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Drought contingency monitoring at Back Creek, New South Wales

Final report prepared for the Murray–Darling Basin Authority by The Murray–Darling Freshwater Research Centre.

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Postal Address GPO Box 1801, Canberra ACT 2601
Office location Level 4, 51 Allara Street, Canberra City
Australian Capital Territory

Tel: (02) 6279 0100 international + 61 2 6279 0100
Fax: (02) 6248 8053 international + 61 2 6248 8053
E-Mail: info@mdba.gov.au
Website: http://www.mdba.gov.au

For further information contact the Murray-Darling Basin Authority office on (02) 6279 0100

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Cover images: Site B2 of Back Creek in (left) February 2010 three months after refilling had commenced, (top right) June 2008 after the creek had dried completely and (bottom right) September 2007 upon commencement of the project. Photographers: R. Durant and C.J. Reid, MDFRC.

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Executive summary

Back Creek is a 9.5 km-long wetland on the Edward–Wakool River system located 20 km north-west of Deniliquin, New South Wales. In 2007, it was selected for disconnection from Yallakool Creek (subsequently the Edward River) to achieve water savings as part of drought contingency planning. The Murray–Darling Basin Commission (now the Murray–Darling Basin Authority) engaged The Murray–Darling Freshwater Research Centre (Contract No. MD962) to monitor changes in the environmental condition of the wetland to detect and respond to risks of environmental damage. This report deals only with the outcomes and implications of this monitoring and does not present the broader details of the program.

Ecological indicators monitored at Back Creek included sulfidic sediments, water levels and quality, blue-green algae, fish, river red gum, vegetation community, birds and groundwater. Twelve tri-monthly surveys were undertaken during the monitoring period from 6 September 2007 to 7 June 2010. Monitoring results were assessed against pre-determined 'trigger values' for management notification based on Wallace et al. (2007), Department of Water and Energy (DWE 2007) and Baldwin et al. (2007). These trigger values provide a point at which managers should assess if an intervention is required.

Sulfidic sediments

Sediments at sites B2, B3 and B5 ranged from pH 4.1–4.4 and therefore met the pH <4.5 trigger value in the decision support tool of Baldwin et al. (2007) for determining the risk sulfidic sediments occurring at a wetland. A subsequent and detailed analysis of sediment cores found only low levels of sulfidic materials at Back Creek and therefore a low risk of acidification to the wetland if dried (Baldwin et al. 2008). The surface water pH of >6 at Back Creek following wetland drying and refilling provided evidence that wetland acidification did not occur.

Water levels and quality

Back Creek was partially dry before the first monitoring event in September 2007 and before the installation of the regulator (and gauge) in November 2007. The water level decreased through evaporation and the wetland dried completely (zero point on gauge) by 16 April 2008, remaining dry for ≈20 months. On 26 November 2009 the regulator at Back Creek was opened and the wetland refilled rapidly with water from Yallakool Creek, peaking at 1.8 m at the gauge.

- The mean electrical conductivity of surface water ranged from 118 to 1,830 µS.cm^{-1} before wetland drying and 52 to 61 µS.cm^{-1} after refilling. The highest electrical conductivity of 1,830 µS.cm^{-1} was recorded immediately before complete wetland drying when the evapo-concentration of salts had occurred. This was the one occasion that electrical conductivity exceeded the 1,000 mg.L^{-1} (≈1500 µS.cm^{-1}) trigger value of Wallace et al. (2007). All readings were below the 5,000 µS.cm^{-1} trigger value of Department of Water and Energy (2007).
- Mean surface water pH ranged from 5.75 to 7.98 before wetland drying and 6.35 to 7.30 after refilling. pH levels remained within the acceptable pH 6–9 range of Department of Water and Energy (2007) and Wallace et al. (2007) with the single exception of pH 5.75 in November 2007.
- Mean dissolved oxygen (DO) concentrations at the surface (0.2 m depth) ranged from 4.12 to 13.76 mg.L^{-1} before wetland drying and 1.77 to 3.88 mg.L^{-1} following wetland refilling. Prior to drying, dissolved oxygen levels were above the 5 mg.L^{-1} trigger value of Department of Water and Energy (2007) on all but one occasion (4.12 mg.L^{-1} in March 2008) and always above the 2 mg.L^{-1} trigger value of Wallace et al. (2007). Following refilling, dissolved oxygen levels were below the 5 mg.L^{-1} trigger value of Department of Water and Energy (2007) on all occasions and below the 2 mg.L^{-1} trigger value of Wallace et al. (2007) on three of seven occasions. The low dissolved oxygen levels recorded after wetland refilling are attributed to the dense stands of river red gum that became established on the creek bed during the dry phase. The high loads of leaf litter contributed carbon to the water column, fuelling microbial decomposition of the organic material and thereby consumption of dissolved oxygen from the water column.
- Mean water temperatures ranged from 10.7 to 34.4°C and were within the Department of Water and Energy (2007) acceptable range of 6 to 30 °C for all but one occasion. In March 2008, a high water temperature of 34.4°C was recorded due to the combination of shallow water depth in the last remaining pool of water and high ambient temperatures at the time of sampling.

- Mean turbidity levels were high before complete drying, ranging from 762 NTU to 2,500 NTU. Mean turbidity levels were comparatively low after wetland refilling, ranging from 22 to 132 NTU.

Blue-green algae

Fifteen blue-green algae taxa were sampled over the study period. Counts exceeded the trigger value of 15,000 cells.mL^{-1} of Wallace et al. (2007) for 10 of the 15 samples. One potential toxin producer, *Anabaena spiroides f spiroides*, was sampled at a concentration above the 15,000 cells.mL^{-1} trigger value (15,860 cells. mL^{-1}) at one site in February 2010. The remaining nine samples exceeding 15,000 cells.mL^{-1} were of taxa not known as toxin producers.

Fish

A total of 3,594 fish comprising six native and four exotic species were sampled. None of the native species sampled were considered rare or threatened. Of the fish sampled, 754 fish were captured before complete drying and 2,840 fish after refilling. Prior to drying, carp gudgeon (*Hypseleotris spp*.) was the most abundant taxon sampled (n=680 or 90% of catch). After refilling, the exotic common carp (*Cyprinus carpio*) was recorded at the highest abundance (n=2,609 or 92% of catch), with the population comprised mostly of juveniles. Based on published age/size data for the species, it is unclear whether the common carp were spawned within Back Creek or had washed in from Yallakool Creek upon wetland refilling. However, the rapid growth rate of the cohort of common carp indicates good nursery habitat for the species within Back Creek. The low species richness and abundance of native fish species following refilling may be due to the very low dissolved oxygen levels within Back Creek.

River red gum

The majority of river red gum (*Eucalyptus camaldulensis*) had a crown condition rating of 'moderate cover' for the duration of the monitoring period. Trees at site B5 had an overall lower crown condition than those at sites B2 and B3. Two trees at site B3 and two trees at site B5 met the Wallace et al. (2007) trigger point for management intervention when their crown condition decreased from category 4 (moderate foliage cover) to category 3 (minimal foliage cover) at some time during the monitoring period. However, the condition of river red gum was generally maintained over the full monitoring period. A comparison of tree crown photographs at the start (September 2007) and finish (May 2010) of the study period revealed that 11 of the 30 trees had an overall increase in foliage within the crown, 18 trees showed no clear change and one tree had a decrease in foliage. A significant increase in new foliage growth was observed in December 2009 after refilling commenced and could potentially be due to the refilling event.

Vegetation community

Thirty-two plant taxa from six functional groups were identified from 11 surveys of the wetland-edge vegetation community. The most abundant species sampled was river red gum (*Eucalyptus camaldulensis)* followed by common rush (*Juncus usitatus)*. No rare or threatened plant species were recorded. The noxious weed arrowhead (*Sagittaria platyphylla)* was observed at Back Creek in October 2008 and March 2010 and managers were notified of its occurrence.

During disconnection, the exposure of the creek bed provided opportunities for germination and establishment of vegetation, particularly river red gum seedlings. River red gum germinated along the length of Back Creek and dominated the -30 cm and -60 cm elevations within the established quadrats. The plants grew rapidly on the creek bed, with many exceeding 3 m in height at the end of the study period. The bases of these saplings were inundated upon wetland refilling and some had decreased in condition after five months. It is expected that these saplings will die if soil conditions remain waterlogged. The high loading of organic material from the river red gums on the creek bed has led to the development of low dissolved oxygen levels within the water column following wetland refilling. This has in turn likely influenced the composition of the fish community occurring at the wetland.

