Darling Anabranch Adaptive Management Monitoring Plan: Intervention Monitoring

Summary of Results 2010-2011

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For the NSW Office of Environment and Heritage

October 2010 – September 2011

Final Report

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Contents

1. General introduction

This report presents a summary of results from the first intervention monitoring event of the Darling Anabranch. The report is arranged in the following sections:

1. General introduction (this section)
2. Fish community
3. Yabby populations
4. Frog community
5. Waterbirds
6. Water quality

Intervention monitoring seeks to *"assess the ecological response to interventions or environmental management actions"* (MDBC 2007). Monitoring is carried out within an experimental framework, to assess the ecological responses to managed environmental and uncontrolled flows (Wallace et al 2009).

An environmental flow was delivered to the Darling Anabranch beginning in September 2010, released through Packers Crossing. This was augmented by a flood in October 2010 and the Darling Anabranch flowed into the Murray River for approximately the next 12 months (Figure 1.1).

The Murray-Darling Freshwater Research Centre (MDFRC) monitored this flow event on four stages of the hydrograph: rising flow (spring 2010), peak flow (summer 2010/11), flow recession (autumn 2011), and cessation of flow (winter 2011) (Figure 1.1). Intervention monitoring was carried out at 17 sites along the Darling Anabranch, consistent with condition monitoring sites (see Bogenhuber et al. 2011 for locations).

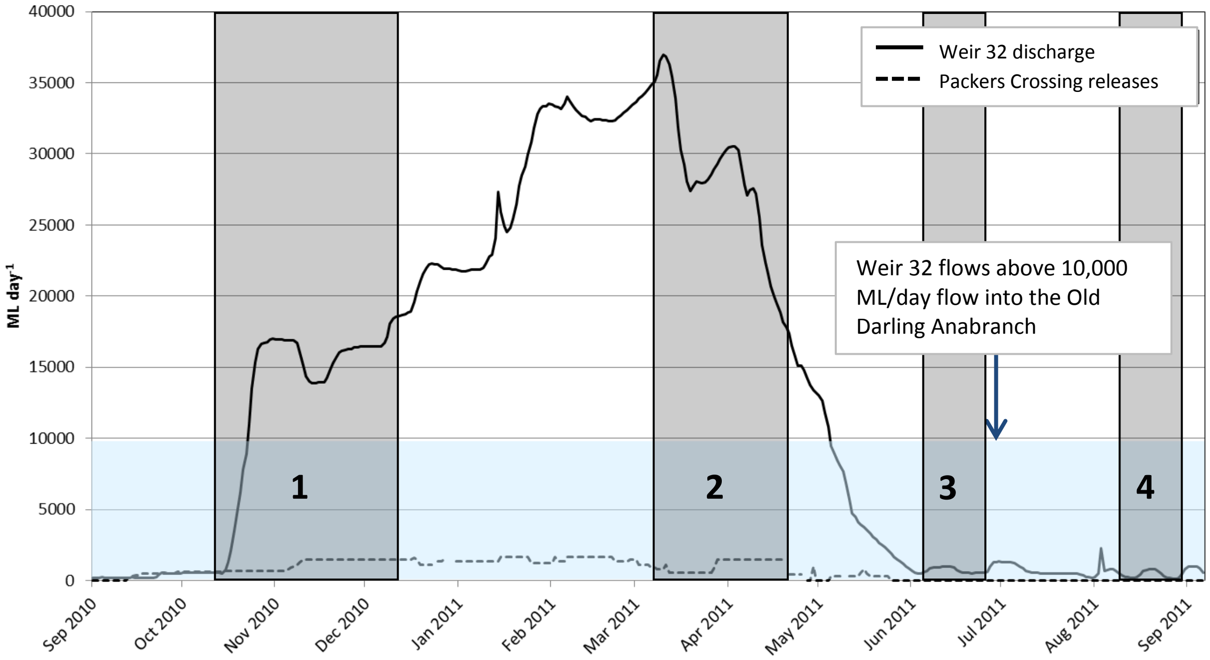

Figure 1.1. Hydrograph during first intervention monitoring event of the Darling Anabranch. Solid line is Weir 32 discharge, dashed line is releases through Packers Crossing. Vertical grey bars indicate survey periods.

2. Fish community

Fish species abundance and diversity were recorded at 17 sites along the Darling Anabranch during four survey periods between October 2010 and September 2011. Surveys were conducted across all stages of a flow event and coincided with each season (Figure 1.1, Section 1).

2.1 Small-bodied fish species

A total of six small-bodied fish species were recorded along the Darling Anabranch, five native species and one exotic species (Table 2.1). The exotic Eastern gambusia (*Gambusia holbrooki*) was most abundant overall by far, with a total abundance of 5689, followed by the native Carp gudgeon (*Hypseleotris spp)*, with a total abundance of 728 (Table 2.1, Figure 2.1).

Survey 1 recorded the highest small-bodied fish species diversity, with survey 2 recording the highest abundance, due to the large number of Eastern gambusia recorded (Table 2.1, Figure 2.1). Carp gudgeon abundance dominated the small-bodied fish species during survey 1, representing 53% of total catch. Carp gudgeon abundance records per 24 net hours decreased in subsequent surveys (Figure 2.1).

Fly-specked hardyhead (*Craterocephalus stercusmuscarum fulvus)* were most abundant in survey 2, with decreasing abundance in consecutive surveys (Figure 2.1). Flat-headed gudgeon *(Philypnodon grandiceps)* and Murray-Darling rainbowfish (*Melanotaenia fluviatilis)* were not recorded in surveys 3 and 4 (Figure 2.1). Australian smelt (*Retropinna semoni)* were generally recorded in low abundances except in winter (survey 4), recording the highest abundance of the small-bodied fish species, representing 44% of total catch (Figure 2.1).

2.2 Large-bodied fish species

A total of six large-bodied fish species were recorded along the Darling Anabranch, two exotic species and four native species (Table 2.1). The native Golden perch (*Macquaria ambigua*) was the most abundant overall by far, with a total abundance of 2902 individuals, followed by the exotic Common carp (*Cyprinus carpio*), which recorded a total abundance of 1448 individuals (Table 2.1, Figure 2.2). Five large-bodied fish species were recorded during surveys 1 to 3, with diversity increasing in survey 4 to six species, due to the presence of Silver perch (*Bidyanus bidyanus*, n=7) (Table 2.1; Figure 2.2).

Golden perch were the most abundant large-bodied fish species recorded in surveys 1, 3 and 4 and accounted for 50% of total large-bodied fish species recorded overall (Figure 2.2). Bony herring (*Nematalosa erebi*) were the most abundant large-bodied fish species during survey 2, accounting for 41% of total large-bodied fish species catch, with abundances decreasing in consecutive surveys (Figure 2.2). Spangled perch were most abundant during surveys 2 and 3 (Fig 2.2).

Common carp recorded highest abundances in survey 1, with the lowest abundance recorded in survey 3 (Figure 2.2). Goldfish (*Carassius auratus*) were recorded in low abundances (Table 2.1).

Large-bodied fish species biomass varied between species and survey periods (Figure 2.3). Common carp accounted for the largest combined biomass quantity throughout surveys 1 to 4; recording 75% of the total large-bodied fish species biomass in survey 1 and 55% in survey 2, with biomass reducing during survey 3 (Figure 2.3).

Golden perch recorded the highest combined biomass for native large-bodied fish species throughout surveys 1 to 4 and accounted for 69% of the total large-bodied fish species biomass in survey 3 (Figure 2.3).

Table 2.1. Total abundance of small and large-bodied fish species recorded during surveys 1 to 4 from 17 sites along the Darling Anabranch, 2010-2011. Exotic species are denoted by an asterisk (*).

	Common name	Species name	Survey 1	Survey 2	Survey 3	Survey 4	Total
Small-bodied fish	Australia smelt	*Retropinna semoni*	1	0	7	71	79
	Flat-headed gudgeon	*Philypnodon grandiceps*	7	7	0	0	14
	Murray-Darling rainbowfish	*Melanotaenia fluviatilis*	1	2	0	0	3
	Carp gudgeon	*Hypseleotris spp.*	299	352	38	39	728
	Eastern gambusia*	*Gambusia holbrooki*	203	5409	38	39	5689
	Fly-specked hardyhead	*Craterocephalus stercusmuscarum fulvus*	48	91	13	10	162
Large-bodied fish	Bony herring	*Nematalosa erebi*	64	832	33	27	956
	Golden perch	*Macquaria ambigua*	896	527	854	625	2902
	Spangled perch	*Leiopotherapon unicolor*	43	252	136	14	445
	Common carp*	*Cyprinus carpio*	681	392	92	283	1448
	Goldfish*	*Carassius auratus*	14	6	1	2	23
	Silver perch	*Bidyanus bidyanus*	0	0	0	7	7
		Total abundance	2257	7870	1212	1117	12456
		Diversity	11	10	9	10	12

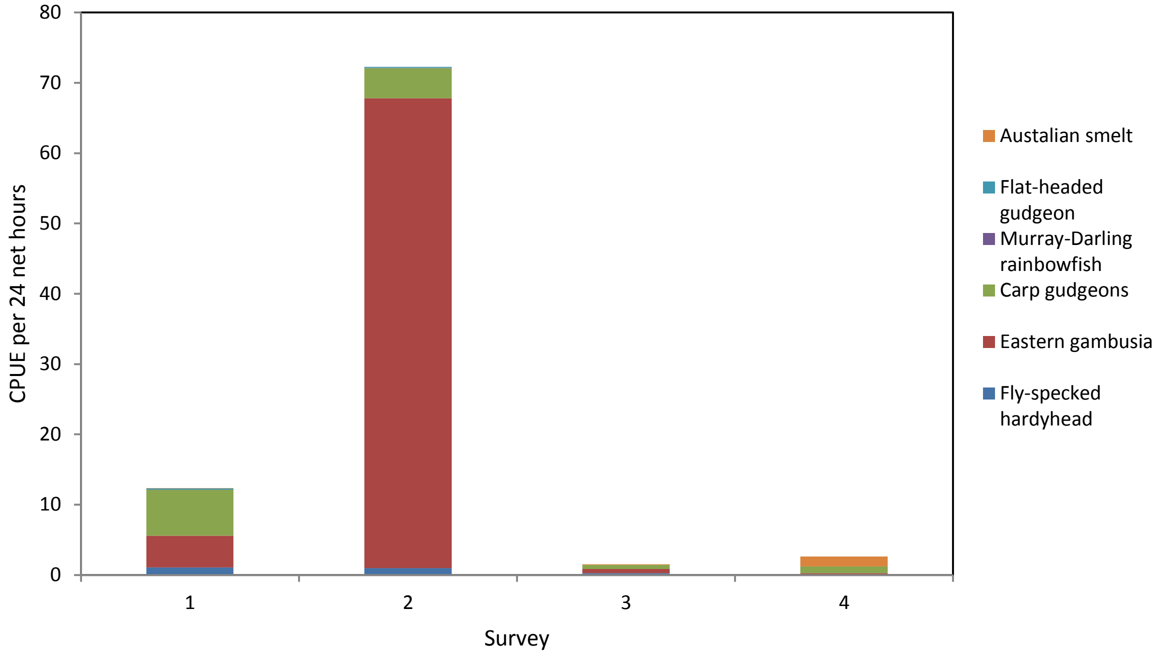

Figure 2.1. Average abundance of small-bodied fish species per 24 net hours, over four survey periods at 17 sites along the Darling Anabranch, 2010-2011.

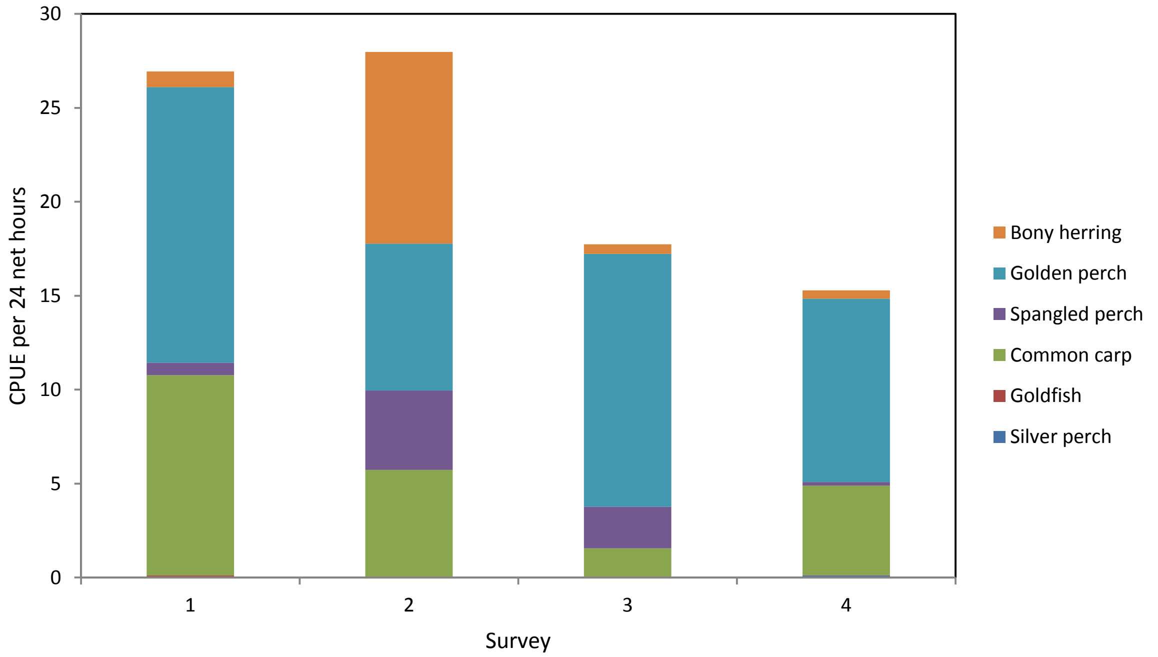

Figure 2.2. Average abundance of large-bodied fish species per 24 net hours, over four survey periods at 17 sites along the Darling Anabranch, 2010-2011.

