	7.81		8.26	7.6	8.36	7.59	276	500	646	730
6	15.5	26.9	15	26.6	2.5	2.92	6.66		8.57	7.5	8.24	7.68	277	499	645	732
7	15.5	26.9	14.8	26.5	2.3	2.33	5.73		8.74	7.43	8.16	7.72	277	502	647	734
8	15.5	26.8	14.8	26.5	2.2	1.96	4.73		7.55	7.41	8.07	7.75	277	491	645	735
9	15.5	26.7	14.7	26.4	2.2	1.63	4.33		7.41	7.28	8.08	7.21	277	480	652	742
Visibility	Winter 10 650mm				Summer 11				Winter 11 1600mm				Summer 12 1000mm			

Site 5 - Mingo Gorge

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	10/11		11/12		10/11		11/12		10/11		11/12		10/11		11/12	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	16.7	30.3	16.5	27.6	6.5	7.74	7.1		7.7	8.72	8.27	7.67	316	749	647	615
2	16.5	30.3	16.4	26.8	6.4	7.15	6.96		7.7	8.62	8.25	7.53	318	776	647	617
3	16.1	29.9	16.2	26.6	5.7	6.32	6.84		8	8.37	8.23	7.53	318	812	647	619
4	16	28.8	16	26.5	5.2	5.3	6.85		7.87	8.14	8.2	7.53	318	871	645	619
5	15.7	28.3	15.8	26.5	4.2	4.59	6.82		7.42	8.04	8.17	7.54	318	877	642	618
6	15.5	28.2	15.7	26.5	3.5	4.11	6.9		7.57	7.99	8.16	7.56	314	876	644	618
7	15.5	28.2	15.7	26.5	3.1	3.91	6.9		7.59	7.96	8.14	7.56	314	875	644	618
8	15.4	28.1	15.6	26.4	2.8	3.54	6.69		7.73	7.92	8.12	7.57	317	866	643	618
9	15.4	28.2	15.5	26.4	2.7	3.92	6.26		7.6	7.95	8.09	7.58	319	877	643	618
Visibility	Winter 10 1100mm				Summer 11 750mm				Winter 11 3000mm				Summer 12 400mm			

Site 6 - Gray's Waterhole

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	10/11		11/12		10/11		11/12		10/11		11/12		10/11		11/12	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	16.4	26.3	16.8	24.1	7	7.3	7.8		7.28	8.37	8.53	7.94	714	931	1345	625
2	16.5	26.1	17	23.9	6.4	7	7.8		7.23	8.35	8.45	7.91	695	934	1348	663
3	16.2	26	16.4	23.8	5.6	6.5	7.66		7.17	8.3	8.46	7.91	684	937	1342	663
4	15.9	26	16.4	23.7	5.2	6.36	7.82		7.19	8.27	8.44	7.89	679	938	1347	663
5	15.4	26	16	23.7	4.7	6.4	7.8		7.15	8.26	8.43	7.89	671	940	1342	663
6	15.2	26	15.9	23.4	4.3	6.33	7.62		7.07	8.29	8.41	7.87	673	940	1342	663
7	15	26	15.8	23.4	4	6.35	7.29		7.08	8.29	8.38	7.87	673	940	1326	663
8	14.9	26	15.6	23.5	3.8	6.35	6.94		7.03	8.26	8.35	7.85	679	941	1316	662
9	14.8	26	15.4	23.5	3.6	6.11	6.35		7.02	8.28	8.36	7.83	681	936	1305	663
Visibility	Winter 10 1000mm				Summer 11 500mm				Winter 11 1400mm				Summer 12 350mm			

Site 7 – Claude Wharton Weir.

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	10/11		11/12		10/11		11/12		10/11		11/12		10/11		11/12	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	17	26.1	15.8	24.4	7.8	7.2	8.29		7.34	7.9	8.47	7.94	691	780	1511	750
2	16.7	25.8	15.7	24.3	8.1	6.8	8.1		80.1	7.9	8.47	7.91	690	780	1511	756
3	16.6	25.7	15.6	24.3	7.9	6.4	8.2		6.97	7.9	8.48	7.91	693	784	1500	756
4		25.6	15.2			6.3	7.91			7.9	8.44			786	1511	
5			15.2				7.7				8.44				1527	
Visibility	Winter 10 800mm				Summer 11 300mm				Winter 11 1100mm				Summer 12 300mm			