Birds

A total of 77 individual waterbirds from 11 species were recorded from four surveys. Species richness ranged from two to seven species for each sampling event. None of the waterbirds sampled is considered to be of conservation concern.

Twenty-six terrestrial bird species were recorded from the four surveys. Species richness ranged from 13 to 20 for each survey. One terrestrial bird species recorded at Back Creek, white-browed woodswallow (*Artamus superciliosus*), has the proposed listing of vulnerable on the New South Wales *Threatened Species Conservation Act 1995*. The restless flycatcher (*Myiagra inquieta*), also recorded at the site, is considered to be declining in the region.

Groundwater

The influence of groundwater on Back Creek was based on interpretations of regional data to 2005. The closest monitoring sites were bores GW501588 and GW501589 located 6 km to the south-east of the confluence of Back Creek with Yallakool Creek. Groundwater salinity in the region was 10,000 to 20,000 µS.cm^{-1}. Groundwater levels were considered unlikely to intercept the creek bed of Back Creek. This prediction was supported by the complete drying of the wetland and the very low electrical conductivity of the water within Back Creek following its refilling.

Future management and recommendations

Taking into account the ecological responses during the recent drying and rewetting of Back Creek, and the unclear status of the natural water regime for the site, it is recommended that:

A management plan is developed for Back Creek to maximise the ecological values of the wetland that incorporates:

- investigation of the natural flow regime of the wetland
- comparison of the natural flow regime with the current regulated flow regime
- development of an optimal water regime for the wetland that provides for:
    - the two-way exchange of water between the wetland and Yallakool Creek
    - the elimination of river red gum that have established upon the creek bed
    - preventing river red gum from re-establishing upon the creek bed
- consideration of the potential benefits of delivering an optimal water regime to the wetland and the infrastructure required
- adaptive management principles, and
- development of a monitoring program to record ecological responses to any changed water regime.

Introduction

Background

In April 2007, the state governments of the Murray–Darling Basin undertook drought contingency planning following sustained low inflows into the system. The adopted measures included the temporary disconnection of some wetlands from their main river channel to reduce water losses from evaporation. Back Creek was one such wetland selected by the New South Wales Government for temporary disconnection to achieve water savings.

The former Murray–Darling Basin Commission (MDBC) engaged The Murray–Darling Freshwater Research Centre (MDFRC) to monitor the environmental condition of Back Creek as part of drought water recovery measures (Contract No. MD962). On 15 December 2008, the new Murray–Darling Basin Authority (MDBA) absorbed all of the functions of the MDBC which ceased to exist. The monitoring program and reporting requirements remained unchanged during this transition.

This report deals only with the outcomes and implications of the environmental monitoring at Back Creek and does not present the broader details of the wetland disconnection program.

Objective of study

imary objective of the project was to assess the ecological condition at Back Creek during and following its disconnection from Yallakool Creek, and for a minimum period of six months following refilling. In particular, the monitoring program sought to provide early detection of changes that may lead to environmental damage at the wetland.

Monitoring strategy

The monitoring strategy involved assessing a range of physical and biological variables against pre-determined ‘trigger values’ or ‘thresholds’ for management notification (Department of Water and Energy 2007; Wallace et al. 2007; Baldwin et al. 2007). These trigger values reflected the levels of each variable at which environmental damage to the wetland ecosystem may be occurring.
The trigger values provided a point at which managers should assess whether intervention was required. Results were also evaluated against data from previous monitoring times, to provide an indication of ecological change. The monitoring team liaised closely with the MDBA and New South Wales Government agencies throughout the project and provided regular updates following each monthly sampling of water quality. Results from all ecological variables were provided in tri-monthly update reports (Durant et al. 2008a, b, c, d, 2009a, b, 2010a; Reid et al. 2009a, b).

Site description

Back Creek is part of the Edward–Wakool River system and is located approximately 20 km north-west of Deniliquin, New South Wales. The creek is approximately 9.5 km in length and connects with the Edward River (within the weir pool created by Stevens Weir) via a 2 km reach of Yallakool Creek (**Figure 1**). Back Creek is surrounded mostly by pasture and crops, and has a narrow riparian zone (on average ↸ 50 m in width).

Recent ecological condition

Before the commencement of this project, a desktop and field assessment of the ecological condition of Back Creek was conducted by Durant and Nielsen (2007) in March 2007. The purpose of the assessment was to identify threatened species, populations and ecological communities of both flora and fauna that are known to (or have the potential to) occur in the region. From this assessment, it was determined that 40 threatened fauna and two threatened flora species have been recorded, or had the potential to occur, in the region. It was also identified that three endangered ecological communities could potentially occur in this region, and one of these was confirmed to exist at Back Creek. The Lower Murray River Catchment area, where Back Creek is located, is classified as an endangered aquatic ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (Durant and Nielsen 2007)

The endangered aquatic ecological community of the Lower Murray catchment includes all native fish and aquatic invertebrates within all natural creeks, rivers and associated lagoons, billabongs and lakes of the regulated Murray River below Lake Hume, including the Edward and Wakool rivers.

Past wetland hydrology

Inflows to Back Creek are influenced by discharge and water levels at the Yallakool Creek offtake regulator. The approximate commence-to-flow for Back Creek is 0.3 m (55 ML.d^{-1}) at the Yallakool Creek offtake (New South Wales Murray Wetlands Working Group 2008). The Yallakool Creek offtake is directly influenced by the weir pool created by Stevens Weir on the Edward River as water will only flow into Yallakool Creek when the gauge at Stevens Weir exceeds 3.5 m (Green and Alexander 2006).

Based on 60 years of records at the Yallakool Creek offtake, water levels were variable over an annual cycle with the highest levels recorded over the summer months and lowest (at zero discharge) for around one to three months each year in June/July/August (Appendix A). Before construction of the Back Creek regulator, water levels in Back Creek were responsive to changes in water level in Yallakool Creek which typically varied over 1 m annually. As such, water levels in Back Creek would have reached low levels for approximately one to three months on an almost yearly cycle due to much of the water draining from Back Creek when water levels in Yallakool Creek decreased (New South Wales Murray Wetlands Working Group 2008). As such, the current water regime at Back Creek is considered to be 'almost permanent' (New South Wales Murray Wetlands Working Group 2008). For the remainder of the year, water is present at variable levels within Back Creek in response to water levels at the Yallakool Creek offtake. It is unclear what the natural flow regime was at Back Creek, or the extent to which the current regulated water regime differs from the natural flow regime.