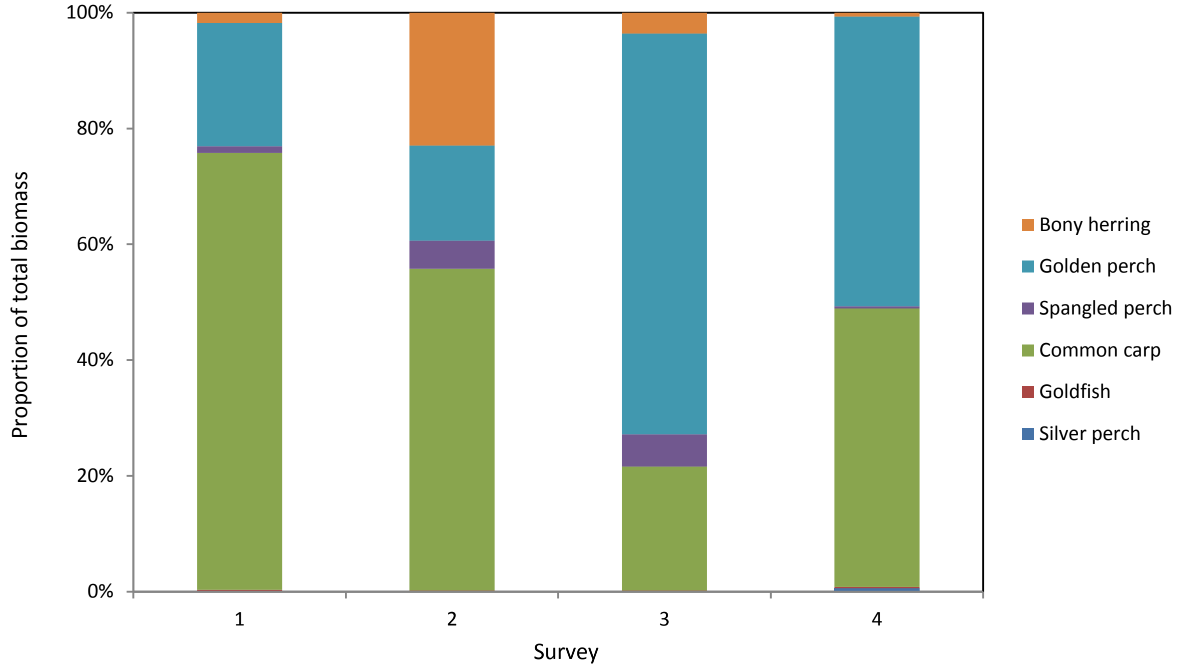

Figure 2.3. Average biomass of large-bodied fish species per 24 net hours, over four survey periods at 17 sites along the Darling Anabranch, 2010-2011.

3. Yabby populations

Yabby (*Cherax destructor*) abundance, sex ratio and carapace length were recorded at 17 sites along the Darling Anabranch during four consecutive survey periods between October 2010 and September 2011. Surveys were conducted across all stages of a flow event and coincided with each season (Figure 1.1, Section 1).

A total of 1865 yabbies were recorded; 57% in baited opera house nets and 43% in fyke nets. Yabby abundance peaked in survey 3, during flow recession, at 953 individuals (Figure 3.1). The lowest number of yabbies was recorded in survey 4 when water had receded to pools (Figure 3.1).

Male and female yabbies were almost in equal proportions overall (51% and 49% of total catch, respectively). Male yabbies accounted for a slightly higher abundance in surveys 1 and 2, with survey 4 recording a 63% abundance of male yabbies and 37% abundance of female yabbies (Figure 3.1) Female yabbies recorded a higher abundance in survey 3 (53% of total catch) (Figure 3.1).

The carapace length recorded from surveys one to four ranged from 9.15 mm to 95 mm (Figure 3.2). Survey 1 recorded the lowest mean carapace length of 38 mm, with the largest carapace length range (9.15 mm to 94 mm) (Figure 3.2). The highest mean carapace length was recorded in survey 2 at 60 mm (Figure 3.2). Survey 4 recorded the lowest carapace length range of 90 mm to 32 mm (Figure 3.2).

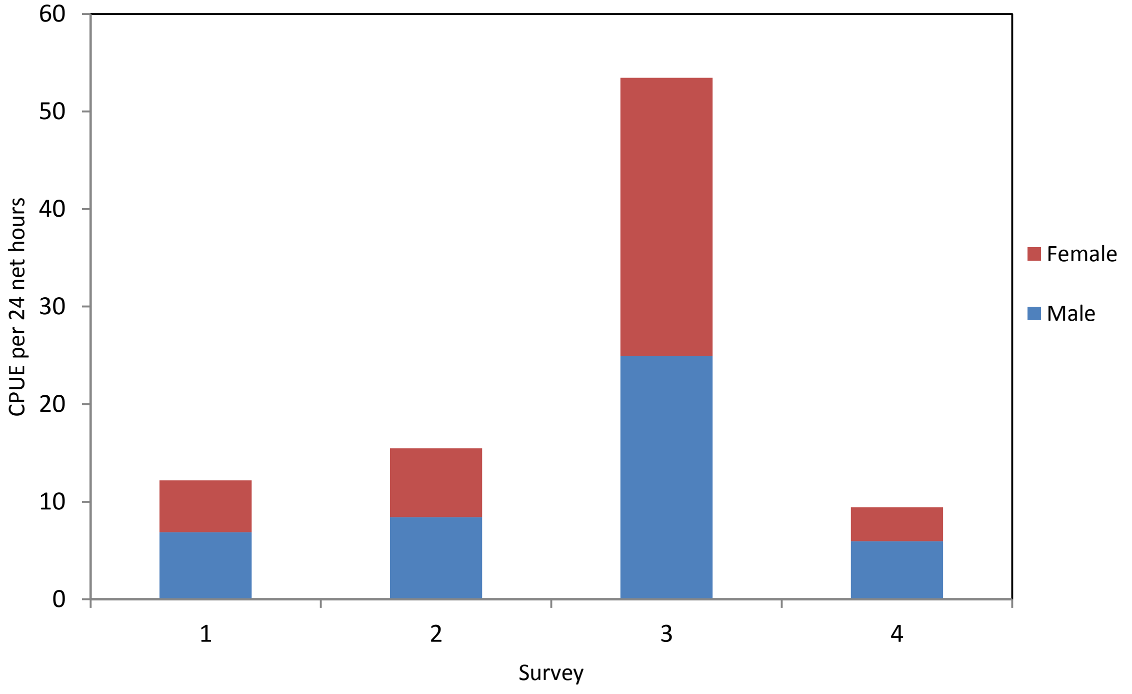

Figure 3.1. Total abundance of yabbies recorded during surveys 1 to 4 from 17 sites along the Darling Anabranch, 2010-11.

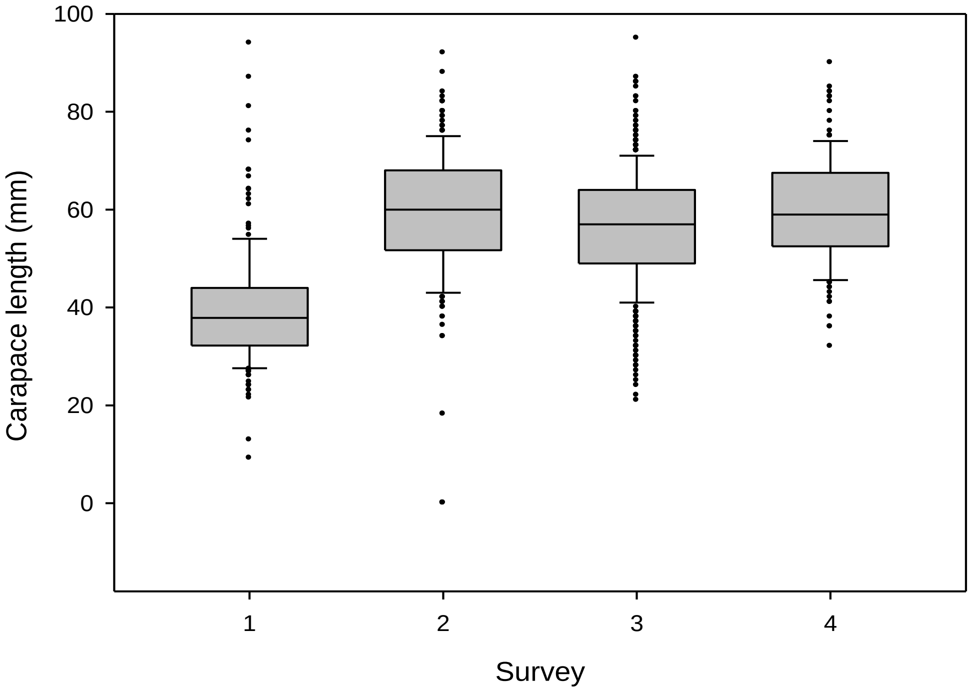

Figure 3.2. Box and whisker plot depicting yabby carapace length during surveys 1 to 4 for the 17 sites sampled along the Darling Anabranch in 2010-2011. Boxes enclose the 25th to 75th percentiles; whiskers enclose the 10th to 90th percentiles; outliers are identified by closed circles; solid line within the box plot represents the mean.

4. Frog community

Frog species abundance and diversity were recorded at 17 sites along the Darling Anabranch during four survey periods between October 2010 and September 2011. Surveys were conducted across all stages of a flow event and coincided with each season (Figure 1.1, Section 1).

A total of 185 frogs from five species were recorded along the Darling Anabranch (Table 4.1). Spotted Marsh Frog (*Limnodynastes tasmaniensis*) records accounted for over half of the total frog abundance (54%).

Frog abundances were greatest during survey 1, with abundances declining in subsequent surveys (Figure 4.1). Similarly, species richness was greatest during survey 1 (Table 4.1). The Spotted Marsh Frog was the most abundant species during survey 1, with abundances in consecutive surveys decreasing (Figure 4.2). The Peron's Tree Frog (*Litoria peronii*) was the most abundant species during survey 2, and the Plains Froglet (*Crinia parinsignifera)* the most abundant species during surveys 3 and 4 (Figure 4.2). One Green Tree Frog (*Litoria caerulea*) was recorded during survey 1 through an incidental sighting (Table 4.1, Figure 4.2).

Table 4.1. Total abundance of frog species recorded during surveys 1 to 4 from 17 sites along the Darling Anabranch, 2010-2011. Figures include frogs surveyed during active searches, recordings and incidental sightings.

Common name	Species name	Survey 1	Survey 2	Survey 3	Survey 4	Total
Peron's Tree Frog	*Litoria peronii*	38	13	1	3	55
Spotted Grass Frog	*Limnodynastes tasmaniensis*	86	11	2	1	100
Barking Marsh Frog	*Limnodynastes fletcheri*	6	1	0	6	13
Plains Froglet	*Crinia parinsignifera*	3	1	5	7	16
Green Tree Frog	*Litoria caerulea*	1	0	0	0	1
	Total abundance	134	26	8	17	185
	Diversity	5	4	3	4	5

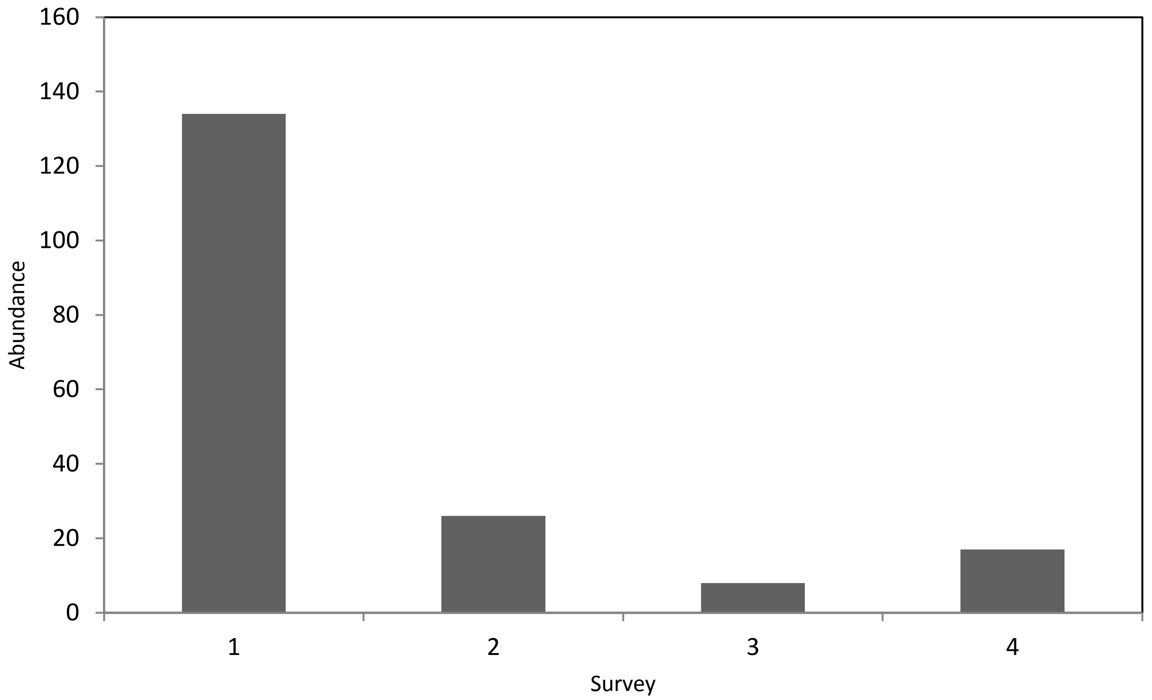

Figure 4.1. Total abundance of frogs over four survey periods at 17 sites along the Darling Anabranch, 2010-11.

