internal report **390**

Diagnosis of a fish kill in Georgetown Billabong near Ranger Uranium Mine on 11 October 2001

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July 2002

supervising scientist

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ENVIRONMENTAL RESEARCH INSTITUTE OF THE SUPERVISING SCIENTIST

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Background

Georgetown Billabong is a shallow back-flow lagoon adjacent to Magela Creek and close to Ranger Uranium Mine. In the wet season it receives water from two sources: water from Magela Creek during backflow and overbank flows that is unaffected by the mine, and water from Georgetown Creek that can potentially be influenced by mining activity. There have been a number of small-scale accidental contamination events on the headwaters of Georgetown Creek during the operation of the mine. The fish community of Georgetown Billabong is monitored annually by ***eriss*** as part of the biological monitoring program for Ranger mine.

On 11 October 2001 ***eriss*** was informed by ERA Ranger Mine Environmental section that a small fish kill had been observed at Georgetown Billabong. Fish kills caused by natural environmental processes are very common in wetlands of the Alligator Rivers Region (Pidgeon 2001). However, since sudden fish kills can also result from some kinds of mine effluent, such as acid mine drainage, ***eriss*** acted quickly to determine whether the fish kill observed in Georgetown Billabong was a natural phenomenon or a result of mining activities.

Procedures

Early in the afternoon of the 11 October a team of ***eriss*** staff visited the billabong to investigate the scale of the fish kill and factors that may be involved.

Fish

The number, size and species of fish affected in the kill and their location were determined by observation from the banks and from a boat in the middle of the billabong on 11 October. The following day a multi-panel gill net was set for 15 minutes to detect the presence of live fish in the billabong. On 15 October Georgetown Billabong was inspected to determine if more fish had died. Three other billabongs, Coonjimba, Gulungul and Baralil, were also visited to determine if fish kills had occurred there recently. Further observations of any dead or dying fish were also made at Georgetown Billabong on 17 and 18 October.

Water quality

Water samples for laboratory analysis of metal concentrations were collected at nine locations along the billabong. At these locations general water quality parameters (pH, Electrical Conductivity, temperature and dissolved oxygen) at the surface and near the bottom were determined using a *Quanta* multi-parameter water meter.

On 12 October the billabong was visited again to determine the physico-chemical structure of the billabong from more detailed depth profiles of the general physico-chemical parameters.

A Datasonde-Hydrolab data logger was deployed to measure changes in water quality over a 24 hour period in the zone where fish died. In particular, this was intended to detect whether night time respiration in the billabong consumed all the available dissolved oxygen creating temporary anoxic conditions. The logger was set to measure dissolved oxygen, pH, electrical conductivity and temperature at 30 minute intervals. On 15 October the probes were placed at a depth of 0.4m for 24 hours. On 17 October the probes were raised to a depth of 0.15m and run for 5 days.

Fish contamination

One large barramundi that was alive, but disabled and near death, was collected on 11 October and tissue samples (muscle, liver, and gills) were taken for chemical analysis of heavy metals. The tissue samples and water samples were forwarded to an external chemical laboratory for analysis.

Results

Fish

A total of 26 fish were found dead or dying on 11 October in Georgetown Billabong. Most of the fish bodies were floating near the outflow end of the billabong in the deepest area of the water body. The fish comprised 25 barramundi (*Lates calcarifer*) 600 to 850 mm in length and one banded grunter (*Amniataba percoides*) 210 mm long.

The dead fish displayed a range of stages of decomposition from several quite fresh fish that may have died that morning to well bloated bodies that could have died two or three days earlier. The barramundi appeared to be well conditioned fish with deep bodies and thick lateral muscle mass. Only one fish, a barramundi was observed to be dying at the time of observation (1400h–1600h). The dying fish was captured as it swam in a disoriented manner in shallow water. It was dissected for tissue samples and had large fat deposits in its abdominal cavity.

A mixed flock of about 30 black kites and whistling kites had gathered at the billabong attracted by the carcasses. These birds were observed eating at least one fish body that had been dragged several metres from the water There were also a number of pied herons and little egrets that could have consumed any floating small fish that drifted into shallow water. It is therefore possible that many more fish than those counted had died.