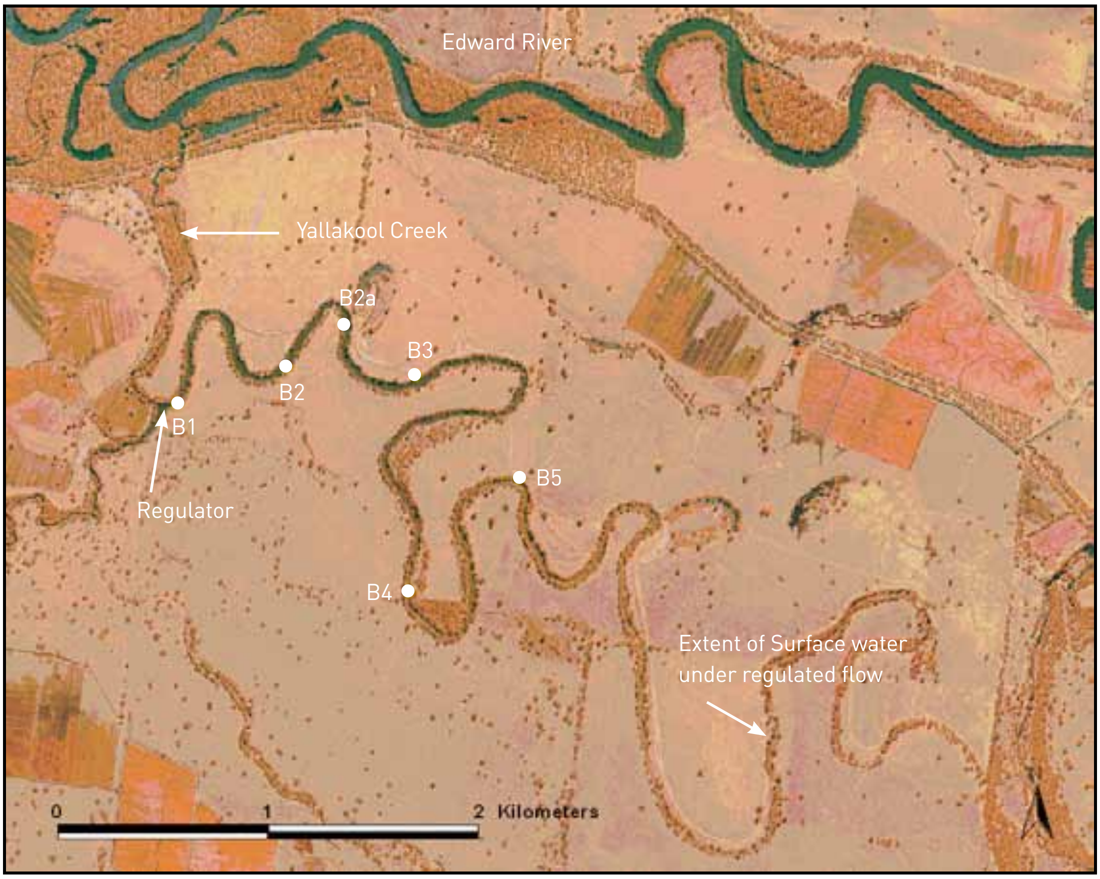


Figure 1. Monitoring sites (B1-B5) at Back Creek

Methods

Monitoring sites at Back Creek were selected to (a) provide spatial coverage of the wetland and (b) represent the main habitat types within the creek. Sites were positioned at least 500 m apart as recommended by Wallace et al. (2007). Site B2a was added during the drying of the wetland as it represented the last remaining pool of water in the creek for obtaining water quality measurements.

Ecological indicators and sampling schedule

The ecological indicators monitored during this study were determined by the protocol for assessing wetlands (Wallace et al. 2007) and additional input from New South Wales Government agencies and the MDBC (now MDBA). Monitoring began on 6 September 2007 with final sampling occurring over 32 months later on 7 June 2010 (**Table 1**). Twelve tri-monthly surveys were completed during this time.

Sulfidic sediments

Three sites were sampled in September 2007 (sites B2, B3 and B5) to assess the likelihood of sulfidic sediment occurrence (and therefore risk of acidification) at Back Creek. The decision-support tool developed by Baldwin et al. (2007) was used, with the protocol incorporating desktop, field and simple laboratory analyses. Trigger values from Baldwin et al. (2007) are shown in **Table 2**.

Water levels and quality

Water levels were measured monthly from a gauge installed at site B2a in November 2007 by the New South Wales Department of Environment and Climate Change (DECC). The gauge was not referenced to Australian Height Datum (m AHD).

Table 1. Back Creek monitoring schedule

Back Creek	2007				2008												2009												2010					
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Water level																																		END OF PROJECT
Water quality																																		
Blue-green algae																																		
Fish																																		
Understorey																																		
Tree health																																		
Photopoints																																		
Waterbird																																		
Acidification potential																																		
Update Report					#1		#1	#2			#3			#4			#5			#6			#7			#8			#9		#9	#10		
Final Report																																		
KEY: Completed		Needed to reschedule						Cancelled (MDBA)																										

Table 2. Sulfidic sediments trigger values for management notification (from Baldwin et al. 2007)

Variable	Trigger value
Electrical conductivity of surface water	> 1,750 μS.cm^{-1}
Electrical conductivity of sediment	> 400 μS.cm^{-1}
pH of surface water	< 4
pH of sediment	< 4.5
Sulfate of surface water	> 10 mg.L^{-1}

The measured variables for water quality were dissolved oxygen (mg.L^{-1}), pH, electrical conductivity (µS.cm^{-1} @ 25°C), water temperature (°C) and turbidity (NTU). These variables were measured *in situ* at three sites (B2, B3 and B5 as water levels permitted) on a monthly basis with a Horiba U-20 multi probe. Water was sampled at the surface of the water column (0.2 m water depth). When water depths exceeded 0.5 m, water quality was also measured at the bottom of the water column (0.2 m above substrate). Water quality trigger values were established by New South Wales Department of Water and Energy (2007) and Wallace et al. (2007) as shown in **Table 3**. Managers were advised when monitoring results met these trigger values.

Blue-green algae

A phytoplankton sample of 0.2 L was collected at 0.2 m water depth at three sites (B2, B3 and B5 as water levels permitted) every three months. Samples were preserved at the point of collection with the addition of 5 mL of Lugol's solution. Blue-green algae species known or suspected to produce toxins were identified to species level and their cell counts recorded. The remaining blue-green algae were identified to genus level and their cell counts recorded. Algae Test Consulting (Malgorzata Przybylska) conducted blue-green algae identification and cell counts.

The trigger value for management notification was when blue-green algae counts exceeded 15,000 cells.mL^{-1} (Wallace et al. 2007).

Fish

Fish were surveyed using a combination of fyke nets (fine and coarse mesh) and electrofishing by backpack as described in Wallace et al. (2007). Fish were sampled using fyke nets every three months and by electrofishing every six months.

The netting technique involved two large coarse mesh and two small fine mesh fyke nets being deployed overnight at each of the three monitoring sites (B2, B3 and B5 as water levels permitted). Nets were set in the afternoon and collected the following morning (typical soak time approximately 12 hours). Large fyke nets (28 mm stretched mesh) had a central wing (8 m x 0.65 m) attached to the first supporting hoop (∅ = 0.55 m) with a 0.32 m stretched mesh entry. Small fyke nets (2 mm stretched mesh) had dual wings (each 2.5 m x 1.2 m) with the first supporting hoop (∅ = 0.4 m) fitted with a square entry (0.15 m x 0.15 m) covered by a plastic exclusion grid with rigid square openings (0.05 m x 0.05 m) to exclude large fish and air breathing fauna.

Backpack electrofishing (LR-24 Smith–Root electrofisher) consisted of 8 x 150 second shots (power on) at each sampling occasion. Each shot involved wading through the water to a maximum depth of 0.7–1.0 m and directing intermittent pulsed current to all available and accessible habitats in order to sample the resident fish fauna.

Captured fish were identified to species level (McDowell 1996; Lintermans 2007), with the exception of *Hypseleotris* spp. (Bertozzi et al. 2000), then counted and measured. All native species were released at their point of capture immediately following processing, and exotic species were euthanised as required by ethics regulations. The standard length (to the nearest 1 mm) was recorded for all species. Where large catches of a species occurred, a sub-sample of at least 15 individuals (including the largest and smallest) was measured for each sampling technique.

The trigger value for management notification was the occurrence of rare or threatened fish species (Wallace et al. 2007).

Table 3. Water quality trigger values for management notification

Variable	DWE (2007)	Wallace et al. (2007)
Temperature	< 6 / > 30 °C	-
Dissolved oxygen	< 5 mg.L^{-1}	< 2 mg.L^{-1}
pH	< 6 / > 9	< 6
Electrical conductivity	> 5,000 µS.cm^{-1}	> 1,000 mg.L^{-1} (≈1,500 µS.cm^{-1})
Turbidity	-	-

River red gum

Three transects each consisting of 10 river red gum trees (*Eucalyptus camaldulensis*) were established along the creek bank at sites B2, B3 and B5. Mature trees containing foliage (i.e. live leaves) were preferentially selected to allow the detection of a potential decline in tree condition. The GPS location of each monitored tree was recorded and the tree was marked with cattle ear tags to assist in locating them at future monitoring times. The condition of the 30 trees was assessed every three months by measuring the variables of crown condition and new growth (Wallace et al. 2007).

Crown condition was assessed as the amount of foliage cover present on each monitored tree relative to its hypothetical maximum given its existing branching structure. In the field, this entailed (a) viewing the branching structure of the tree, (b) visualising the maximum amount of foliage (100%) that could be supported by that branching structure assuming the tree was in full health, and (c) calculating the amount of existing foliage (%) relative to the carrying capacity of the tree. Independent scores to the nearest 5% interval were provided by two observers. From this, a mean score was calculated and the tree assigned to the appropriate category (**Table 4**).