Site 8 - Mundubbera

Depth	Tw (^0C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	10/11		11/12		10/11		11/12		10/11		11/12		10/11		11/12	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	15.1	26.4	16.8	26.6	6.6	10.32	10.25		6.55	8.37	8.32	7.76	664	736	1216	525
2	15.1	25.2	16.1	25.6	6.4	7.19	10		6.93	8.03	8.29	7.66	665	720	1213	530
3	15.1	24.7	14.2	25	6.3	6.9	8.51		7.01	7.84	8.15	7.58	665	713	1265	527
4	14.3	24.6	13.8	24.9	4.8	5.45	7.5		7.01	7.77	8.01	7.53	646	708	1365	527
5	14.3	24.5	13.8	24.6	4.6	5.14	4.8		6.98	7.72	7.85	7.07	643	712	1517	529

Visibility Winter 10 1000mm Summer 11 300mm Winter 11 900mm Summer 12 250mm

7.4 Summary of water quality data for 2012-2014.

(NR=not recorded due to equipment malfunction) (Tw= water temperature)

Site 1 - Isis

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	12/13		13/14		12/13		13/14		12/13		13/14		12/13		13/14	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	16.4	22.4	21.5	26.7	NR	10	8.95	8.83	7.77	7.84	7.19	8.32	621	602	921	1482
2	16	22.5	21.5	26.7	NR	9.59	11.5	8.77	7.73	7.74	7.19	8.31	617	600	922	1482
3	15.7	22.5	21.5	26.6	NR	8.52	11.1	7.55	7.72	7.73	7.19	8.26	616	601	921	1456
4		22.5	21.5			8.78	10.96			7.73	7.19			602	922	
5			21.4				9.4				7.19				921	
Visibility	Winter 12 1000 mm				Summer 13 900 mm				Winter 13 700 mm				Summer 14 800 mm			

Site 2 - Figtree

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	12/13		13/14		12/13		13/14		12/13		13/14		12/13		13/14	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	17.8	23.8	22.4	25.9	NR	8.26	8	8.23	7.97	7.26	7.2	7.96	650	578	1044	1521
2	17	23.7	22.4	25.8	NR	8.12	8.8	7.2	8.05	7.25	7.2	7.98	656	590	1044	1521
3		23.6		25.7		8.05		7.29		7.25		7.93		591		1521
Visibility	Winter 12 1900 mm				Summer 13 800 mm				Winter 13 1100 mm				Summer 14 1500 mm			

Site 4 - Kalliwa

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	12/13		13/14		12/13		13/14		12/13		13/14		12/13		13/14	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	16.7	23.8	21	26.5	NR	2.98	8.47	7.86	8.02	6.71	7.36	8.32	629	555	893	1583
2	16.4	23.7	20.5	26.4	NR	3.22	8.14	7.65	8.01	6.72	7.39	8.25	631	559	900	1586
3	15.9	23.6	20.1	26.2	NR	3.2	8.32	5.86	7.96	6.7	7.39	8.19	630	559	902	1593
4	15.6	23.6	19.2	26.2	NR	3.2	8.27	5.8	7.88	6.69	7.4	8.17	631	567	902	1593
5	15.4	23.6	18.6	26.1	NR	3.5	6.28	5.3	7.81	6.67	7.39	8.13	630	572	904	1594
6	15.4	23.5	18.3	26.0	NR	3.94	6.67	4.5	7.74	6.65	7.45	8.00	634	565	910	1593
7	15.3	23.5	18.2	25.7	NR	3.89	6.33	1.4	7.69	6.62	7.52	7.94	634	566	921	1593
8	15.3	23.5	18.1	25.5	NR	6.18	5.94	1.04	7.64	6.6	7.4	7.80	637	575	940	1583
9	15.2	23.5	18.1	25.3	NR	5.14	6.89	0.9	7.59	6.54	7.45	7.82	638	577	949	1576
Visibility	Winter 12 1200 mm				Summer 13 700 mm				Winter 13 1000 mm				Summer 14 800 mm			