On Monday 15 October one new disabled, but still alive, barramundi was observed at Georgetown Billabong but no dead fish were observed at the other billabongs examined. On 17 October a further two disabled barramundi were observed at Georgetown Billabong. These fish were estimated to be approximately 500 mm long. They were swimming at the surface in a very disoriented manner in very shallow water at the upstream end of the billabong that they would not normally enter during the day.

The gill net deployed briefly in the deep outflow end of the billabong on 12 October captured 2 fork-tailed catfish (*Arius leptaspis*) 300 and 400 mm long, 3 longtom (*Strongylura kreftii*) 300–380 mm long and 3 tarpon (*Megalops cyprinoides*) 300–350 mm. This indicated that there were other medium sized fish species present that had survived the adverse conditions that killed the larger barramundi.

The range of stages of decomposition of dead fish indicated that fish mortality had occurred over a protracted period but there was probably an initial pulse of mortality involving the largest fish in the billabong just prior to 11 October. No sign of fish kills was evident at other nearby shallow billabongs on 15 October.

Water quality

General parameters

It is normal at this time of year in Top End billabongs and swamps for water levels to decline rapidly and for water quality to deteriorate as well. By 11 October 2001 the water body in Georgetown Billabong had shrunk to an area of about 600m long by 40–50 m wide (about half its length in the wet season) and its depth had declined considerably (figure 1). This left two basins 1–2 m deep in the centre, each about 80 m long, with the remaining area less than 0.5 m deep.

The water was very turbid and this was probably a result of substrate disturbance by large vertebrates. There had been considerable activity by feral pigs digging around the margins of the water and in the water among the *Eleocharis* stands at the shallow upstream end. This activity caused extensive disturbance to the substrate and a general thinning of the aquatic vegetation. There were also 100–150 magpie geese present. These were also observed foraging along the margins and in the *Eleocharis* stands by digging in the mud causing further substrate disturbance.

Field measurements of pH were around 6.4 (table 1) which is normal for billabongs along Magela Creek at this time of year (Hart & McGregor 1982). There was little change in pH with depth. Also pH values were similar at all locations so there was no evidence of a longitudinal gradient that would indicate an input of acidic water from mine effluent via Georgetown Creek.

Conductivity, temperature and dissolved oxygen (table 1) showed some stratification of the water mass at this time of day (mid afternoon). Both dissolved oxygen and temperature were considerably higher near the surface than near the bottom while conductivity was consistently higher near the bottom.

The depth profile of these parameters (figure 2) showed that the warmer and oxygen rich water occupied a layer less than 30 cm deep. The conductivity gradient also showed a marked change below about 50 cm deep indicating that diurnal mixing of the surface layers was generally not extending below that level.

Table 1 also shows that at the time of this fish kill physico-chemical conditions in the water could vary somewhat from day to day. The temperature and dissolved oxygen concentration of the surface layer were much lower on the 11 October than on the 12 October. This was most likely a result of a storm that occurred on the 11 October during the water measurements. The cloud cover associated with the buid up to the storm undoubtedly affected these values by reducing the amount of light for photosynthesis, and hence oxygen production in the water, and solar radiation for heating the water. The rainfall would have then caused a pulse of surface aeration that would have temporarily increased dissolved oxygen levels at the surface. There was no storm the following day and there was only scattered light cloud in the afternoon when measurements were made enabling much higher surface dissolved oxygen levels and higher water temperature to develop.

These measurements indicated that during the day there was adequate oxygen for fish and other biota (more than 1 mg/L) near the surface but insufficient oxygen below 50cm. However, the problem for fish often happens at night when there is no photosynthesis to add oxygen to the water and all the oxygen available in the water is consumed by the animals, plants and microbes associated with decaying plant material and other organic matter. The occurrence of this phenomenon was examined with the Datasonde-hydrolab logging dissolved oxygen and other parameters.

The results from the logger placed at a depth of 40 cm on 15–16 October showed that in the deeper water layer the dissolved oxygen levels remained very low (less than 0.8 mg/L) throughout the 22 hour measurement period (1600 h to 1430 h) (figure 3). There was also a decline through the evening from around 0.8 mg/L at sunset to around 0.4 mg/L around midnight. From sunrise until midday when the logger was removed there was no increase in dissolved oxygen at this depth so that for a large part of the day there was very little oxygen available in the deeper water of the billabong.