The amount of new growth (new leaves including epicormic growth) on a tree was assessed relative to the amount of foliage present at the time of the survey. Independent scores to the nearest 5% interval were provided by two observers. From this, a mean score was calculated and the tree assigned to the appropriate category (**Table 5**).

A vertical photograph of each tree crown was obtained every three months to provide a visual record of each tree. A marker peg was placed in the ground under each tree for the duration of the study, to identify the place where the photograph was to be taken every time. A Pentax Optio W30 camera was positioned in a specially designed wooden cradle, which contained a circular spirit level to help maintain the camera in a horizontal plane and to obtain a vertical photograph. The camera holder was placed on the marker peg, shaded to prevent glare on the image (where possible), and oriented relative to the base of the tree. The camera was set to infinity focus, fully wide angle, auto exposure and no flash.

In addition to the field visual assessments of tree condition, photographs of the crown of each tree were compared for December 2007 (the first time photographs were taken of all river red gum trees) and May 2010 (the final sampling event). Based on the foliage present within the crown, each tree was scored as having an increase, decrease or no change in foliage between times.

The trigger value for management notification was a deterioration in river red gum crown condition from category 4 (moderate foliage cover) to a category 3 (minimal foliage cover) or less (Wallace et al. 2007).

Table 4. Categories of crown condition (based on Wallace et al. 2007)

Category	Description and range	% cover
0	No crown or sparse dead leaves (dead or near dead)	0
1	Full or substantial crown of dead leaves (near dead)	0
2	Sparse crown of live leaves (highly stressed)	<10
3	Minimal cover (stressed)	10-25
4	Moderate cover (moderately stressed)	26-75
5	Full cover (healthy)	76-100

Table 5. Categories of new growth (based on Wallace et al. 2007)

Category	Description and range	% cover
0	None	0
1	Sparse	<10
2	Minimal cover	10-25
3	Moderate cover	26-75
4	Dense cover	76-100

Vegetation community composition

Vegetation was monitored on a tri-monthly basis at sites B2, B3 and B5 to identify changes to the vegetation community as a result of wetland disconnection. The vegetation community was not sampled on the initial survey due to the addition of this ecological indicator to the contract after monitoring had commenced. At each site, five fixed 15 x 1 m^2 quadrats (comprising 15 individual cells of 1 m x 1 m) were established perpendicular to the wetland at +60 cm, +30 cm, 0 cm, -30 cm and -60 cm elevations from the estimated bank-full position. The location of each quadrat was recorded by GPS and marked with a survey peg.

The occurrence of each plant species that had live roots within each cell was recorded. In addition, the percentage cover of each species at ground level was recorded for each cell.

The identification of all plants to species level was precluded by factors such as life history stage. In these instances plants were recorded to genus or family level where possible, or as an immature angiosperm (monocot or dicot) when genus or family levels were unable to be determined. Identification of vegetation species was based on Cunningham et al. (2006), Moore (2005) and Sainty and Jacobs (1981, 2003).

Life cycle patterns and plant responses to the presence or absence of water are key factors in classifying wetland species into functional groups. The functional group categorisation aids in understanding community responses in relation to disturbance, rather than attempting to follow an individual species over time (Brock and Casanova 1997). Each understorey species sampled was assigned to one of 10 functional groups (**Table 6**).

The trigger value for management notification was the occurrence of rare or threatened vegetation species (Wallace et al. 2007).

Birds

Birds were surveyed by Ecosurveys Pty Ltd, Deniliquin (Rick Webster) every three months. Bird surveys were not conducted on the initial survey period because the addition of this ecological indicator to the contract occurred after monitoring had commenced.

Waterbird species, abundances and general activity were recorded by active searches of suitable habitat at all five sites (100 m either side of a central point). In addition, opportunistic sightings of all species, including terrestrial birds, were recorded. For the purpose of this study, waterbirds are defined as species that are ecologically dependent on wetlands (Department of Environment, Water, Heritage and the Arts 2001). Terrestrial birds are defined as species that are not directly dependent on wetlands.

Trigger values were not established for birds by Department of Water and Energy (2007) or Wallace et al. (2007). However, managers were notified when rare or threatened species were identified.

Photo points

Five photo points were established at Back Creek (site B1, B2, B3, B4 and B5) to document visual changes of the wetland. A landscape image was taken at each photo point every three months over the study period. The image obtained from the first sampling event was used to frame subsequent images. The camera was shaded to prevent glare on the image. Photographs were taken using the same camera and settings described for the river red gum vertical photo points.

Table 6. Classification of species functional groups (from Casanova and Brock 2000; Casanova 2007)

Primary category	Secondary category	Description
Terrestrial	Dry species: Tdr	Species that germinate, grow and reproduce where there is no surface water and the water table is below the soil surface.
Terrestrial	Damp species: Tda	Species that germinate, grow and reproduce on saturated soil.
Amphibious fluctuation-tolerators	Emergent species: ATe	Species that germinate in damp or flooded conditions, that tolerate variation in water level, and grow with their basal portions under water and reproduce out of the water.
Amphibious fluctuation-tolerators	Low-growing species: ATl	Species that germinate in damp or flooded conditions, that tolerate variation in water level, that are low-growing and tolerate complete submersion when water levels rise.
Amphibious fluctuation-tolerators	Amphibious flood tolerators: ATw	Woody species that tolerate flooded conditions.
Amphibious fluctuation – responders	Morphologically plastic species: ARp	Species that germinate in flooded conditions, grow in both flooded and damp conditions, reproduce above the surface of the water, and that have morphological plasticity (e.g. heterophylly) in response to water level variation.
Amphibious fluctuation – responders	Species with floating leaves: ARf	Species that germinate in flooded conditions, grow in both flooded and damp conditions, reproduce above the surface of the water, and that have floating leaves when inundated.
Submerged	Emergent species: Se	Species that germinate and reproduce under water and also grow above the surface of the water.
Submerged	r-selected species: Sr	Species with rapid growth, germinate and reproduce under water.
Submerged	k-selected species: Sk	Species that have slower growth, germinate and reproduce under water.

Groundwater

Groundwater data for Back Creek was provided by New South Wales Department of Water and Energy. The following information is based on advice provided to MDFRC from Mitchell (2008).

There are no groundwater monitoring sites close to Back Creek. Interpretations of groundwater in the vicinity of Back Creek were based on regional data, with the most recent data on the State Groundwater Database being 2005. The closest monitoring sites with recent groundwater level information were for bores GW501588 and GW501589 (monitored by Murray Irrigation Limited) located approximately 6 km to the south-east of the confluence of Back Creek and Yallakool Creek. Data is presented for these bores as the best available groundwater data for assessment.

Results

Sulfidic sediments

Trigger values

Sediments at B2, B3 and B5 ranged from pH 4.1–4.4 and therefore met the pH <4.5 trigger value in the decision support tool of Baldwin et al. (2007).

A subsequent and detailed analysis of sediment cores found only low levels of sulfidic materials at Back Creek and therefore a low risk of acidification to the wetland if dried (Baldwin et al. 2008).

Results for several components of the decision-support tool in Baldwin et al. (2007) are presented in **Table 7**. The pH of the sediment met the pH <4.5 trigger value at all three sites tested. The protocol of Baldwin et al. (2007) subsequently recommended that a more detailed investigation of the occurrence of sulfidic sediments be undertaken by directly analysing sediments.

In response to these findings, the former MDBC requested MDFRC to directly analyse sediments at Back Creek for the presence of sulfidic materials. A brief overview of this separate study is provided in the discussion, and further details can be found in Baldwin et al. (2008).

Table 7. Measurements of variables at Back Creek to determine the risk of sulfidic sediments occurring at the wetland

Site	EC surface water (uS.cm^{-1})	EC →1750 uS.cm^{-1}?	EC of sediment (uS.cm^{-1})	EC→400 uS.cm^{-1}?	pH of surface water	Surface water pH←4?	pH of sediment	Sediment pH ←4.5?	Sulfate surface water (mg SO_4.L)	Sulfate →10 mg.L^{-1}?
Site B2	91	No	55	No	6.81	No	4.10	Yes	2.2	No
Site B3	88	No	31	No	6.57	No	4.20	Yes	2.3	No
Site B5	176	No	54	No	6.83	No	4.40	Yes	3.2	No

Water levels

Back Creek was partially dry before the first monitoring event in September 2007 and before the installation of the regulator (and gauge) in November 2007. The water level decreased through evaporation and the wetland dried completely by 16 April 2008, remaining dry for ≈20 months (**Figure 2**).
On 26 November 2009, the regulator at Back Creek was opened to allow refilling with water from Yallakool Creek and it stayed open for the remainder of the monitoring period. In the six months following the opening of the regulator, water levels in Back Creek peaked at 1.80 m at the gauge. Given that the zero point on the gauge approximated the drying point of the wetland, water depth in Back Creek ranged from zero to 1.80 m over the study period.