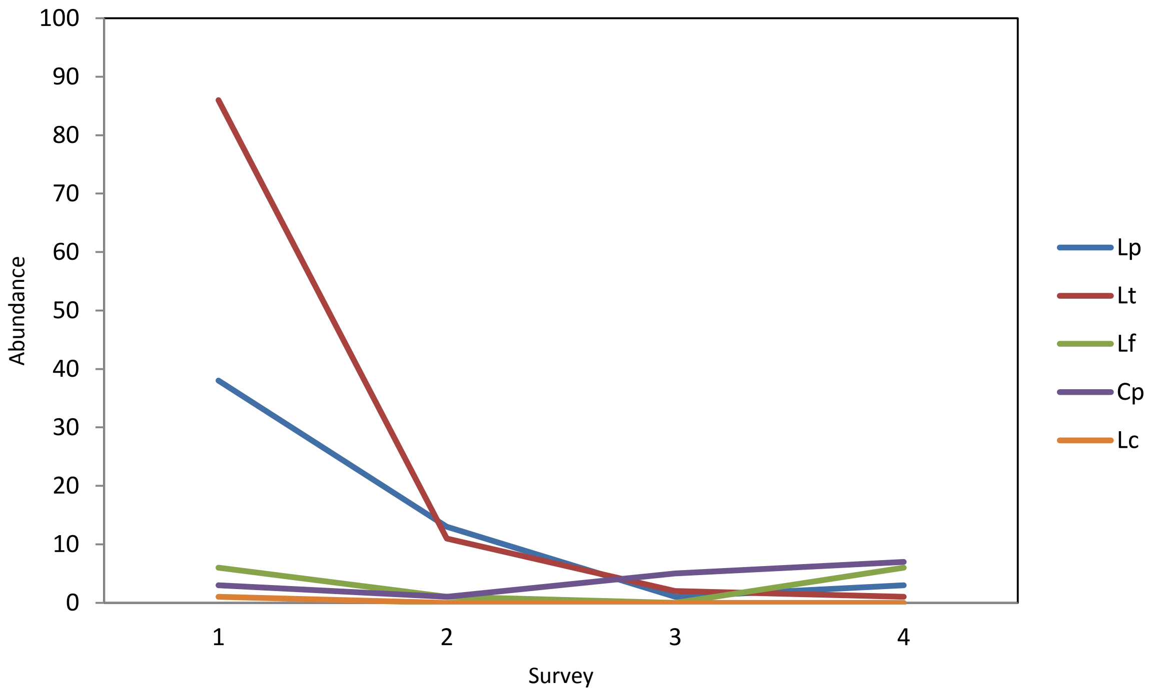

Figure 4.2. Abundance of each frog species recorded during surveys 1 to 4 from 17 sites along the Darling Anabranch, 2010-11 where Lp = Peron's Tree Frog, Lt = Spotted Marsh Frog, Lf = Barking Marsh Frog, Cp = Plains Froglet and Lc = Green Tree Frog.

5. Waterbirds

Waterbird abundance and diversity were recorded at 17 sites along the Darling Anabranch during four survey periods between October 2010 and September 2011. Surveys were conducted across all stages of a flow event and coincided with each season (Figure 1.1, Section 1).

A total of 4253 waterbirds from 32 species were recorded along the Darling Anabranch (Table 5.1). Nearly half of the abundance records (42%) were of Black-tailed native hens (*Gallinula ventralis)* (Table 5.1).

The number of waterbird species increased over time from survey 1 to survey 3, decreasing slightly in the final survey (Figure 5.1). Waterbird abundance increased over time with a large increase in the final survey due to the high numbers of Black-tailed native hens (Figure 5.1).

Large waders were the most diverse functional group (10 species), whereas herbivores were the numerically dominant functional group, due to the large numbers of Black-tailed native hens (Figures 5.2 and 5.3). Only two shorebirds were recorded, the Black-fronted dotterel (*Elseyornis melanops*) and Masked lapwing (*Vanellus miles*) (Table 5.1).

Black-tailed native hens were the most abundant waterbird recorded, followed by Grey teal (*Anas gracilis*), Wood duck (*Chenonetta jubata*), Little black cormorant (*Phalacrocorax sulcirostris*), Pacific black duck (*Anas superciliosa*), Pacific heron (*Ardea pacifica*) and Great cormorant (*Phalacrocorax carbo*), all with over 100 records (Table 5.1). Patterns in the abundance of these waterbird species differed over the four survey periods. Wood duck for example recorded highest numbers in surveys 2 and 3, Pacific heron numbers increased from survey 1 through to survey 4, and lowest abundances were recorded in the second survey for Little black cormorant, Pacific black duck and Grey teal (Figure 5.4).

Nearly one third of species (10) were recorded during all four surveys, and only three species – Black swan (*Cygnus atratus*), Masked lapwing and Little egret (*Ardea garzetta*) – were recorded during only one survey (Table 5.1).

Table 5.1. Total abundance of waterbird species recorded during surveys 1 to 4 from 17 sites along the Darling Anabranch, 2010-2011, in decreasing order of abundance. Common names and functional groups (FG) follow those in (Kingsford et al 2012): Pi = Piscivore, La = Large wader, He = Herbivore, Du = Ducks and small grebes.

FG	Common name	Species name	Survey 1	Survey 2	Survey 3	Survey 4	Total
He	Black-tailed native hen	*Gallinula ventralis*	29	79	32	1638	1778
Du	Grey teal	*Anas gracilis*	148	77	103	91	419
He	Wood (maned) duck	*Chenonetta jubata*	32	143	153	63	391
Pi	Little black cormorant	*Phalacrocorax sulcirostris*	66	30	68	184	348
Du	Pacific black duck	*Anas superciliosa*	51	32	63	17	163
La	Pacific (White-necked) heron	*Ardea pacifica*	1	16	53	57	127
Pi	Great cormorant	*Phalacrocorax carbo*	3	30	56	17	106
La	Nankeen (rufous) night heron	*Nycticorax caledonicus*	3	1		91	95
He	Eurasian coot	*Fulica atra*	37	20	21	17	95
Du	Little (Australasian) grebe	*Tachybaptus novaehollandiae*	35		50		85
Pi	Darter	*Anhinga melanogaster*			27	52	79
La	Plumed (Intermediate) egret	*Casmerodius albus*			64	12	76
La	White-faced heron	*Ardea novaehollandiae*	7	26	35	7	75
La	Great egret	*Ardea alba*	20		15	36	71
Pi	Little pied cormorant	*Phalacrocorax melanoleucos*		10	16	35	61
Du	Hardhead	*Aythya australis*	1		42	6	49
La	Straw-necked ibis	*Threskiornis spinicollis*		32	9	4	45
La	Royal spoonbill	*Platalea regia*		2	40		42
Du	Pink-eared duck	*Malacorhynchus membranaceus*	5	21			26
Sh	Black-fronted dotterel	*Elseyornis melanops*	7	9	2	3	21
La	White (sacred) ibis	*Threskiornis molucca*		5	12	1	18
Pi	Pied cormorant	*Phalacrocorax varius*		5	9	2	16
He	Australian shelduck	*Tadorna tadornoides*	3	2	7		12
He	Purple swamphen	*Porphyrio porphyrio*	3		3	6	12
Pi	Pelican	*Pelecanus conspicillatus*	4	4	4		12
Du	Chestnut teal	*Anas castanea*			8	2	10
He	Dusky moorhen	*Gallinula tenebrosa*		6	3		9
Du	Hoary-headed grebe	*Poliocephalus poliocephalus*		1	1	2	4
La	Yellow-billed spoonbill	*Platalea flavipes*		1		2	3
He	Black swan	*Cygnus atratus*			2		2
Sh	Masked lapwing	*Vanellus miles*		2			2
La	Little egret	*Ardea garzetta*				1	1
		Total abundance	455	554	898	2346	4253
		Diversity	18	23	27	24	32

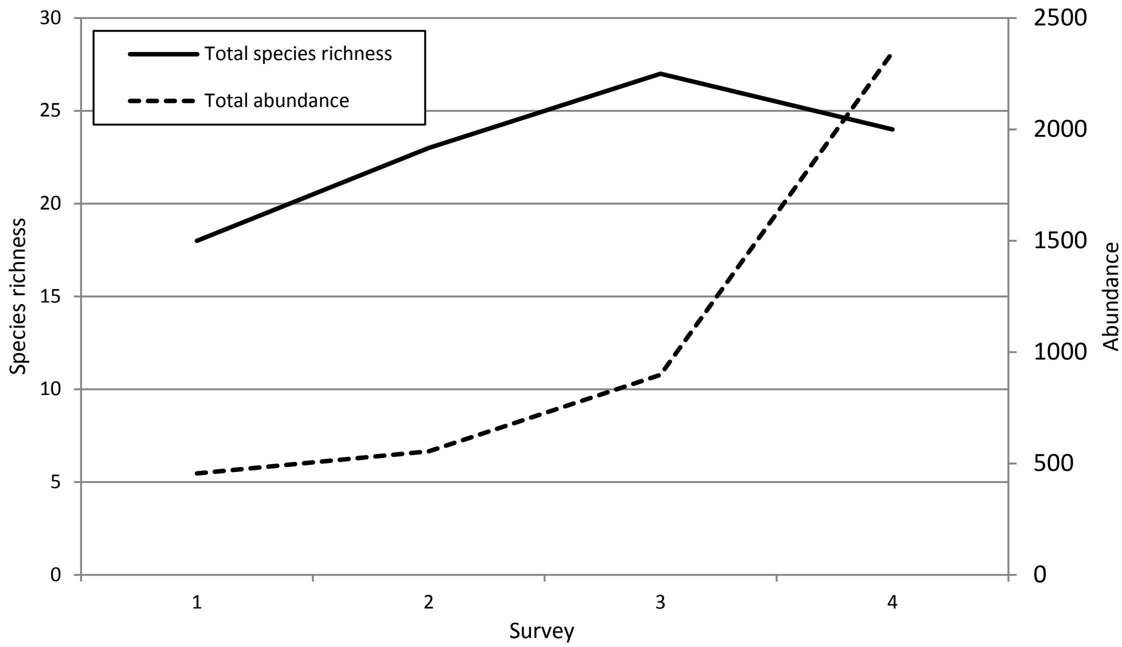

Figure 5.1. Waterbird species richness and abundance over four survey periods at 17 sites along the Darling Anabranch, 2010-2011.

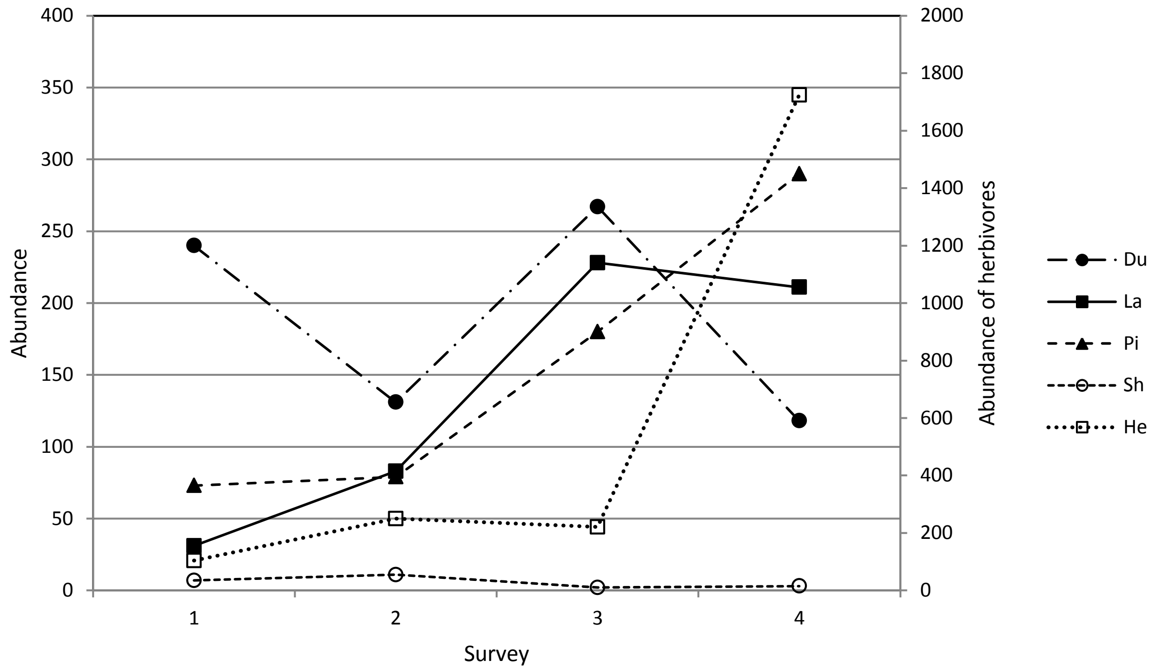

Figure 5.2. Total abundance of waterbirds in each functional group over four survey periods at 17 sites along the Darling Anabranch, 2010-2011. Note herbivore abundance is plotted on the right hand axis at a different scale. Functional groups follow those in (Kingsford et al 2012): Du = Ducks and small grebes, He = Herbivore, La = Large wader, Pi = Piscivore, Sh = Shorebird.