A different diurnal pattern of oxygen dynamics was shown when the logger was placed near the surface. There were three patterns of change each day (figure 4) when storms occurred:

1. a gradual increase during the day associated with photosynthesis;
2. sudden larger increases in dissolved oxygen associated with storm events, usually late afternoon or early evening;
3. a rapid drop in dissolved oxygen soon after the storm increase and then a more gradual decline during the rest of the night.

As there had been no rain prior to the fish kill observation it is most likely that similar conditions, or worse, pertained at that time. With storms occurring on most days after the fish kill the daily minimum dissolved oxygen levels climbed to around 1.5 mg/L averting the danger of any further fish kills, even if some large barramundi still remained in the billabong. The rain also caused an increase of 0.3m in water depth. The increased volume of the billabong and higher oxygen concentrations would have greatly improved the conditions for fish.

Water chemistry

Results of metal analyses from the water samples are shown in table 2. Levels of copper, manganese and uranium were elevated in comparison to other shallow billabongs in the region (Cameron, pers.com) showing the influence of mining activity in the catchment of Georgetown billabong. Manganese and uranium concentrations were well below the environmental health and public health limits and the lowest recorded NOEC for fish.

Copper levels exceeded the environmental health trigger but not the public health limit or the lowest recorded NOEC for fish. Thus, it is not likely to have been responsible for any fish mortality.

Aluminium concentrations were within the range of uncontaminated shallow billabongs in the region. Most of these billabongs exceed the ANZECC & ARMCANZ 2000 environmental health trigger for low pH (<6.5) waters and some also exceed the lowest NOEC or LC_{50} for fish. However, the trigger values and LC_{50} levels for aluminium in high pH water (pH>6.5) are considerably higher and the aluminium levels in Georgetown Billabong did not exceed these values. Given that the pH in the billabong (6.42–6.61) was close to 6.5 the higher trigger values may be more appropriate in this instance. Also, the toxicity of aluminium to fish in natural waters can be influenced by other chemical parameters such as dissolved organics and silica (Camilleri et al 2001) and their effects on relatively low levels such as those indicated here in surface waters of this region is not well understood.

Zinc values were also high but showed such a wide range (1–138 ug/L) that some of the results undoubtedly reflect sample contamination rather than true environmental levels. Zinc determinations are notorious for these effects. Consequently it is not possible to use these data in this diagnosis

Fish contamination

There is generally little information on the toxic effects of metals in fish tissue to the health of the fish making it difficult to make inferences about the consequences of different levels of metals measured in fish monitoring programs (Lloyd 1992). Metal concentrations in liver, muscle and gill tissue from the dying barramundi in Georgetown Billabong (table 3) were within the range for healthy fish measured by ***eriss*** in bioaccumulation studies of metals in fish in 2002. It is, therefore, unlikely that any of these metals were responsible for the fish kill.

Values for public health limits could only be obtained for three of the metals measured and all tissues were well below those values. Consequently there would be no public health risk from metal contamination from eating fresh fish from this water body.

Conclusions

Whilst the water chemistry of Georgetown Billabong displayed evidence of low level contamination from mining with slightly elevated levels of uranium, manganese and copper, only copper exceeded the ANZECC & ARMCANZ 2000 environmental health triggers. However, none of the metals, including copper, exceeded the lowest recorded NOEC or LC_{50} for fish in ANZECC & ARMCANZ 2000. Consequently, it is highly unlikely that mine waste contaminants were involved in this fish kill and fish mortality was a result of natural processes adversely affecting the water quality for fish.

None of the metals exceeded the ARMCANZ 1996 Public Health limit for drinking water or the ANZFA 2002 limits for fish tissue for human consumption indicating little risk from metal contamination from human consumption of the water or fish from this billabong.

The most likely cause of the fish kill was hypoxic conditions resulting from natural environmental factors. This conclusion is based on the presence of hypoxic conditions soon after the fish kill and the confinement of fish mortality to larger fish of one species. The latter is more consistent with the effect of low oxygen concentrations than with the toxic effects of dissolved metals which would be expected to affect a wider range of species and affect smaller fish more severely than larger fish. The continued mortality over a number of days is also consistent with effects of metabolic oxygen depletion observed elsewhere in Kakadu (e.g. Goose Camp Billabong).