Water quality

Water quality was initially sampled at the three sites B2, B3 and B5. Additional sites were added (as close as possible to the original sites) as these original sites dried. From December 2007 to March 2008 all measurements were taken from the last remaining pool of surface water near site B2a. After the release of water into Back Creek in November 2009, sampling recommenced at sites B2, B3 and B5 as water levels permitted.

In most cases, the mean of three surface water measures are presented for each sampling time. Due to shallow water depths before complete drying of the creek, only surface water quality measurements (at 0.2 m depth) were taken for this period. Since refilling commenced, surface (0.2 m depth) and bottom (0.2 m depth from substrate) water quality measurements were taken as water levels permitted.

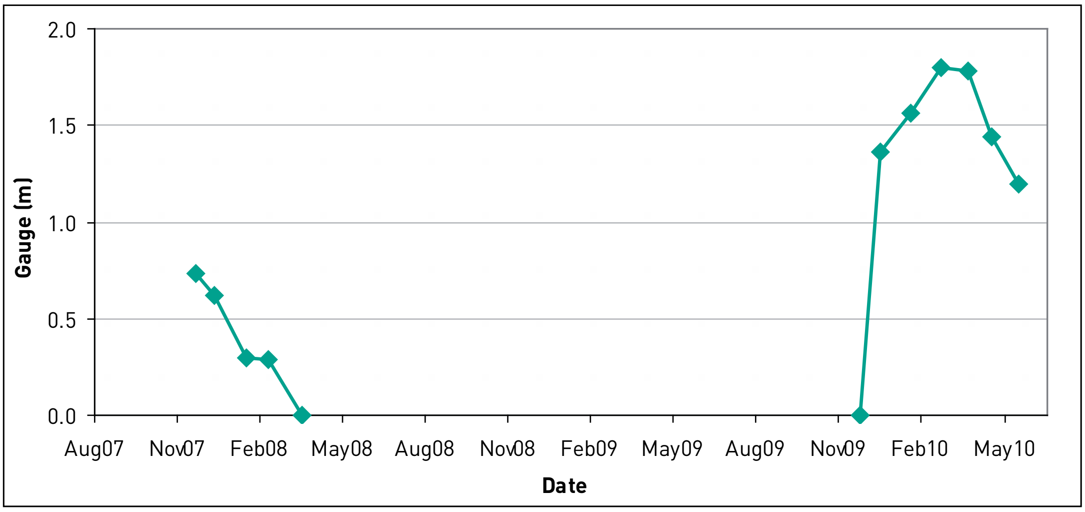


Figure 2. Water level at the established gauge at Back Creek (site B2a). The wetland was dry from April 2008 to November 2009.

Electrical conductivity

Trigger values

Electrical conductivity did not exceed the 5,000 μS.cm^{-1} trigger value of the New South Wales Department of Water and Energy (2007). However, in March 2008 (when 1,830 μS.cm^{-1} was measured at site B2a), electrical conductivity exceeded the ≈1,500 μS.cm^{-1} trigger value of Wallace et al. (2007).

Mean surface water electrical conductivity was relatively low (<350 μS.cm^{-1}) throughout the study period with the exception of one sampling occasion (**Figure 3**). The lowest single-site electrical conductivity value of 44 μS.cm^{-1} was recorded in May 2010 at site B2, with the highest value of 1,830 μS.cm^{-1} measured in March 2008 at site B2a. The high electrical conductivity value corresponded with a very low water depth before complete wetland drying.

Since the wetland was refilled, mean electrical conductivity levels were within the range of 52–61 μS.cm^{-1}.

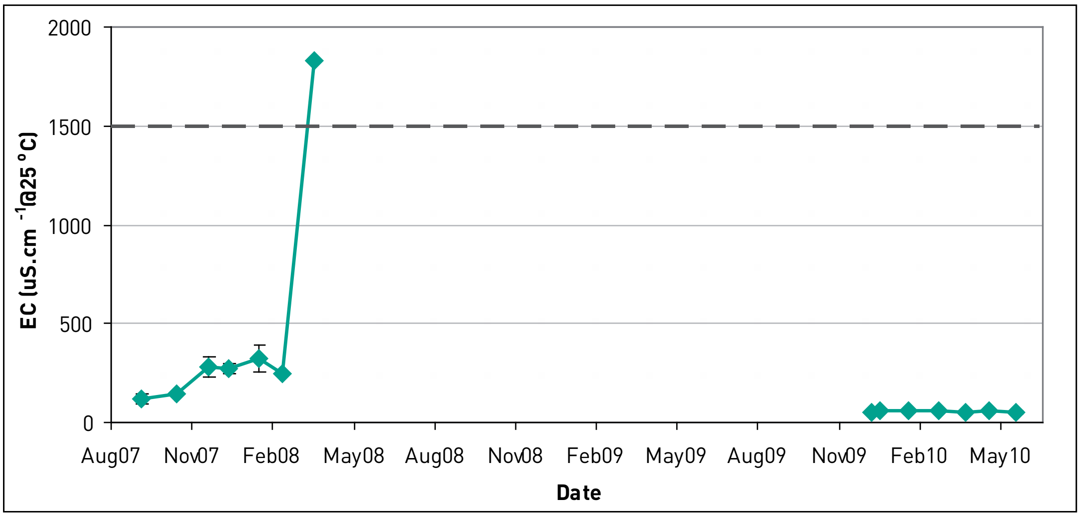


Figure 3. Mean (±1 S.E.) electrical conductivity (μS.cm^{-1}@25 °C) at Back Creek. The dashed line represents the 1,500 μS.cm^{-1} trigger value of Wallace et al. (2007). The wetland was dry from April 2008 to November 2009.

pH

Trigger values

Mean surface water pH levels generally remained within the acceptable pH range of 6–9 as stipulated in Department of Water and Energy (2007) and Wallace et al. (2007). Mean pH levels were outside of this range on one occasion in November 2007 (pH 5.75).

No readings exceeded the pH 9 trigger value of Department of Water and Energy (2007).

Mean pH levels were slightly acidic on most sampling occasions and ranged from 5.75 to 7.98 before drying and 6.35 to 7.30 after refilling commenced (**Figure 4**). Surface water pH remained within the pH 6–9 acceptable range of Department of Water and Energy (2007) and Wallace et al. (2007) for all sites and times with the exception of November 2007 when the mean surface water pH was 5.75.

Three individual site measurements of pH were outside Department of Water and Energy (2007) and Wallace et al. (2007) acceptable range. Before Back Creek dried completely, pH was 5.59 and 5.91 at sites B2a and B3 respectively in November 2007, and 5.68 at site B3 in December 2007.

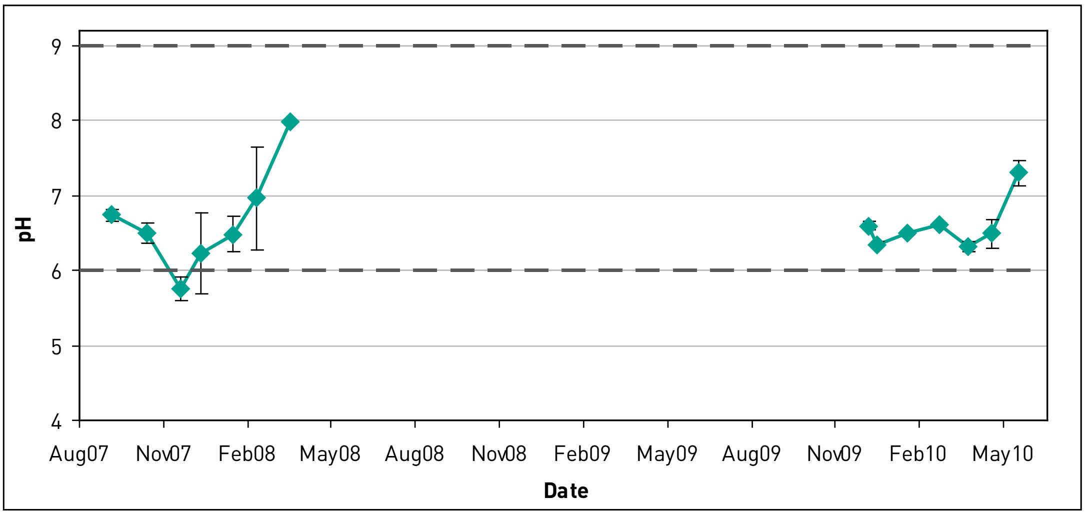


Figure 4. Mean (±1 S.E.) pH at Back Creek. The dashed lines represent the pH 6 and pH 9 trigger values. The wetland was dry from April 2008 to November 2009.