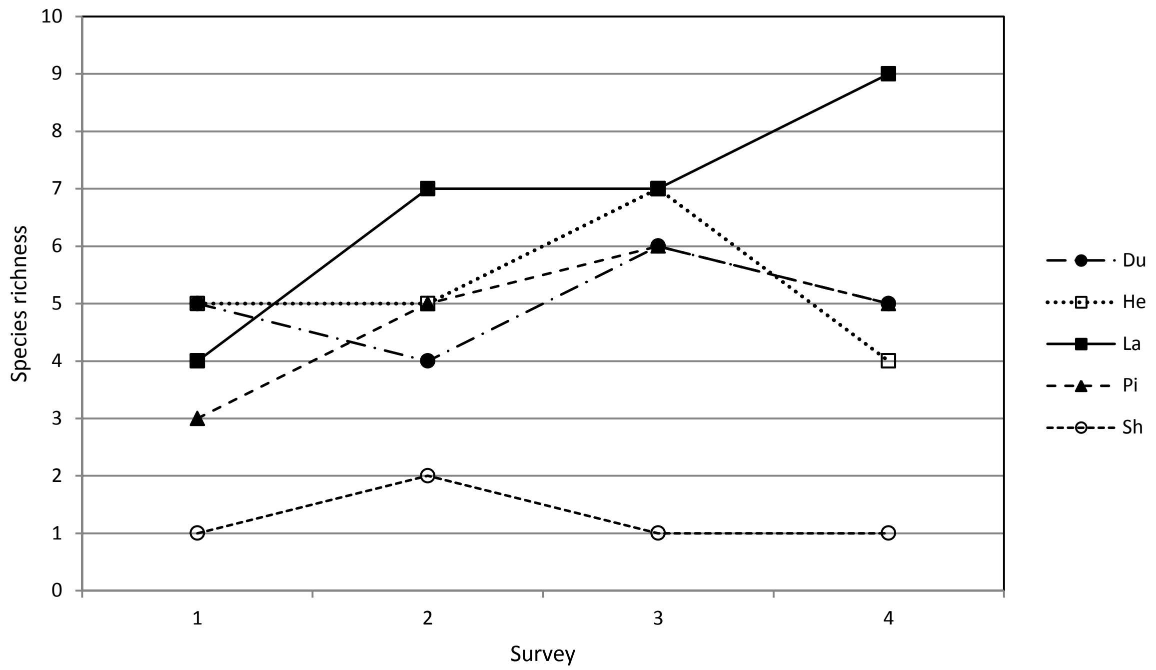

Figure 5.3. Total species richness of each waterbird functional group over four survey periods at 17 sites along the Darling Anabranch, 2010-2011. Functional groups follow those in (Kingsford et al 2012): Du = Ducks and small grebes, He = Herbivore, La = Large wader, Pi = Piscivore, Sh = Shorebird.

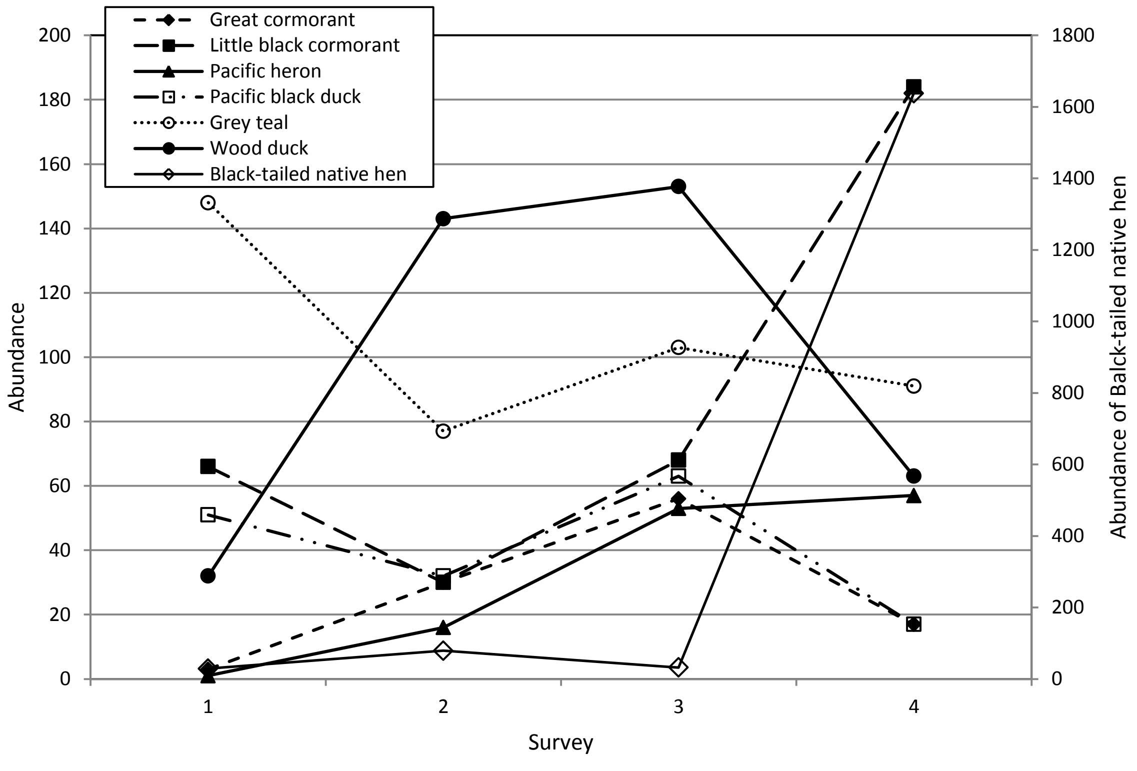

Figure 5.4. Abundance of six most abundant waterbird species over four survey periods, for the 17 sites surveyed along the Darling Anabranch 2010-2011. Note Black-tailed native hen abundance is plotted on the right hand axis at a different scale.

6. Water quality

6.1. Instantaneous Vertical Profiles

Instantaneous vertical profiles of temperature, dissolved oxygen (DO), electrical conductivity (EC), turbidity, and pH were recorded at 17 sites along the Darling Anabranch during four intervention monitoring survey periods. Site 6 was sampled upstream and downstream of a man-made obstruction, represented as 6a (upstream) and 6b (downstream). The survey periods are detailed in Figure 1.1, Section 1.

Temperature

Mean water temperature across all sites ranged from 9.37 to 28.47 °C during the survey period (Figure 6.1). The biggest difference in temperatures among sites occurred during the second and fourth surveys, in autumn and late winter respectively (Figure 6.1). Temperatures were least variable, and also lowest, during the third survey period in early winter (Figure 6.1).

Temperature variation between sites could be influenced by time of day surveyed, which varied among sites and among surveys.

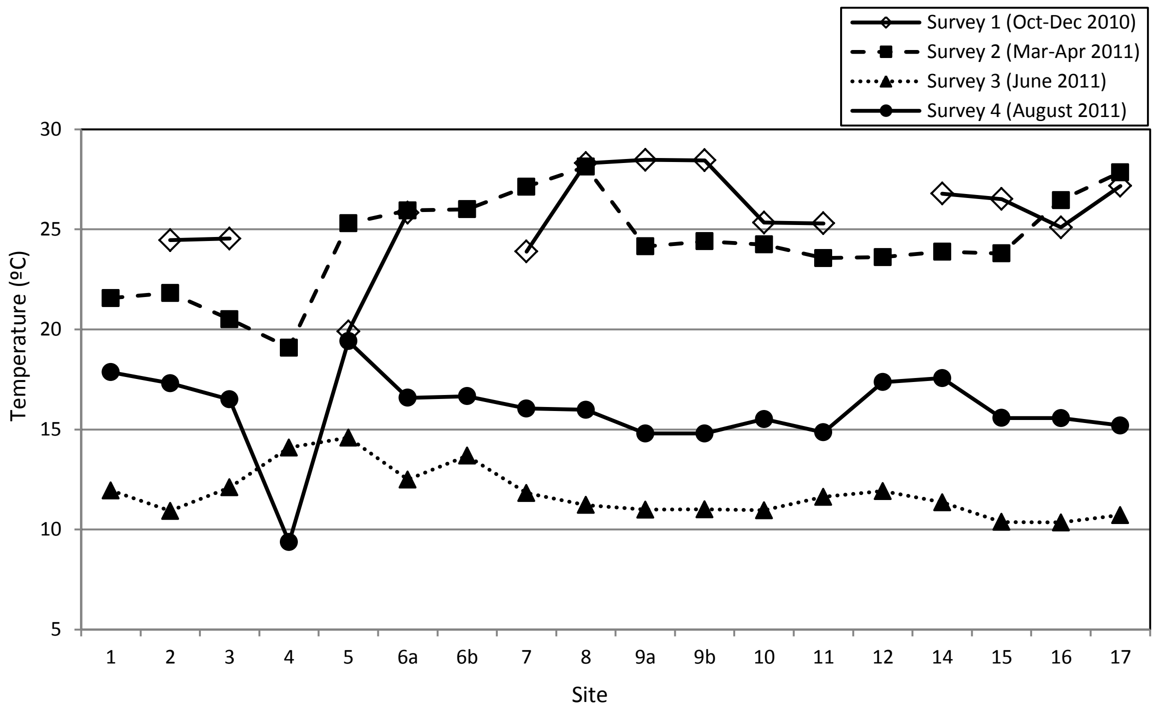

Figure 6.1. Temperature at sites 1 to 17 (average of top and bottom), from the four intervention monitoring surveys of the Darling Anabranch, 2010-2011.

Dissolved oxygen

Dissolved oxygen varied between survey periods and between sites and was generally lower during the first two survey periods, and highest during the peak flow survey in early winter (survey 3, Figure 6.2). Although water levels at most sites had dropped significantly by survey 4 in late winter, DO generally remained higher than at the beginning of flow (Figure 6.2), corresponding with lower water temperatures (Figure 6.1).

The peak in DO recorded at site 5 during survey 4 (Figure 6.2) was associated with shallow water (less than 0.3 m depth) in pools, and the presence of algae throughout the water column (Figure 6.3).

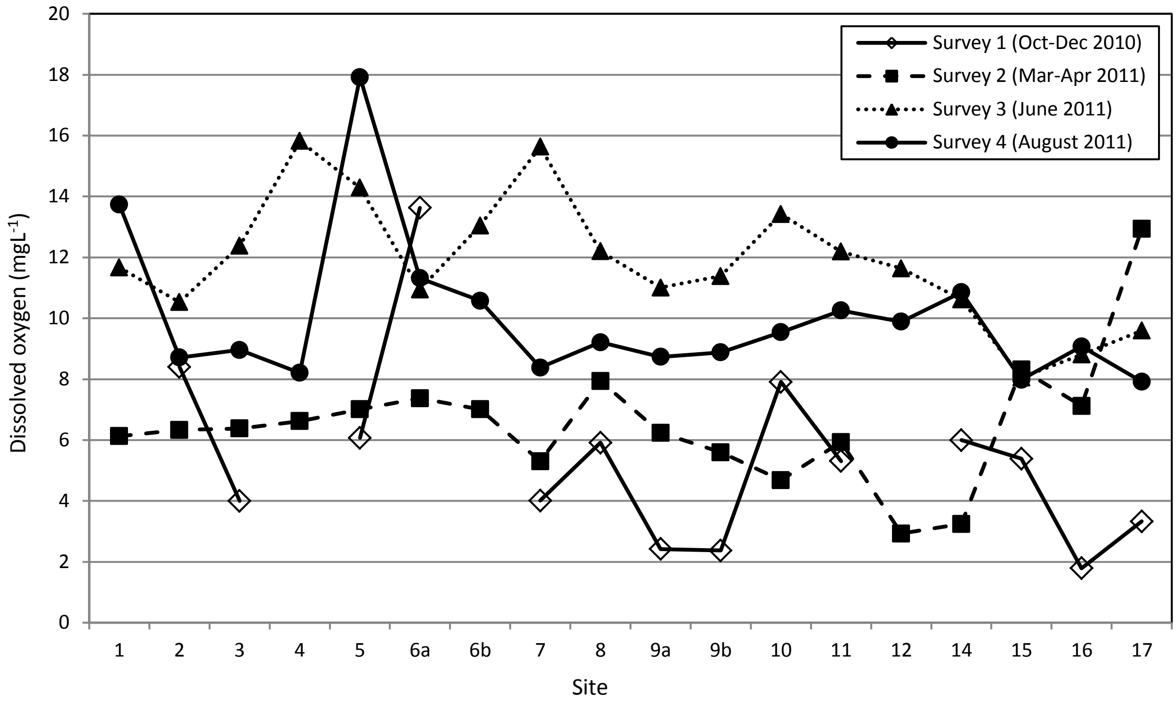

Figure 6.2. Dissolved oxygen at sites 1 to 17 (average of top and bottom), from the four intervention monitoring surveys of the Darling Anabranch, 2010-2011.

Figure 6.3. Pools of water containing algae throughout the water column

Electrical conductivity

Electrical conductivity (EC), measured in μScm^{-1}, estimates the amount of total dissolved salts in the water. All EC records were within the ANZECC guidelines (between 125 and 2200 μScm^{-1} for slightly disturbed lowland river ecosystems, (ANZECC and ARMCANZ 2000)).

During the first survey EC levels were higher at downstream sites (sites 14 to 17) and lowest at upstream sites (sites 2 and 3, and 5 and 6; Figure 6.4). These results suggest that accumulated surface salt has been transported downstream by the initial flow through the system. By the second survey this effect is not reflected in the results, with downstream sites (sites 15 to 17) recording the lowest EC readings (Figure 6.4). This could also be attributed to the influence of the rising Murray River Lock and Weir 9 weir pool, where these sites are situated.

Highest EC was recorded in survey 4 at sites along the Old Darling Anabranch (sites 1 to 4, Figure 6.4). Water levels at these sites had dropped and contracted to pools during this survey period, concentrating salts through evaporation.

Site 6, located on Redbank Creek, displayed consistently lower EC compared to the other sites (Figure 6.4). This is attributed to the constant inflows of water from Lake Cawndilla, which has lower EC compared with discharge over Weir 32 (Figure 6.5).