The hypoxic conditions were caused by nocturnal depletion of oxygen in the surface oxygenated layer of the thermally stratified water body. In the days following this fish kill dissolved oxygen in Georgetown Billabong declined on most evenings to concentrations of around 1 mg/L near the surface and even lower concentrations (around 0.5 mg/L) at greater depth. In the absense of storms prior to the fish kill it is reasonable to presume that even lower dissolved oxygen levels were reached at night and this is the most likely cause of fish mortality. The hypoxic conditions that occurred provided lethal conditions for larger fish (2+ or older barramundi) with a large total oxygen demand but there was clearly just enough oxygen for other, mostly smaller, fish of various species to survive.

A number of natural factors would have combined to contribute to creating this adverse situation for fish. The most important factor is likely to have been evaporation causing a decline in water volume and hence a decline in the total potential amount of oxygen available to the aquatic biota. High water temperature at this time (28 – 36C) decreases the solubility of oxygen and hence the total potentially available oxygen. It also increases the metabolic rate of microbes which increases the total oxygen demand of the billabong further increasing the potential for total oxygen depletion at night.

Bioturbation by feral pigs and magpie geese digging for food in the sediments of shallow areas was another obvious process adversely affecting the water quality of the billabong. The resulting increased turbidity would have reduced potential oxygen input to the water from photosynthesis by reducing amount of light available to plants and algae. The disturbance would also have caused suspension of dead organic matter accumulated on the bottom and in the sediments in anoxic conditions to more aerobic conditions in the water column, thereby increasing the rate of microbial respiration in the water column and hence total oxygen consumption.

References

ANZECC & ARMCANZ 2000. *Australian and New Zealand guidelines for fresh and marine water quality*. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

ARMCANZ 1996. *Australian Drinking Water Guidelines 1996*. National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra ACT.

ANZFA 2002. Food Standards Code. Australia New Zealand Food Authority, Website www.anzfa.gov.au.

Camilleri C, Markich SJ, Noller BN, Turley CJ, Parker G & van Dam R 2001. Silica reduces the toxicity of aluminium to a tropical freshwater fish. Internal Report 381, Supervising Scientist, Darwin. Unpublished paper.

Hart BT & McGregor RJ 1982. *Water quality characteristics of eight billabongs in the Magela Creek catchment*. Research report 2, Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

Lloyd R 1992. *Pollution and freshwater fish*. Fishing News Books, Blackwell Scientific Publications Ltd, Oxford.

Pidgeon B 2001. Natural causes of fish kills in Top End waterways. NATURAL FISH KILLS, ***eriss note*** December 2001.

Acknowledgements

We thank Chris LeGras, David Norton, James Palmer, Wayne Barbour, and Clinton Mc Cullough of ***eriss*** who responded quickly to the report of this fish kill event to assist in providing the information for this diagnosis. Chris Le Gras also provided valuable advice on chemical analysis and Paul Martin kindly calculated the probable public health limit for uranium in fish tissues. The fish kill was reported to ***eriss*** by Nadine Reithmuller of ERA and we are grateful for her prompt advice.

Table 1 General water quality parameters in Georgetown Billabong on 11 and 12 October 2001

		pH		Dissolved Oxygen (mg/L)		Conductivity (μS/cm)		Temperature (^oC)	
Date	Depth	mean	SD	mean	SD	mean	SD	mean	SD
11-10-01	Surface	6.42	0.09	2.28	1.11	90	8.7	30.6	1.1
(n = 9)	Bottom	6.46	0.13	0.49	0.26	131	11.44	28.04	0.49
12-10-01	Surface	6.61	0.12	6.06	1.43	84	5.21	36.31	1.11
(n = 5)	Bottom	6.42	0.27	0.36	0.17	110.6	12.79	28.16	0.54

Measurements taken at mid afternoon (1400–1600h)

Table 2 Metal concentrations in water samples from Georgetown Billabong on 11 October 2001 following a fish kill compared to environmental and public health limits and lowest No Observable Effect Concentration (NOEC) for fish in published toxicity tests