Site 5 - Mingo Gorge

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	12/13		13/14		12/13		13/14		12/13		13/14		12/13		13/14	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	15	24.4	19.4	29.6	NR	7.37	7.58	11.64	7.84	8	7.66	8.50	716	1043	1079	1687
2	14.7	23.9	19.1	28.8	NR	7.7	8.79	9.10	7.83	7.98	7.66	8.46	720	1021	1102	1692
3	14.6	23.7	18.9	28.1	NR	9.8	8.81	7.50	7.82	7.93	7.66	8.38	721	1027	1168	1699
4	14.6	23.6	18.7	27.8	NR	10.72	8.5	6.86	7.82	7.96	7.65	8.30	720	1031	1207	1700
5	14.5	23.6	18.6	27.7	NR	10.4	8.3	8.61	7.82	7.96	7.65	8.26	724	1032	1233	1706
6	14.5	23.6	18.6	27.6	NR	10.3	6.1	8.50	7.83	7.96	7.79	8.23	724	1038	1271	1703
7	14.5	23.6	18.5	27.5	NR	10.21	6.11	8.39	7.83	7.97	7.73	8.17	725	1037	1320	1704
8	14.5	23.6	18.5	27.4	NR	9.02	6.24	9.14	7.83	7.96	7.73	8.18	725	1034	1347	1701
9	14.5	23.6	18.4	27.2	NR	8.85	6.2	6.50	7.83	7.96	7.71	8.12	725	1041	1357	1701
Visibility	Winter 12 1900 mm				Summer 13 1100 mm				Winter 13 1500 mm				Summer 14 800 mm			

Site 6 - Gray's Waterhole

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	12/13		13/14		12/13		13/14		12/13		13/14		12/13		13/14	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	14.7	22.6	20.5	29.5	10.1	7.96	11.14	10.70	7.09	7.71	7.56	8.61	740	1204	1768	1563
2	14.5	22.5	20.2	28.6	8.7	7.78	11.2	9.30	7.39	7.7	7.56	8.59	741	1202	1768	1582
3	14	22.5	19.5	27.8	9.17	8.49	12.67	7.50	7.52	7.7	7.55	8.54	7.46	1201	1767	1588
4	13.7	22.6	18.9	27.6	9.76	8.54	12.43	6.90	7.59	7.78	7.55	8.50	748	1203	1766	1596
5	13.6	22.6	18.7	27.4	10.07	8.63	11.54	4.56	7.68	7.79	7.54	8.37	744	1211	1771	1591
6	13.5	22.6	18.4	27.1	10.14	8.74	11.16	4.82	7.72	7.8	7.54	8.28	744	1204	1774	1594
7	13.4	22.6	18.3	27.1	10.22	8.75	12.08	5.10	7.75	7.81	7.63	8.21	743	1206	1775	1602
8	13.3	22.6	18.3	26.6	10.3	8.93	12.82	4.35	7.7	7.82	7.66	8.04	747	1206	1774	1602
9	13.3	22.5	18.2	26.4	13.19	9.1	12.7	3.03	7.79	7.82	7.69	7.85	746	1206	1775	1600
Visibility	Winter 12 1100 mm				Summer 13 900 mm				Winter 13 1700 mm				Summer 14 900 mm			

Site 7 – Claude Wharton Weir.

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	12/13		13/14		12/13		13/14		12/13		13/14		12/13		13/14	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	16.1	22.5	18.4	26.5	NR	7.19	7.42	8.72	7.65	7.81	7.58	8.37	791	1254	1766	1453
2	15.9	22.4	18.1	26.6	NR	7.91	7.63	8.83	7.68	7.72	7.58	8.25	794	1260	1777	1450
3	15.6	22.2	17.9	26.6	NR	7.61	8.7	9.17	7.72	7.69	7.6	8.19	788	1262	1781	1449
4	14.7	22.2	17.8	26.5	NR	7.36	9.88	12.71	7.75	7.58	7.58	8.11	793	1264	1782	1448
5		22.1	17.8			6.73	9.76			7.56	7.6			1268	1784	
6		22				6.84				7.55				1270		
Visibility	Winter 12 1500 mm				Summer 13 600 mm				Winter 13 1500 mm				Summer 14 1000 mm			

Site 8 - Mundubbera

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	12/13		13/14		12/13		13/14		12/13		13/14		12/13		13/14	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	14.7	22.7	20.5		NR	9	11.26		7.4	7.81	7.45		649	1145	1554	
2	14.6	21.9	19.5		NR	8.72	11.61		7.42	7.75	7.45		640	1141	1564	
3	14.6	21.5	18.4		NR	8.14	11.04		7.46	7.69	7.46		645	1135	1552	
4	14.5	21.4	17.7		NR	8.28	9.3		7.4	7.65	7.46		640	1146	1560	
5	14.5	21.3	17.7		NR	8.24	7.44		7.4	7.63	7.46		640	1150	1594	
Visibility	Winter 12 900 mm				Summer 13 900 mm				Winter 13 1300 mm				Summer 14 mm			