Water temperature

Trigger values

Mean surface water temperatures remained within the Department of Water and Energy (2007) acceptable range of 6–30 °C for all sampling occasions with one exception; mean water temperature was 34.4°C in March 2008.

Mean surface water temperatures varied primarily in response to seasonal changes in ambient air temperatures. Before drying, temperatures ranged from 16.0 ˚C to 34.4°C and after filling ranged from 10.7 ˚C to 23.1 °C (**Figure 5**). The mean temperature of 34.4 °C in March 2008 was the only measurement to be outside of the Department of Water and Energy (2007)6–30°C acceptable range, and corresponded with very low water depth in the last pool of surface water before complete drying.

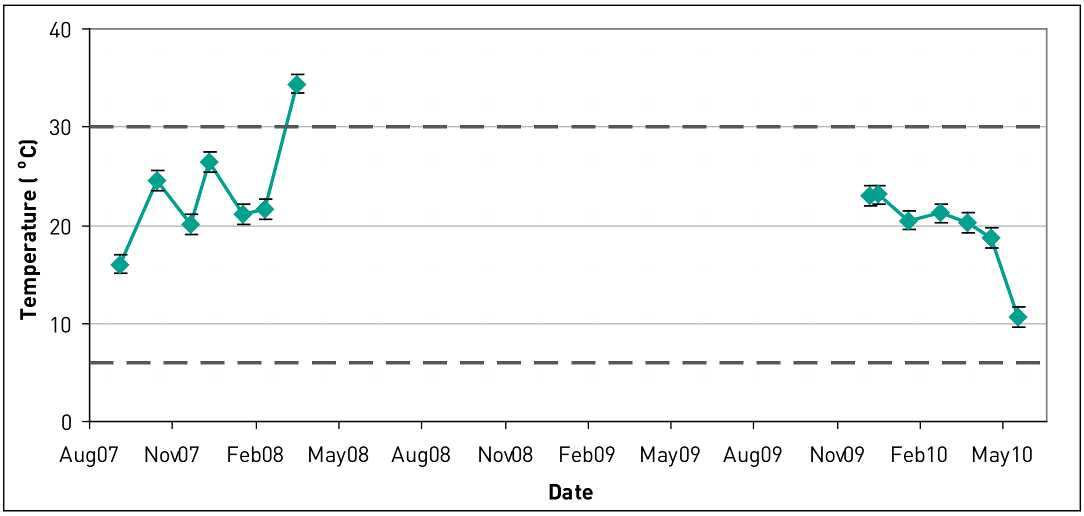


Figure 5. Mean (±1 S.E.) surface water temperatures (°C) at Back Creek. The dashed lines represent the 6°C and 30°C trigger values. The wetland was dry from April 2008 to November 2009.

Dissolved oxygen

Trigger values

Before wetland drying, mean dissolved oxygen (DO) concentrations at the surface (0.2 m depth) were above the 5 mg.L^{-1} trigger value of Department of Water and Energy (2007) on all sampling occasions with one exception (4.12 mg.L^{-1} in March 2008), and always above the 2 mg.L^{-1} trigger value of Wallace et al. (2007).

After refilling Back Creek, all mean dissolved oxygen concentrations recorded at the surface were below the 5 mg.L^{-1} trigger value of Department of Water and Energy (2007). On three of seven sampling occasions, the mean dissolved oxygen levels were below the 2 mg.L^{-1} trigger value of Wallace et al. (2007).

The lowest individual measurement of 0.18 mg.L^{-1} was recorded at site B5 near the bottom (0.2 m from substrate) of the water column on 24 February 2010 following wetland refilling.

Mean dissolved oxygen concentrations at the surface (0.2 m depth) ranged from 4.12 mg.L-1 to 13.76 mg.L-1 before wetland drying, and 1.77 mg.L-1 to 3.88 mg.L-1 following wetland refilling (**Figure 6**).

Individual site measurements of dissolved oxygen at the surface (0.2 m depth) of the water column were below the 5 mg.L^{-1} trigger value of Department of Water and Energy (2007) on one of the seven sampling occasions before drying, and all of the seven sampling occasions after refilling. All individual site measurements of dissolved oxygen at the surface were above the 2 mg.L^{-1} trigger value of Wallace et al. (2007) before wetland drying, but at least one site was below this trigger value on five of the seven sampling occasions after wetland refilling.

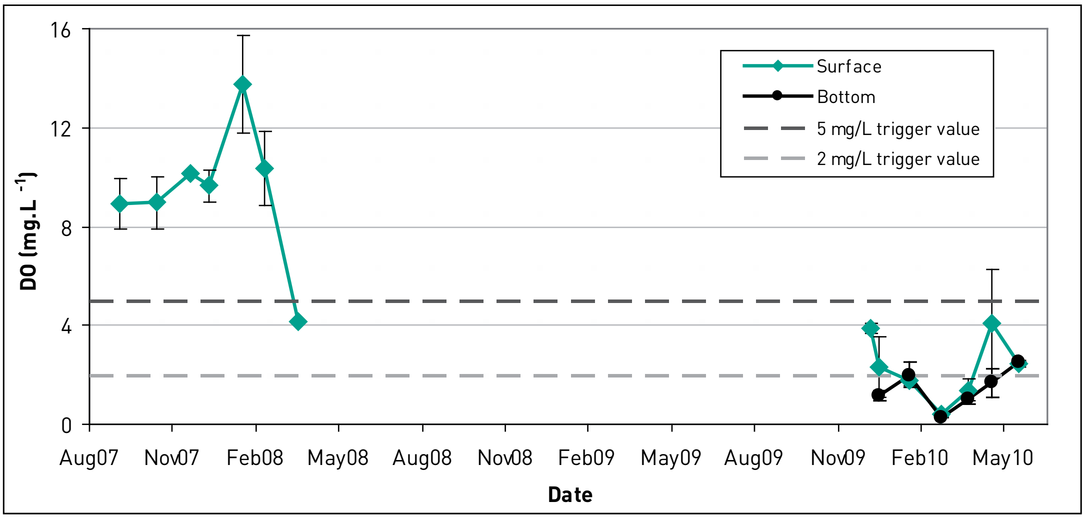


Figure 6. Mean (±1 S.E.) dissolved oxygen concentrations (mg.L^{-1}) at the surface and bottom of the water column at Back Creek. The dashed lines represent the dissolved oxygen levels below which the trigger value is met (5 mg.L^{-1} of Department of Water and Energy (2007) and 2 mg.L^{-1} of Wallace et al. (2007)). The wetland was dry from April 2008 to November 2009.

Turbidity

Trigger values

No trigger values were established for turbidity by Department of Water and Energy (2007) or Wallace et al. (2007).

Mean turbidity levels ranged from 11–2,500 NTU.

Mean turbidity levels at Back Creek were high before complete drying, ranging from 762 NTU to 2,500 NTU (**Figure 7**). Since refilling commenced in November 2009, mean turbidity levels were comparatively low, ranging from 22 to 132 NTU.