Metal	Units	Range		Mean	SD	Environmental health limit	Lowest NOEC	Public health limit [2]
		Min -	Max			(95% trigger)[1]	for fish [1]	
Al	µg/L	10.4 -	36.4	25.87	8.08	0.8	15	100
Cd	µg/L	0.01 -	0.02	0.01	0.00	0.2	0.5	2.0
Cr	µg/L	0.4 -	0.6	0.44	0.07	1.0	61	50
Cu	µg/L	1.26 -	2.05	1.59	0.24	1.4	2.6	2,000
Fe	µg/L	32 -	92	52.11	21.17	300	1500	300
Mg	mg/L	4.3 -	5.4	4.94	0.36			
Mn	µg/L	0.49 -	102.5	30.03	41.69	1700	1270	500
Ni	µg/L	0.44 -	0.83	0.60	0.14	11	13.7	20
Pb	µg/L	0.03 -	0.11	0.05	0.03	3.4	5.65	10
U	µg/L	0.22 -	0.44	0.31	0.08	5	400	20
Zn	µg/L	1 -	138.2	70.43	46.87	8	24	3000

All samples filtered <0.45um; n = 9.

[1] ANZECC & ARMCANZ 2000

[2] ARMCANZ 1996

Table 3 Metal concentrations in liver, muscle and gill tissue from a disabled barramundi (*Lates calcarifer*) in Georgetown Billabong, 11 October 2001

Metal	Units	Liver	Muscle	Gills	Public health limit [1]
Al	mg/kg	<10	<10	63	ND
Cd	mg/kg	<0.05	<0.05	<0.05	**0.05**
Cr	mg/kg	<2	<2	<2	ND
Cu	mg/kg	9.9	0.3	3.1	ND
Fe	mg/kg	955	14	336	ND
Mg	mg/kg	211	1342	707	ND
Mn	mg/kg	9.7	0.6	14	ND
Ni	mg/kg	<0.2	<0.2	0.3	ND
Pb	mg/kg	<0.1	<0.1	<0.1	**0.5**
U	mg/kg	<0.05	<0.05	<0.05	**0.18**[2]
Zn	mg/kg	34	11	60	ND

[1] ANZFA 2002

[2] Derived from the ANZECC and ARMCANZ 2000 calculation of safe levels for drinking water assuming solid food is 90% of diet and average ingestion by an adult is 2 kg/day.