7.5 Summary of water quality data for 2014-2016.

(NR=not recorded due to equipment malfunction) (Tw= water temperature)

Site 1 - Isis

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	14/15		15/16		14/15		15/16		14/15		15/16		14/15		15/16	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	25.4	28.7	NR	28.0	8.50	11.25	NR	6.73	8.94	8.51	NR	8.04	1068	337	NR	488
2	25.2	28.9	NR	28.0	8.86	11.28	NR	5.87	8.34	8.33	NR	7.95	1068	337	NR	496
3	25	28.9	NR	28.0	7.92	10.55	NR	5.33	8.32	8.17	NR	7.92	1078	337	NR	496
4	23.9	29	NR	27.8	7.20	10.11	NR	4.88	8.24	8.09	NR	7.84	1081	338	NR	493
5	22.7		NR		5.60		NR		8.14		NR		1070		NR	
Visibility	Winter 14 700 mm				Summer 15 50 mm				Winter 15 850 mm				Summer 16 300 mm			

Site 2 - Figtree

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
(m)	14/15		15/16		14/15		15/16		14/15		15/16		14/15		15/16	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	26.7	29.8	19.5	26.0	9.13	7.18	NR	5.54	8.84	8.47	NR	8.47	1531	350	NR	440
2	24.7	29.5	19.5	26.0	10.75	7.91	NR	5.25	8.88	8.25	NR	8.39	1523	349	NR	440
3	24.3	29.4	19.5	26.0	10.5	8.42	NR	5.2	8.85	8.24	NR	7.97	1524	350	NR	440
Visibility	Winter 14 1900 mm				Summer 15 100 mm				Winter 15 750 mm				Summer 16 150 mm			

Site 4 - Kalliwa

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	14/15		15/16		14/15		15/16		14/15		15/16		14/15		15/16	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	19.7	28.0	NR	28.2	7.10	5.63	NR	3.31	8.40	8.43	NR	8.48	1511	1044	NR	439
2	19.7	27.8	NR	28.1	7.36	5.26	NR	2.75	8.37	8.28	NR	8.34	1517	1076	NR	439
3	19.6	27.7	NR	27.8	7.41	5.16	NR	2.44	8.34	8.18	NR	8.25	1519	1098	NR	440
4	19.5	27.6	NR	27.6	8.15	9.05	NR	2.29	8.34	8.05	NR	8.18	1521	1117	NR	440
5	19.5	27.6	NR	27.6	8.13	9.2	NR	2.22	7.81	8.27	NR	8.05	1523	1117	NR	440
6	18.8	27.6	NR	27.5	5.8	9.37	NR	2.22	7.94	8.15	NR	7.98	1531	1117	NR	439
7	18.7	27.5	NR	27.2	4.98	12.56	NR	1.8	7.89	8.03	NR	7.9	1533	1113	NR	435
8	18.6	27.5	NR	26.8	4.69	11.69	NR	1.35	7.86	7.98	NR	7.8	1536	1108	NR	430
9	18.2	27.5	NR	27.7	4.31	11.28	NR	1.65	7.81	7.94	NR	7.7	1540	1098	NR	434
Visibility	Winter 14 800 mm				Summer 15 900 mm				Winter 15 800 mm				Summer 15 200 mm			