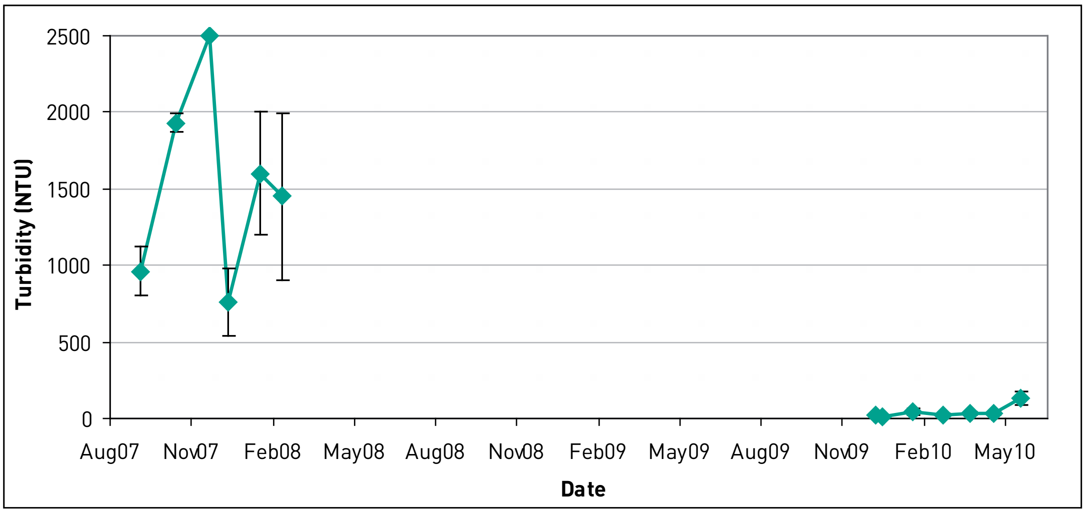


Figure 7. Mean (±1 S.E.) turbidity (NTU) at Back Creek. The wetland was dry from April 2008 to November 2009.

Blue-green algae

Trigger values

Blue-green algae cell counts exceeded the trigger value of 15,000 cells.mL^{-1} specified in Wallace et al. (2007) for 67% of samples before drying and 67% of samples after wetland refilling. The majority of high counts were of non-toxin producing taxa.

Two potential toxin producers (*Anabaena spiroides f spiroides* and *Anabaena circinalis*) and two suspected but unconfirmed potential toxins (*Cylindrospermum licheniforme* and *Planktolyngbya subtilise*) were recorded at Back Creek. However, only the potential toxin producer *Anabaena spiroides f spiroides* was sampled at a concentration above the 15,000 cells.mL^{-1} trigger value (15,860 cells.mL^{-1}) at site B2 in February 2010.

Blue-green algae was sampled on 5 September 2007 at three sites, 11 December 2007 at two sites and one site on 28 March 2008 due to decreasing water levels along the creek. Blue-green algae sampling did not occur at Back Creek during the dry phase from April 2008 to November 2009. Since refilling, sampling occurred at three sites on all sampling occasions.

A total of 15 blue-green algae taxa were recorded during the study period (Appendix B). Counts of blue-green algae exceeded the 15,000 cells.mL^{-1} threshold of Wallace et al. (2007) for 10 of the 15 samples (**Table 8**). However, most of these high cell counts belonged to non-toxic taxa.

No known or potential toxin producers were recorded before drying. Since refilling occurred in November 2009 two potential toxin producers were recorded at two sites (B2 and B3) in February 2010 and two suspected but unconfirmed potential toxin producers at one site (B5) in May 2010 (**Table 9**). The potential toxin producer *Anabaena spiroides f spiroides* was sampled in February 2010 at site B2 at levels above the trigger value stipulated in Wallace et al. (2007).

Table 8. Blue-green algal counts (dominant taxon count in parentheses) at Back Creek. Shading denotes when blue-green algae cell counts exceeded the 15,000 cells.mL^{-1} trigger value.

Date	Site B2 (cells.mL^{-1})	Site B2a (cells.mL^{-1})	Site B3 (cells.mL^{-1})	Site B4 (cells.mL^{-1})	Site B5 (cells.mL^{-1})
Prior to drying					
5 Sep 2007	5,420 (4,070 *Aphanocapsa* spp.)	N/A	15,910 (10,370 *Aphanocapsa* spp.)	N/A	17,390 (12,460 *Planktolyngbya* spp.)
11 Dec 2007	258,690 (236,640 *Merismopedia* spp.)	N/A	8,970 (5,520 *Merismopedia* spp.)	N/A	N/A
28 Mar 2008	N/A	85,690 (80,190 *Geitlerinema* spp.)	N/A	N/A	N/A
After refilling					
18 Dec 2009	11,040 (9,830 *Aphanocapsa* spp.)	N/A	7,400 (7,340 *Aphanocapsa* spp.)	9,020 (8,880 *Aphanocapsa* spp.)	N/A
25 Feb 2010	107,880 (87,210 *Aphanocapsa* spp.)	N/A	79,450 (76,900 *Aphanocapsa* spp.)	N/A	43,780 (43,600 *Aphanocapsa* spp.)
21 May 2010	46,370 (40,430 *Aphanocapsa* spp.)	N/A	103,860 (103,860 *Aphanocapsa* spp.)	N/A	157,210 (156,970 *Aphanocapsa* spp.)

Table 9. Blue-green algal counts for 'potential toxin producers' and 'suspected but unconfirmed potential toxin producers' at Back Creek. Shading denotes when blue-green algae cell counts exceeded the 15,000 cells.mL^{-1} trigger value.

Date	Site B2 (cells.mL^{-1})	Site B3 (cells.mL^{-1})	Site B5 (cells.mL^{-1})
25 Feb 10	15,860 Anabaena spiroides f spiroides[1]	410 Anabaena circinalis11,730 Anabaena spiroides f spiroides[1]	
21 May 10			190 Cylindrospermum licheniforme250 Planktolyngbya subtilis[2]

[1] Potential toxin producer

[2] Suspected but unconfirmed potential toxin producer

Fish

Trigger values

Six native and four exotic fish species were sampled at Back Creek.

No fish species of conservation concern were sampled within the creek. Hence, the trigger value of maintenance of aquatic habitat for rare or threatened fish species was not met (Wallace et al. 2007).

A total of 3,594 fish comprising six native and four exotic species were recorded from five sampling times. Of these, 59 fish were sampled with electrofishing (two surveys) and 3,535 fish were caught in fyke nets (**Table 10**). Before drying, 754 fish comprising five native and three exotic species were recorded, and 2,840 fish comprising three native and four exotic species were recorded after refilling occurred. Water levels in March 2008 were too low for either netting or electrofishing, although observations of dead common carp (*Cyprinus carpio*) were made as the creek bed dried.

The exotic common carp was the most abundant species sampled overall (n=2,641 or 73% of total catch), with carp gudgeons (*Hypseleotris* spp.) the most abundant native taxon sampled overall (n=765 or 21% of total catch). Before drying, the native carp gudgeon was the most abundant taxon sampled (n=680 or 91% of total catch) with common carp the most abundant exotic species sampled (n=32 or 4.2% of total catch). After refilling commenced, common carp was the most abundant species sampled (n=2,609 or 91% of total catch) with carp gudgeons the most abundant native species sampled but at considerably lower abundance (n=85 or 3% of total catch).

Table 10. Fish species and their relative abundances from netting (net) and electrofishing (elec) at Back Creek. Exotic fish are highlighted with an asterisk.

Common name	Scientific name	Before drying: Oct 07		Dec 07	After refilling: Dec 09	Feb 10		May 10
		Net	Elec	Net	Net	Net	Elec	Net
Australian smelt	Retropinna semoni	15	9					
Carp gudgeons	Hypseleotris spp.	587	2	91	2	46	1	36
Flat-headed gudgeon	Philypnodon grandiceps	1						
Dwarf flat-headed gudgeon	Philypnodon macrostomus	6						
Fly-specked hardyhead	Craterocephalus stercusmuscarum fulvus	2						5
Murray–Darling rainbowfish	Melanotaenia fluviatilis					9		
Common carp*	Cyprinus carpio	27	1	4	1,626	621	35	327
Eastern gambusia*	Gambusia holbrooki	1				23	7	57
Goldfish*	Carassius auratus	4	4			3		24
Oriental weatherloach*	Misgurnus anguillicaudatus					16		2
	Richness	8	4	2	2	6	3	6
	Count	643	16	95	1,628	718	43	451
	Total richness	8		2	2	6		6
	Total count	659		95	1,628	761		451

Common carp

The size structure of the common carp population at Back Creek following wetland filling is shown in **Figure 8**. The first sampling event occurred on 21 December 2009, which was 25 days after Back Creek started to receive inflows. An abundant community of older larvae and early juveniles was sampled at this time (median size of 20 mm), and this young-of-the-year cohort continued to grow over the other two consecutive sampling events of 23 February 2010 (median size of 63 mm) and 19 May 2010 (median size of 83 mm).