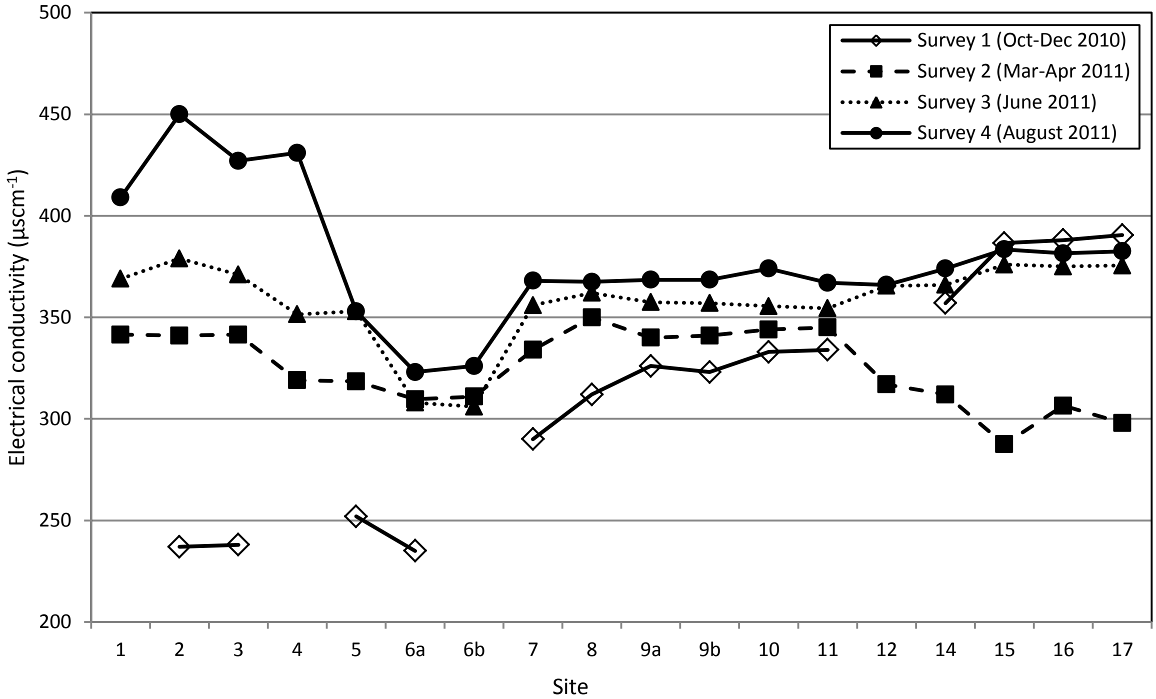

Figure 6.4. Electrical conductivity at sites 1 to 17 (average of top and bottom), from the four surveys of intervention monitoring along the Darling Anabranch, 2010-2011.

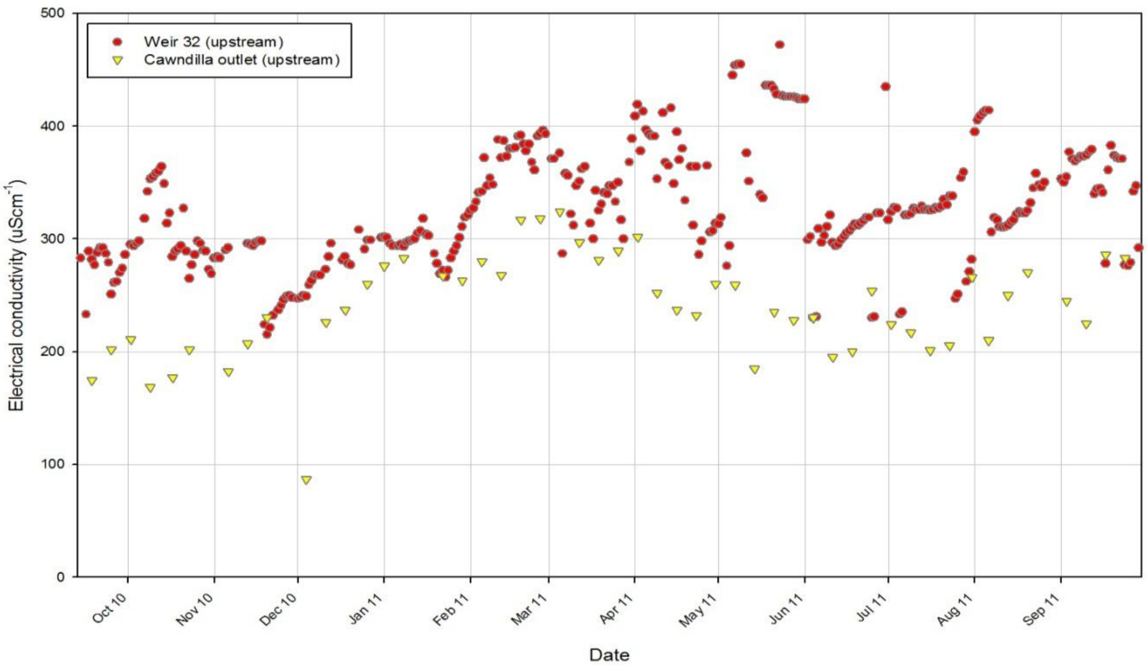

Figure 6.5. Electrical conductivity of Darling Anabranch source water, October 2010 to September 2011.

Turbidity

Turbidity varied widely throughout the Darling Anabranch channel during the four survey periods and was frequently higher than ANZECC guidelines (6 to 50 nephelometric turbidity units (NTU's), for Lowland rivers, (ANZECC and ARMCANZ 2000)) (Figure 6.6).

Lowest turbidity was recorded within the Murray River Lock and Weir 9 weir pool during the first survey (sites 15 to 17), and highest turbidity occurred at site 2 during survey 4 when water in the channel had contracted to shallow disconnected pools (Figure 6.6).

For the Darling Anabranch as a whole, lowest turbidity occurred during survey 3 when flow was receding but water remained relatively deep (Figure 6.6). Survey 2 recorded the highest turbidity results overall (Figure 6.6), which reflect flow conditions at this time – rising flow with high velocity and inundation of the floodplain – and the associated transport of suspended sediments and organic matter.

Site 6 recorded relatively low turbidity throughout the first intervention event, most similar to the downstream weir pool sites (Figure 6.6), reflecting its permanent inundation due to top-up flows from Lake Cawndilla.

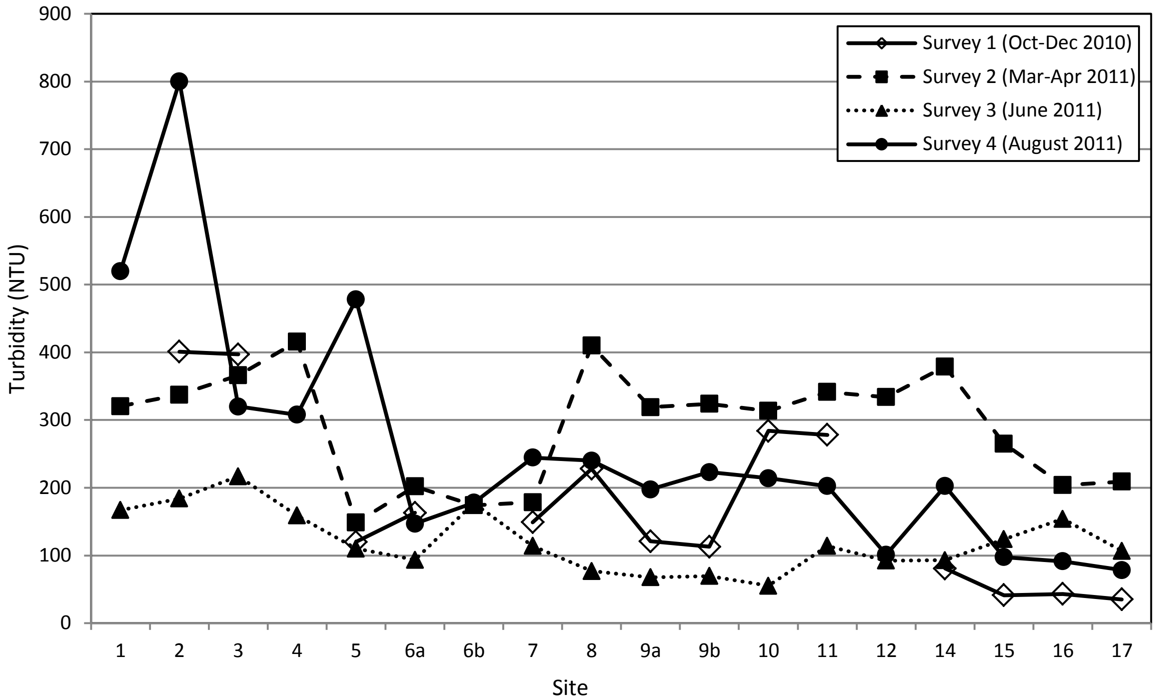

Figure 6.6. Turbidity at sites 1 to 17 (average of top and bottom), from the four intervention monitoring surveys of the Darling Anabranch, 2010-2011.

pH

pH was near neutral to alkaline throughout the Darling Anabranch during the intervention monitoring period (Figure 6.7), exceeding ANZECC guidelines the majority of the time at most sites (upper limit of 8 for lowland rivers, (ANZECC and ARMCANZ 2000)). Lowest pH was recorded during survey 1, except at site 6 which recorded the highest individual pH reading overall, of 9 (Figure 6.7). It is possible that this reading was due to an error with the recording equipment. Generally pH increased over time, with highest pH value recorded at nine of the 17 sites during survey 4 (Figure 6.7).

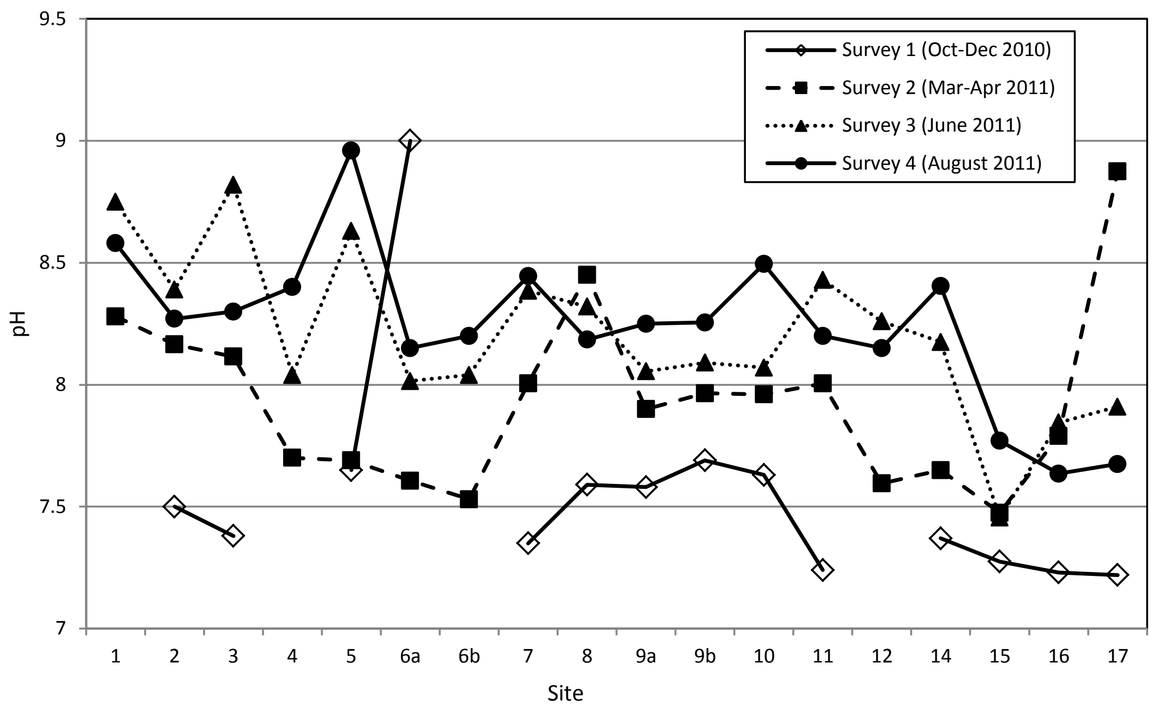

Figure 6.7. pH at sites 1 to 17 (average of top and bottom), from the four intervention monitoring surveys of the Darling Anabranch, 2010-2011.

6.2. Continuous Vertical Profiles

A real-time water quality logging network was established at 183 Dam (Site 9), Toora Station (Site 11) and upstream of Oakbank Dam. The logging network recorded dissolved oxygen (DO), electrical conductivity (EC), temperature and water depth.

Dam 183 (Site 9)

Environmental water reached the 183 Dam water quality logger station at approximately 12:00pm on 28 October 2010, 46 days after leaving Packers Crossing on 13 September 2010.

Dissolved oxygen

Figure 6.8 displays DO recorded from the surface between November 2010 and April 2011. DO concentrations were initially low and fluctuated between 0 and approximately 6 mgL^{-1} until late March 2011 (Figure 6). Flooding of dry sediment often results in depleted oxygen levels in the water column through the breakdown of accumulated nutrients and organic matter (Hladyz et al. 2011), hence the low DO levels recorded during the initial flow are not unexpected. The large irregular fluctuations between late January and late March could be an effect of storm events, which were numerous throughout this period (BOM 2012c) and can cause erratic stratification establishment and break down (K. Whitworth, pers. comm.). The drop in DO in April 2011 coincides with the partial closure of the 183 regulator.

Following the regulator closure, the regular diurnal fluctuations of both DO and temperature at the surface were disrupted, DO levels dropped and water temperature ceased to undergo daily heating and cooling (Figure 6.9). Thereafter DO concentration increased with gradually increasing water levels (Figure 6.10). Separation of dissolved oxygen recorded at the surface and bottom of the water column suggest thermal stratification, supported by the difference in temperature at the surface and bottom (delta T, Figure 6.10).