Site 5 - Mingo Gorge

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	14/15		15/16		14/15		15/16		14/15		15/16		14/15		15/16	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	22.6	27.6	18.0	29.5	12.2	5.45	8.3	5.23	8.57	8.35	7.53	8.53	1527	485	477	383
2	22.3	27.6	17.8	28.9	24.1	5.02	8.31	4.88	8.58	8.25	7.64	8.45	1540	485	476	380
3	21.6	27.6	17.7	28.8	22.2	5.29	8.13	4.21	8.56	8.14	7.54	8.39	1546	485	476	379
4	21.2	27.6	17.6	28.8	17.35	4.98	7.94	3.58	8.51	8.09	7.67	8.33	1540	485	476	382
5	21.1	27.6	17.5	28.8	16.37	5.13	7.8	3.33	8.48	7.99	7.54	8.25	1544	485	476	381
6	21.5	27.6	17.5	28.7	15.89	4.91	7.62	3.13	8.46	7.92	7.48	8.18	1546	485	476	380
7	20.9	27.6	17.5	28.7	15.1	5.02	7.5	2.94	8.41	7.82	7.43	8.13	1552	485	476	380
8	20.7	27.6	17.4	28.6	14.6	4.63	7.2	2.82	8.37	7.78	7.31	8.04	1555	487	478	379
9	20.6	27.6	17.3	28.3	14.3	4.66	6.63	2.66	8.33	7.73	7.32	8.03	1555	487	480	372
Visibility	Winter 14 1000 mm				Summer 15 100 mm				Winter 15 1200 mm				Summer 16 200 mm			

Site 6 - Gray's Waterhole

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	14/15		15/16		14/15		15/16		14/15		15/16		14/15		15/16	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	22.2	30.0	19.3	30.5	11.27	7.94	10.64	6.45	8.44	8.53	8.12	8.59	1592	542	917	390
2	22.0	29.7	17.7	29.9	11.4	8.12	11.0	6.21	8.46	8.24	8.04	8.51	1593	549	902	387
3	22.0	29.6	17.7	29.8	10.7	7.93	11.16	6.2	8.48	8.11	8.05	8.45	1599	551	904	387
4	22.0	29.5	17.0	29.8	10.7	8.10	8.82	6.06	8.19	7.96	7.76	8.45	1598	552	944	384
5	21.2	29.5	16.9	29.7	10.7	8.57	8.11	6.03	8.47	7.88	7.57	8.33	1605	553	947	382
6	20.3	29.5	16.7	29.5	11.47	8.50	7.40	6.00	8.38	7.82	7.46	8.39	1574	552	923	382
7	19.1	29.5	16.6	29.3	12.1	8.48	6.91	5.95	8.23	7.74	7.43	3.42	1558	551	930	383
8	18.7	29.5	16.6	29.0	11.3	8.28	6.96	5.87	8.10	7.75	7.45	8.37	1567	551	931	381
9	18.5	29.5	16.6	28.9	10.3	8.28	7.00	5.54	7.99	7.73	7.47	8.35	1567	551	931	381
Visibility	Winter 14 1200 mm				Summer 15 100 mm				Winter 15 1100 mm				Summer 16 200 mm			

Site 7 – Claude Wharton Weir.

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	14/15		15/16		14/15		15/16		14/15		15/16		14/15		15/16	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	21.2	26.4	17.5	29.4	10.4	8.27	NR	7.13	8.26	8.25	7.83	8.32	1836	596	1098	668
2	20.1	16.4	17.5	29.0	10.9	8.13	NR	5.59	8.26	8.11	7.85	8.24	1850	594	1098	669
3	20.0	26.4	17.4	28.6	10.95	8.66	NR	4.16	8.25	8.03	7.83	8.22	1848	592	1099	670
4	19.8	26.4	17.3	28.2	11.01	8.41	NR	3.54	8.12	8.01	7.82	8.14	1844	592	1099	667
5		26.4		27.7				3.44				8.12				664
Visibility	Winter 14 1200 mm				Summer 15 150 mm				Winter 15 1500 mm				Summer 16 200 mm			

Site 8 - Mundubbera

Depth	Tw (^{0}C)				Dissolved Oxygen (mg/L)				pH				Conductivity (ppm)			
	14/15		15/16		14/15		15/16		14/15		15/16		14/15		15/16	
	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum	Wint	Sum
1	21.2	28.1	17.6	28.0	10.56	9.12	9.56	4.4	8.23	7.88	7.77	9.17	1674	667	1065	544
2	21.1	27.5	17.2	27.8	9.98	10.72	9.50	3.84	8.22	7.87	7.78	9.36	1678	667	1065	540
3	21.1	27.2	16.7	27.7	8.66	9.34	8.55	3.58	8.21	7.73	7.65	9.16	1652	669	1067	536
4	20.4	27.1	16.6	27.6	8.24	9.53	8.08	3.56	8.17	7.65	7.54	8.91	1674	666	1069	536
5			16.6				7.85				7.46				1075	
Visibility	Winter 14 1400 mm				Summer 15 1000 mm				Winter 15 1300 mm				Summer 16 1000 mm			