ND No data available

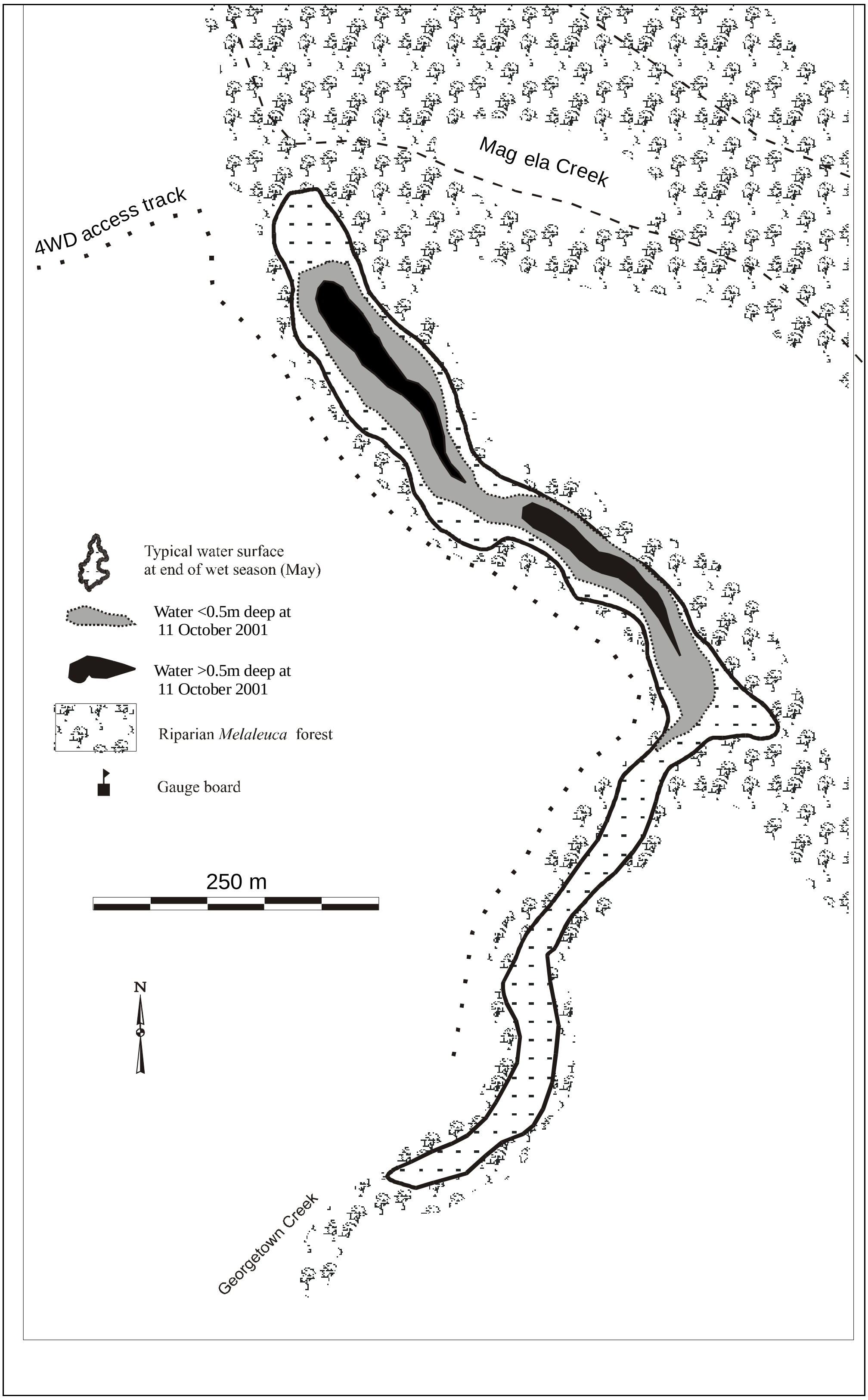

Figure 1 Map of Georgetonw Billabong, Magela Creek showing area of water of 11 October 2001 compared to typical area at end of wet season (May).

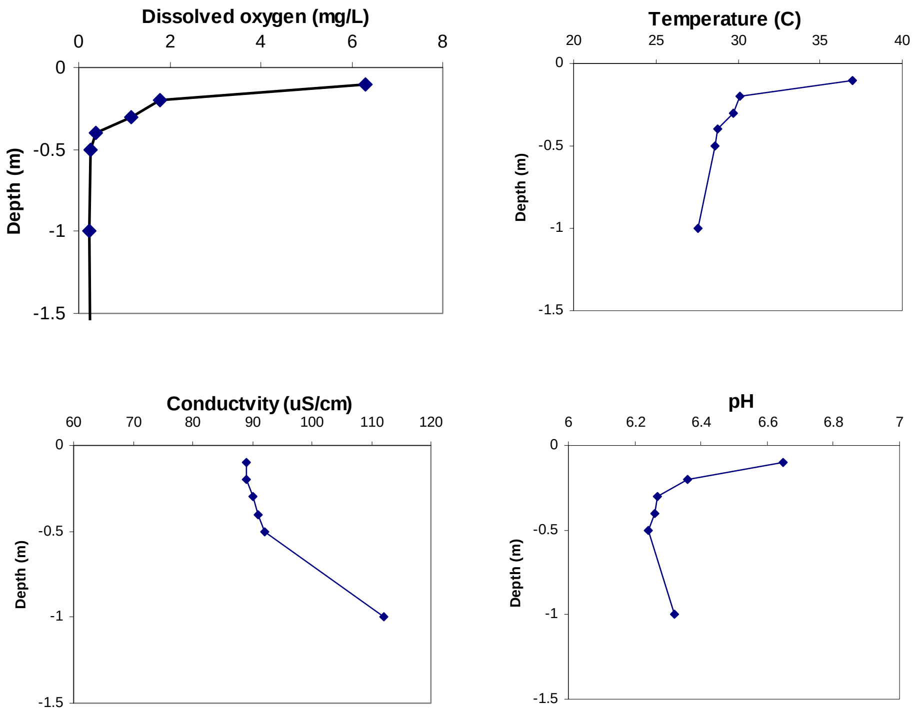

Figure 2 Depth profile of water quality parameters in Georgetown Billabong on 12 October 2001 at 1400 hours.