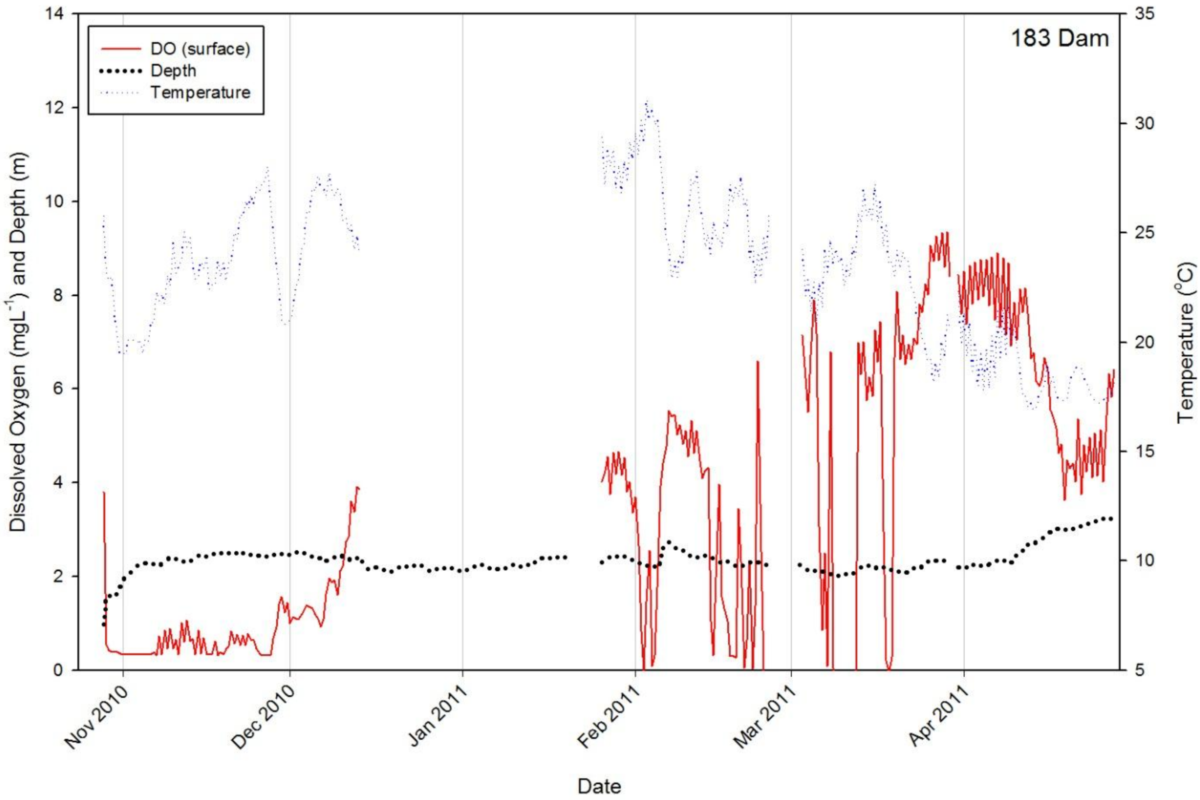

Figure 6.8. Dissolved oxygen (surface), temperature and depth recorded between November 2010 and April 2011 at 183 Dam.

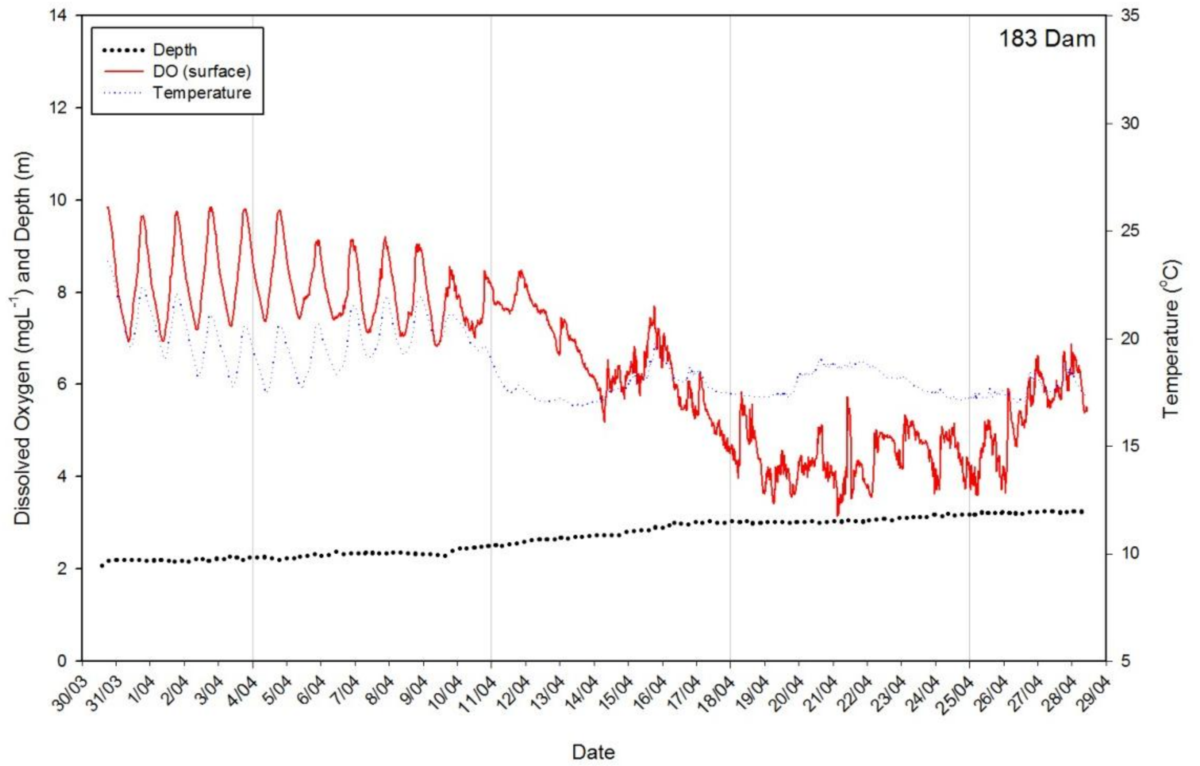

Figure 6.9. Dissolved oxygen (surface), temperature and depth recorded in April 2011 at 183 Dam.

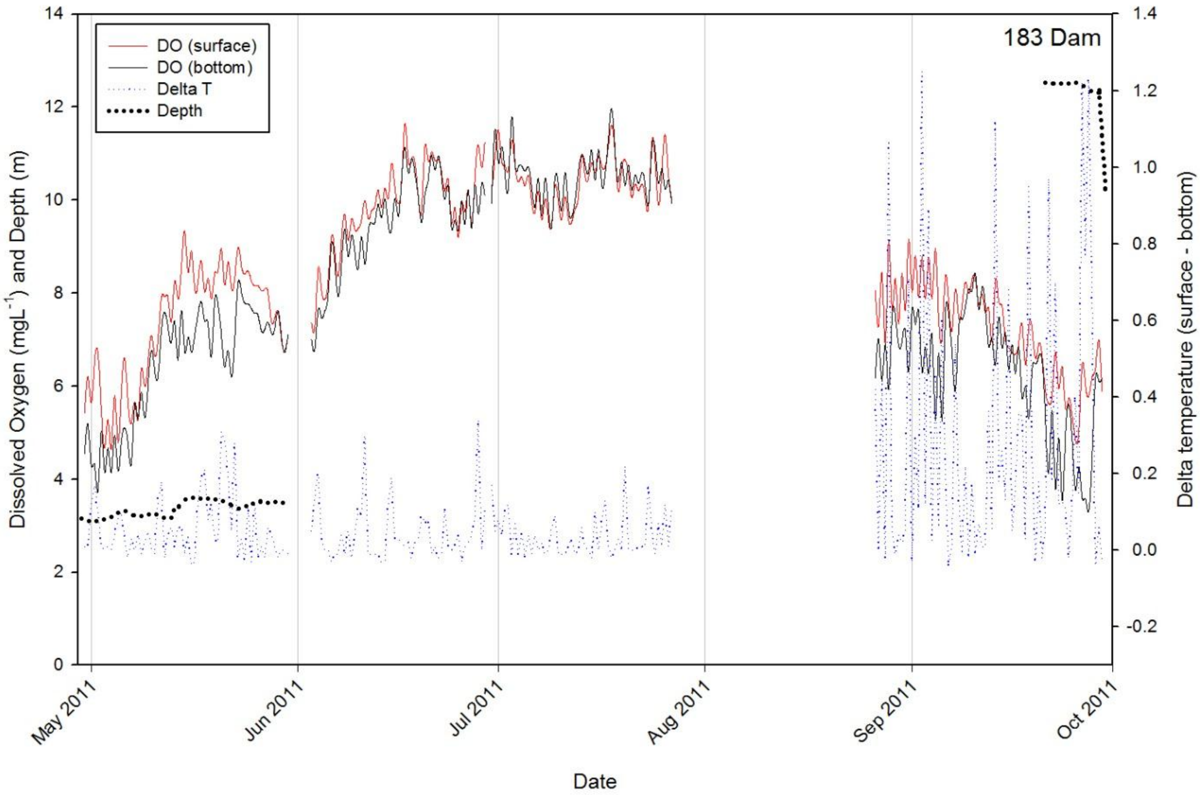

Figure 6.10. Dissolved oxygen (surface and bottom), delta T (difference in temperature between surface and bottom) and depth recorded between May and September 2011 at 183 Dam.

Electrical conductivity, water temperature and depth

The initial flow that reached 183 Dam in late October 2010 displayed a peak in EC of 660 μScm^{-1} for approximately three days (Figure 6.11). Following this, EC remained between approximately 250 and 400 μScm^{-1} for the duration of monitoring (Figure 6.11). Overall water temperature was higher during summer, decreasing gradually over autumn (Figure 6.11). Sharp declines in EC in late November 2010 and early February 2011 are associated with rapid decreases in water temperature (approximately 7 degrees in 60 hours), corresponding with high rainfall events ((BOM 2012b), (BOM 2012c)) (Figure 6.11). The rainfall event in February 2011 (113 mm at Willow Point recorded on 6 February, (BOM 2012c)) resulted in an increase in water depth of over 400 mm (Figure 6.12a), and a decrease of nearly 200 EC (Figure 6.12b).

Water temperature decreased from the beginning of April to the end of May 2011, corresponding with a substantial increase in water depth from approximately 2 metres to around 3.5 metres (Figure 6.13). This was due to the partial closure of the 183 regulator, mentioned above. Additional data from NSW Office of Water for the period between May and December 2011 show that a relatively constant depth is maintained at 183 Dam (Figure 6.14). (Note the difference in actual depth compared with MDFRC data is because measuring instruments are not in the same location.) The drop in water level in December 2011 occurred following the opening of the 183 regulator, and water levels dropped to below March levels (Figure 6.14).

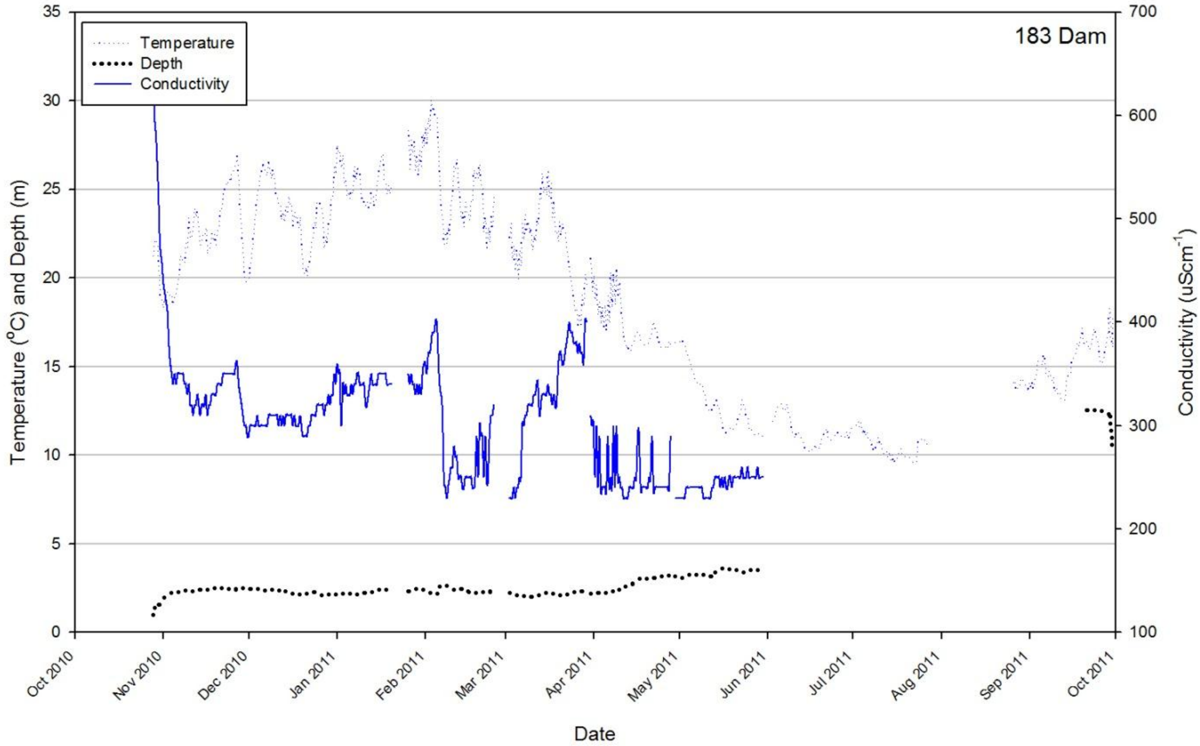

Figure 6.11. Temperature, depth and conductivity recorded between November 2010 and September 2011 at 183 Dam.