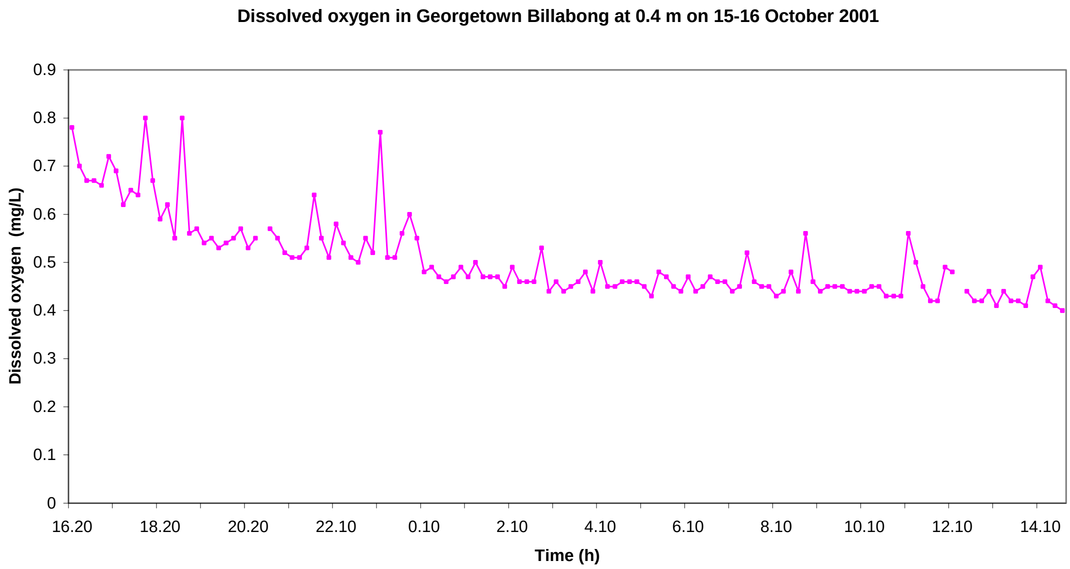

Figure 3 Diurnal pattern of dissolved oxygen at 0.4 m deep in Georgetown Billabong on 15–16 October 2001

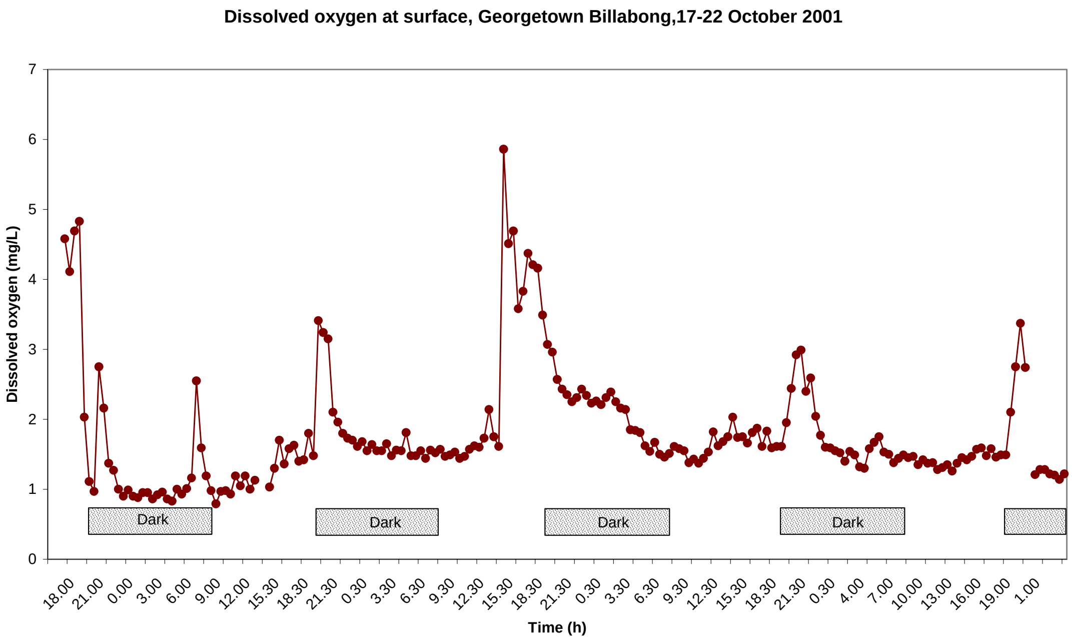

Figure 4 Diurnal pattern of dissolved oxygen at the surface (0.15 m) over 5 days from 17 to 22 October 2001. Sudden increases in dissolved oxygen were associated with rain storms.