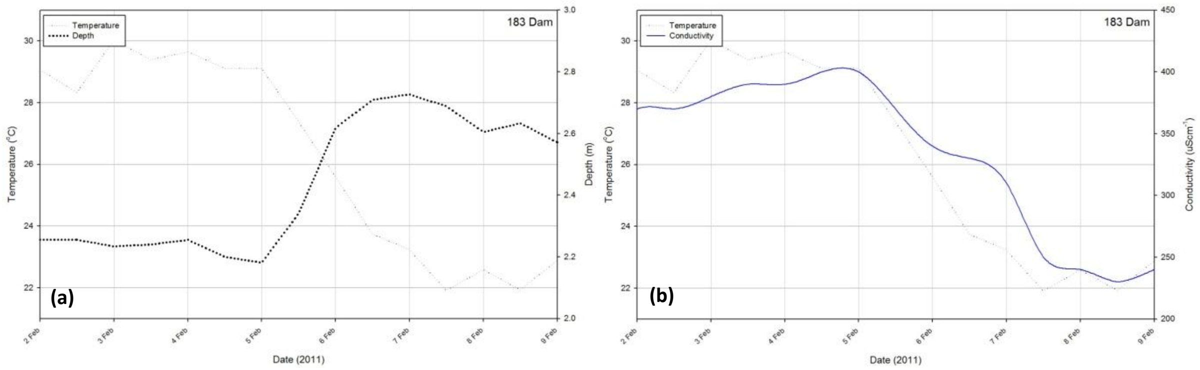

Figure 6.12. (a) Temperature and water depth and **(b)** temperature and electrical conductivity, following the February 2011 rainfall event, 183 Dam.

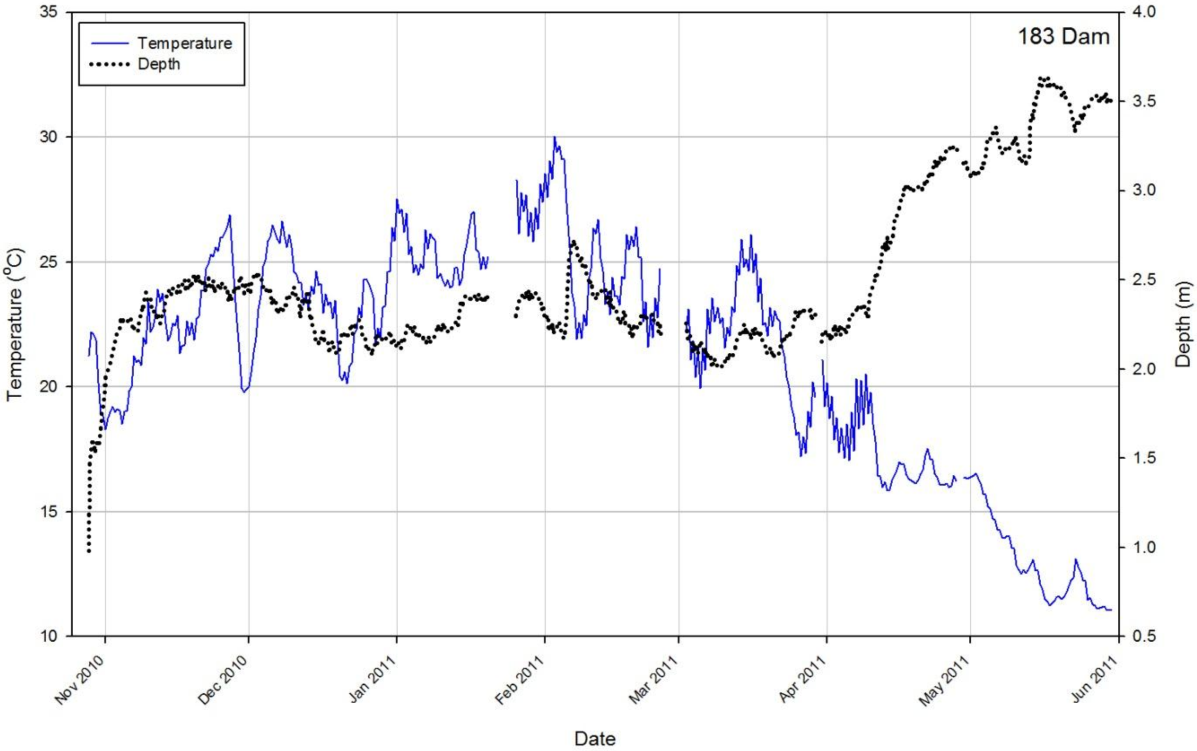

Figure 6.13. Water temperature and depth recorded from November 2010 to June 2011 at 183 Dam.

Figure 6.14. Water depth upstream of 183 Dam. Graph courtesy of NSW Office of Water.

Toora Station (Site 11)

Environmental water reached the Toora Station logger network at approximately 8:30am on 13 November 2010, 62 days after leaving Packers Crossing on 13 September 2010.

Dissolved oxygen

DO levels were low (< 5 mgL^{-1}) during the initial flow, beginning to increase to above 6 mgL^{-1} by February 2011 (Figure 6.15). In March 2011, DO at the surface fluctuated erratically between 0 and 7 mgL^{-1} (Figure 6.15). The difference in DO between the surface and bottom of the water column during this period could be caused by blackwater returning from the floodplain (perhaps runoff from high rainfall events) failing to mix through the water column, resulting in crashes in DO at the surface without affecting the bottom DO (K. Whitworth, pers. comm.). The consistently higher temperatures recorded at the top supports this possible explanation. Storm events can also cause stratification to establish and break down erratically, however usually with DO crashing and recovering at the bottom rather than at the surface (K. Whitworth, pers. comm.).

DO levels at the surface recover to above 8 mgL^{-1} in April 2011, and remain so until late September 2011 (Figure 6.16). An increase in DO from May through June 2011 corresponds with decreasing water temperature (Figure 6.16). The decrease in DO in September is associated with an overall increase in water temperature and decreasing water depth (Figure 6.16). Fluctuations in DO and water temperature for this month virtually mirror one another (Figure 6.16).

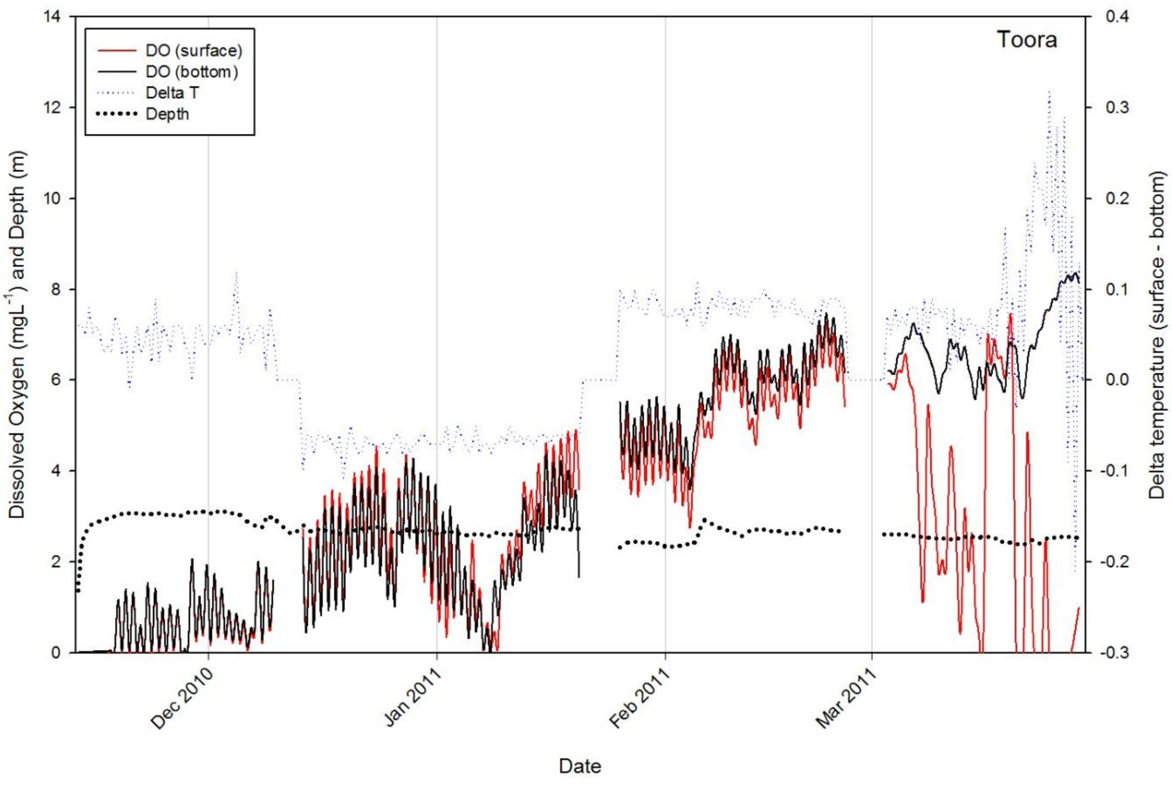

Figure 6.15. Dissolved oxygen (surface and bottom), delta T (difference in temperature between surface and bottom) and depth recorded between November 2010 and March 2011 at Toora.

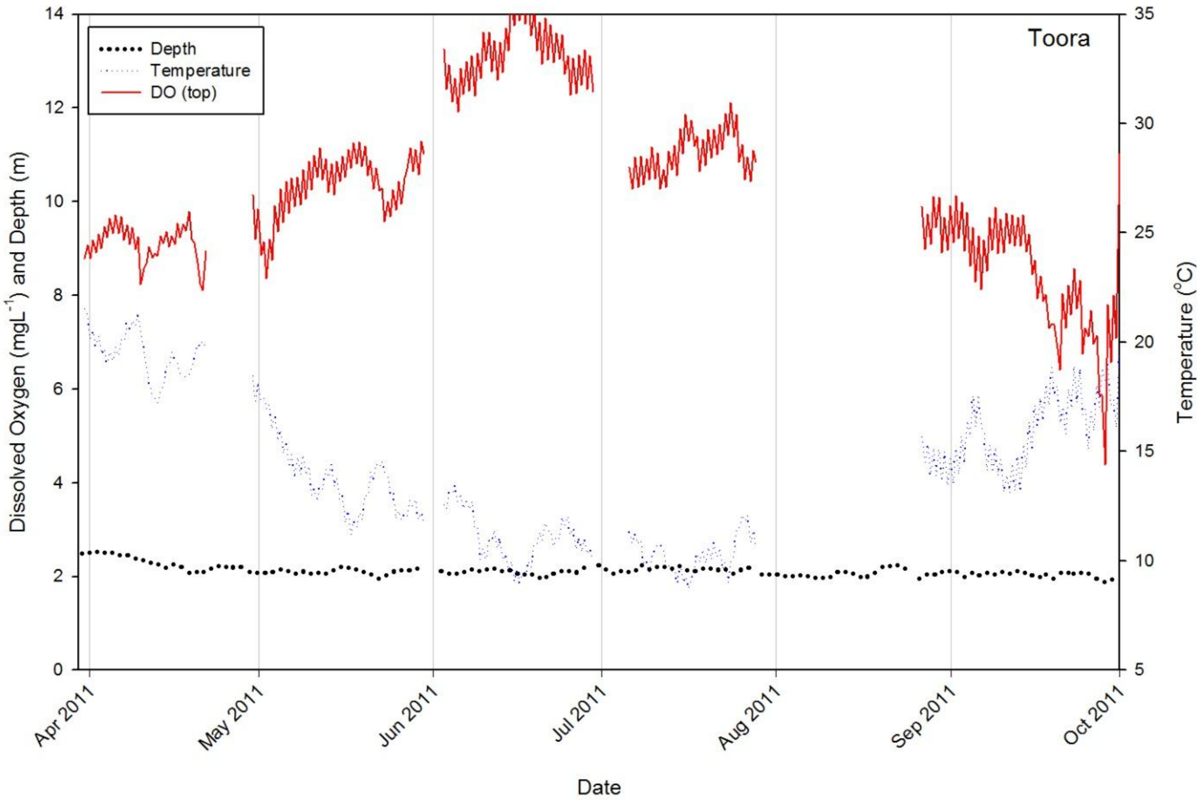

Figure 6.16. Dissolved oxygen (surface), temperature and depth recorded between April and September 2011 at Toora.

Electrical conductivity, water temperature and depth

The initial flow that reached Toora in November 2010 displayed a peak in EC of 640 µScm^{-1} for approximately four days (Figure 6.17). Following this, EC remained between approximately 300 and 400 µScm^{-1} for the duration of monitoring (Figure 6.17). Overall water temperature was higher during summer, decreasing gradually over autumn/winter, and increasing again in spring (Figure 6.17). A decline in EC in early February 2011, associated with a rapid decrease in water temperature (approximately 8 degrees in 48 hours), corresponded with high rainfall on 5 and 6 February (BOM 2012a) (Figure 6.17). Total rainfall over these two days of 129 mm (BOM 2012a) resulted in an increase in water depth of over 600 mm, and a decrease of over 80 EC.

Water levels were highest with the initial flow in November, reaching over 3.1 m, and declined after this with considerable fluctuation, possibly due to runoff from localised rainfall events (Figure 6.18). The large decline in water level in April 2011 corresponds with the partial closure of 183 Dam upstream (refer to 183 Dam above), and water levels remained around 2 m until logging ceased at the end of September (Figure 6.18).

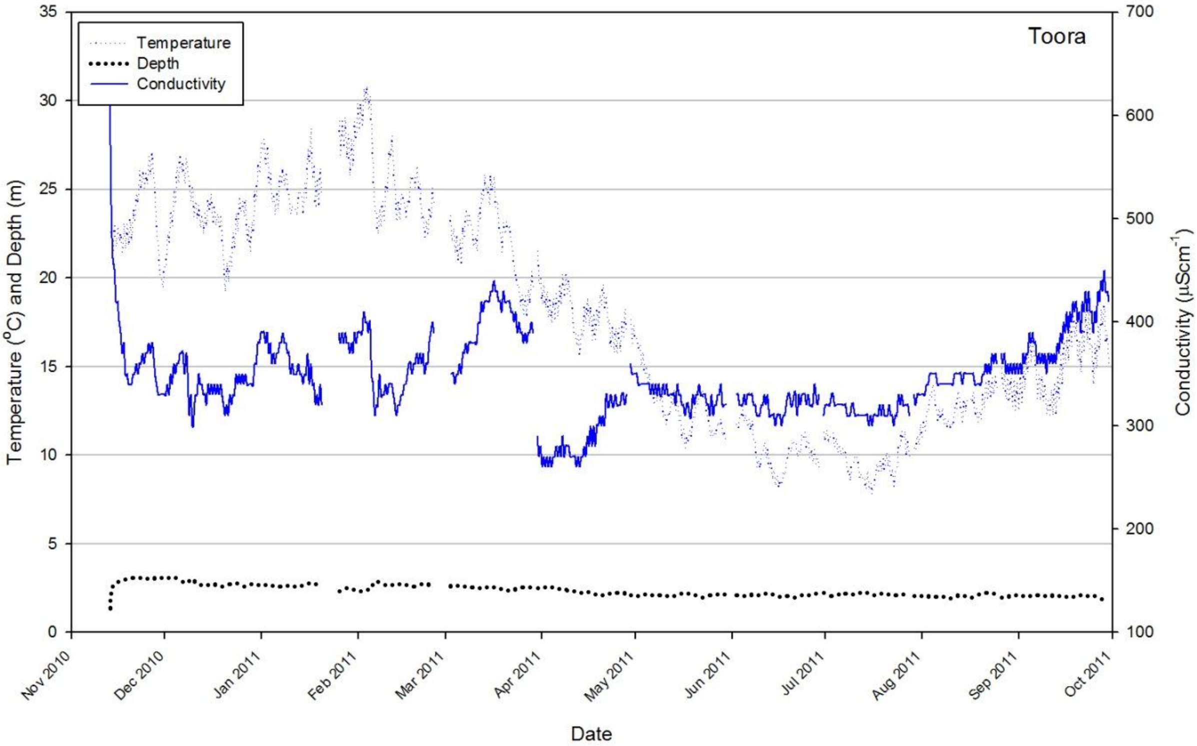

Figure 6.17. Temperature, depth and conductivity recorded between November 2010 and September 2011 at Toora.

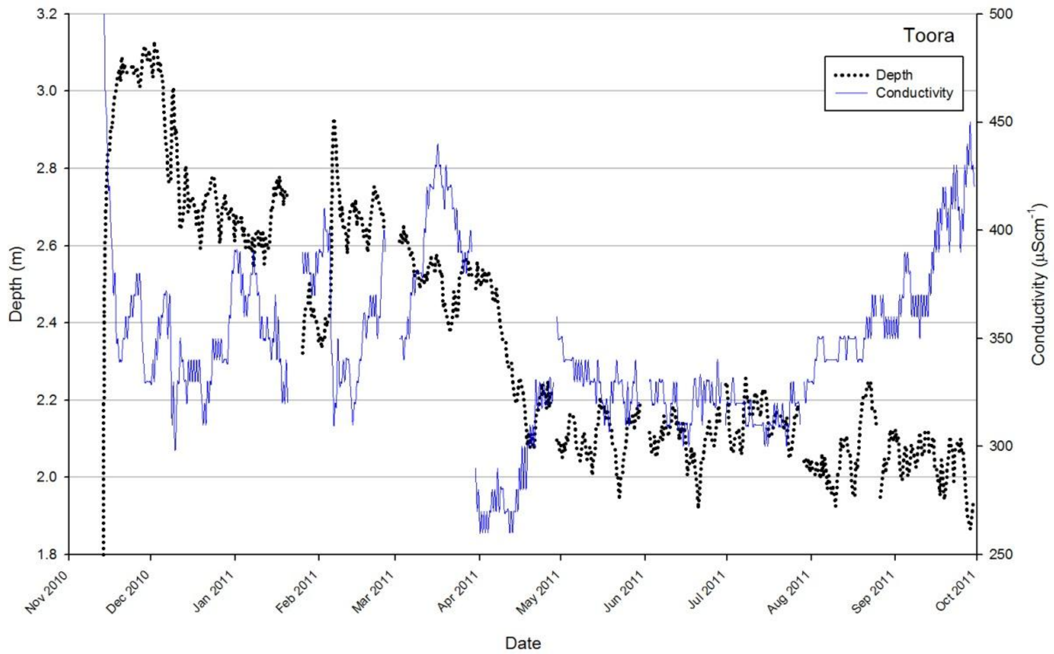

Figure 6.18. Depth and conductivity recorded between November 2010 and September 2011 at Toora Station.

Oakbank Dam

Flows were recorded entering the Murray River at ~ 500MLday^{-1} on 7 December 2010, which suggests that the environmental flow reached the Oakbank Dam logger network in early December, approximately 80 days after leaving Packers Crossing on 13 September 2010.

Dissolved oxygen

DO levels were low (< 5 mgL^{-1}) following the arrival of the environmental flow in December 2010, and remained low until April 2011 (Figure 6.20). The Murray River near the Darling Anabranch outflow experienced low DO levels throughout this period (Whitworth et al 2011). From April through to the end of July 2011 DO levels increased to a maximum of nearly 14 mgL^{-1} at the surface (Figure 6.20). DO readings between March and July 2011 suggest stratification however this is not reflected in the temperature data (Figure 6.20). The difference in DO between the surface and bottom of the water column may be due to insufficient mixing of water flowing down the Darling Anabranch and water backing up from the Murray River Lock and Weir 9 weir pool. The DO probes may also have been affected by biofilms growing on the membrane, resulting in elevated DO readings. This is likely in July when DO at the surface is often above 12 mgL^{-1} (Figure 6.20). Algal films are often observed on the logger stations at this site.

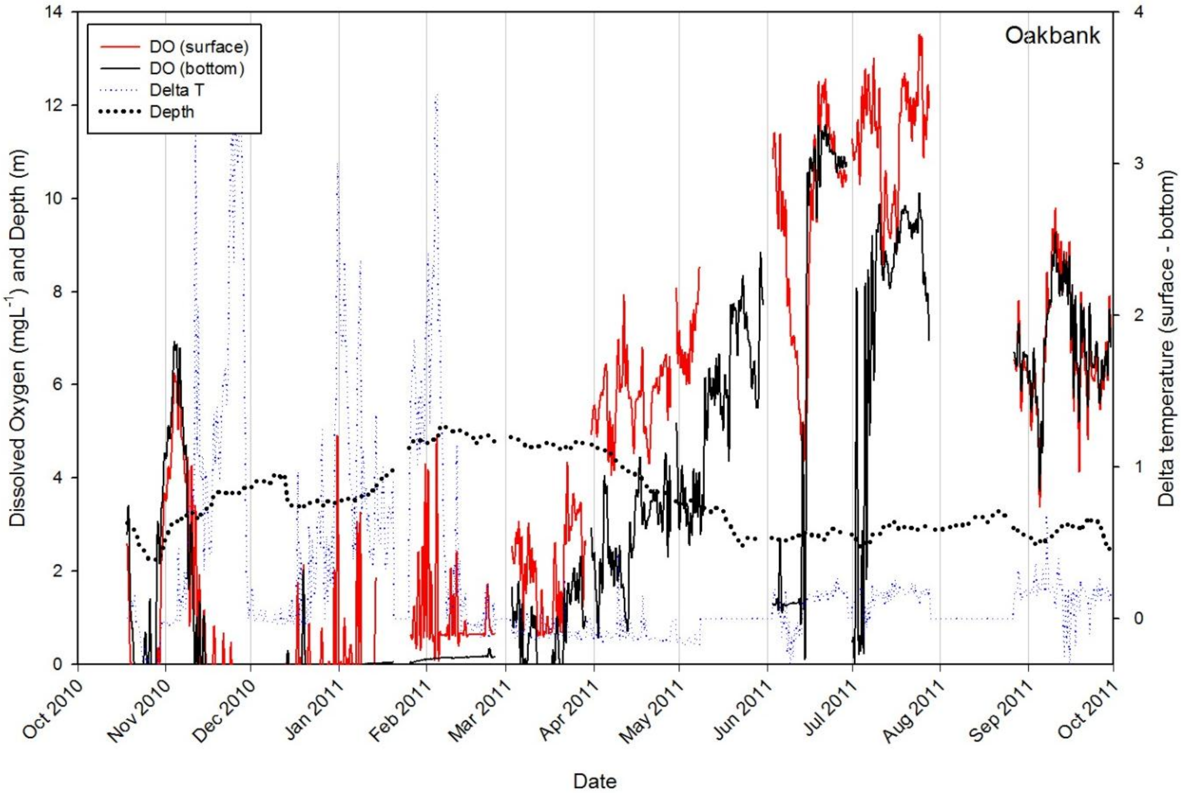

Figure 6.20. Dissolved oxygen (surface and bottom), delta T (difference in temperature between surface and bottom) and depth recorded between October 2010 and September 2011 at Oakbank.

Electrical conductivity, water temperature and depth

The initial flow that reached the Oakbank logger station in December 2010 displayed a peak in EC of 680 µScm^{-1} for approximately three days (Figure 6.21). This was an increase of over 400 EC compared with the Murray River weir pool. Following this, EC was fairly high – between 400 and 500 µScm^{-1} – until mid-February, when it began gradually decreasing (Figure 6.21). After March 2011 EC remained largely between 200 and 400 µScm^{-1} for the duration of monitoring (Figure 6.21). Overall water temperature was higher during summer, decreasing gradually over autumn/winter, and increasing again in spring (Figure 6.21).

Water levels rose from late October to December 2010; flows from the Anabranch had not yet reached Oakbank hence these reflect the increasing levels in the Murray River. After the Anabranch flow reached Oakbank in early December 2010 there was a drop in water level, followed by a steady increase until mid-February 2011 to a maximum depth of 5.17 m (Figure 6.21). Water depth remained high, around 5 m, throughout February and March 2011, then decreased to between approximately 2.7 and 3.2 m for the remainder of the survey period (Figure 6.21). The decline in water level over April/May corresponds with the partial closure of 183 Dam upstream (refer to 183 Dam above).

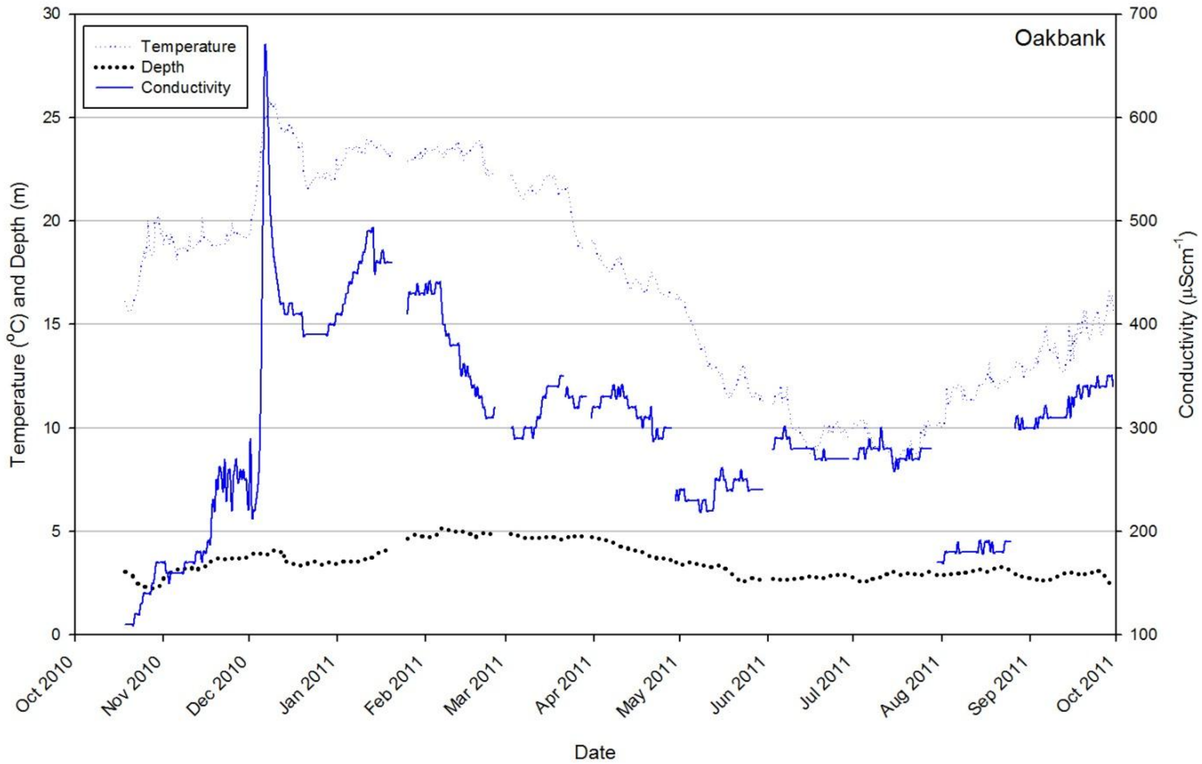

Figure 6.21. Temperature, depth and conductivity recorded between November 2010 and September 2011 at Oakbank.

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