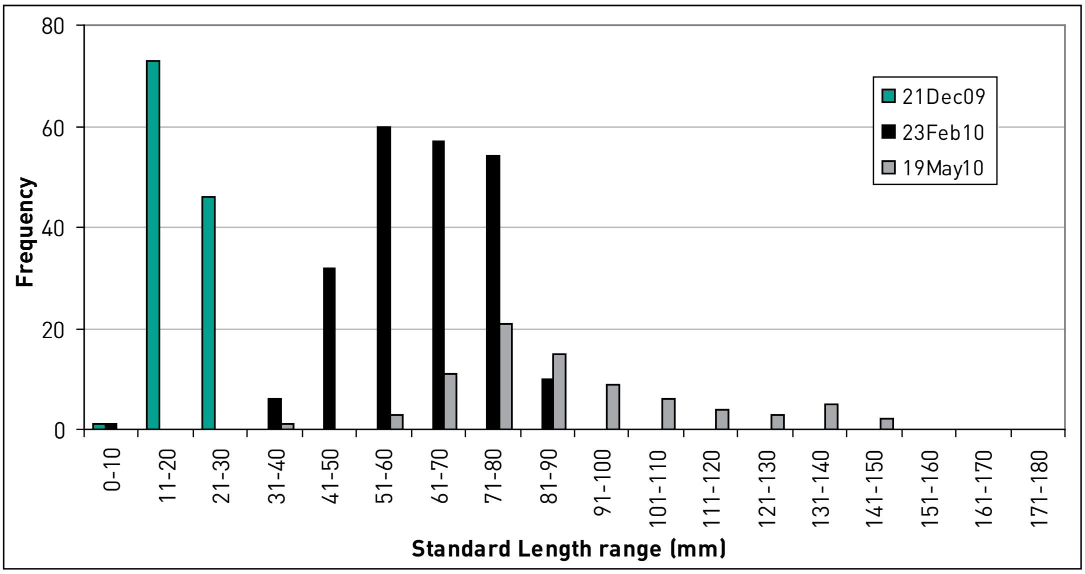


Figure 8. Length-frequency distributions of common carp (*Cyprinus carpio*) at Back Creek following wetland refilling from 26 November 2009.

River red gum

Trigger values

Most river red gum (*Eucalyptus camaldulensis*) had a crown condition rating of 'moderate cover' on each sampling occasion.

Four trees met the Wallace et al. (2007) trigger point for management notification when crown condition deteriorated from category 4 (moderate foliage cover) to category 3 (minimal foliage cover).

Crown condition

The majority (>63%) of river red gum on each sampling occasion were rated as category 4 (moderate foliage cover) for their crown condition (**Figure 9**). No trees were classified as categories 0, 1 (near dead) or 2 (highly stressed) at any time during the monitoring period. For all trees and times, crown condition was category 4 or 5 with the exception of five trees that were recorded as category 3 (stressed) in December 2007, December 2008 and May 2010.

In addition to the categorical presentation of crown condition (**Figure 9**), the mean foliage vigour (based on percentage scores of crown condition) is presented for each transect (n=10 trees per transect; **Figure 10**). This graph highlights the lower condition of trees at site B5 (furthest from the inlet) relative to the other sites, in addition to seasonal changes in crown condition.

A direct comparison of vertical photographs of each river red gum tree at the start (September 2007) and finish (May 2010) of the project revealed that 11 of the 30 trees had an overall increase in foliage within the crown over the study period, 18 trees showed no clear change and one tree had a decrease in foliage. Examples of the vertical river red gum photographs are provided in Appendix C.

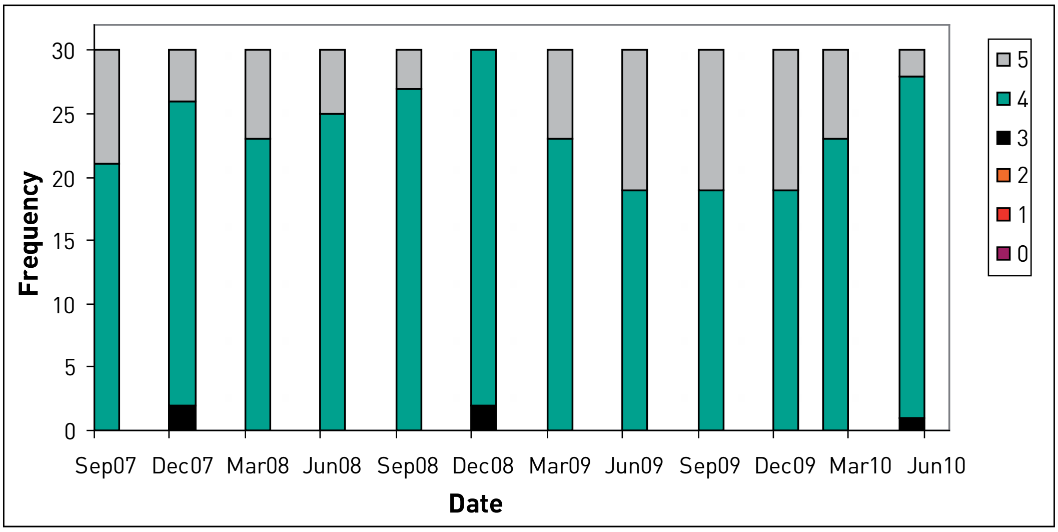


Figure 9. Crown condition of river red gum at Back Creek based on categories (see methods for description of the six categories).

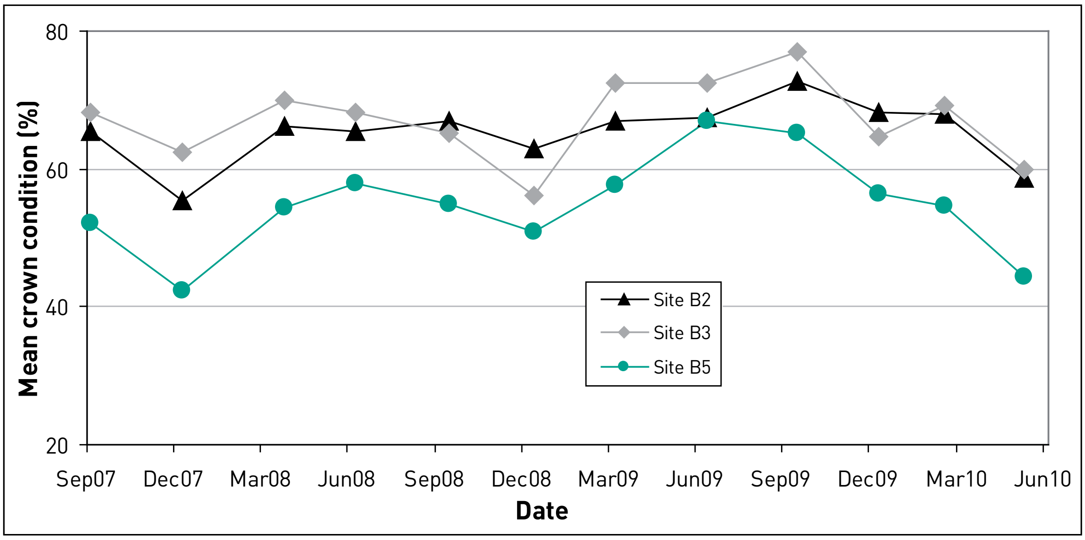


Figure 10. Mean crown condition scores (%) for river red gum at each of three transects (n=10 trees per transect) at Back Creek.

New foliage

The greatest amount of new foliage growth occurred in December 2009, when 22 trees were recorded as having over 10% of their foliage as new growth (**Figure 11**). All trees had new growth recorded for at least one sampling time over the monitoring period.

In addition to the categorical presentation of new growth (**Figure 11**), the mean new growth (based on percentage scores of new growth) is presented for each transect (n=10 trees per transect; **Figure 12**).

This graph highlights the increase in new growth in December 2007 and December 2009 that may relate to seasonal growth. The very high amount of new growth at sites B2 and B3 in December 2009 may also be a response to the refilling of the creek. This notion is strengthened by site B5 not having received water at the time of the survey (December 2009) and the lower new growth scores recorded there.

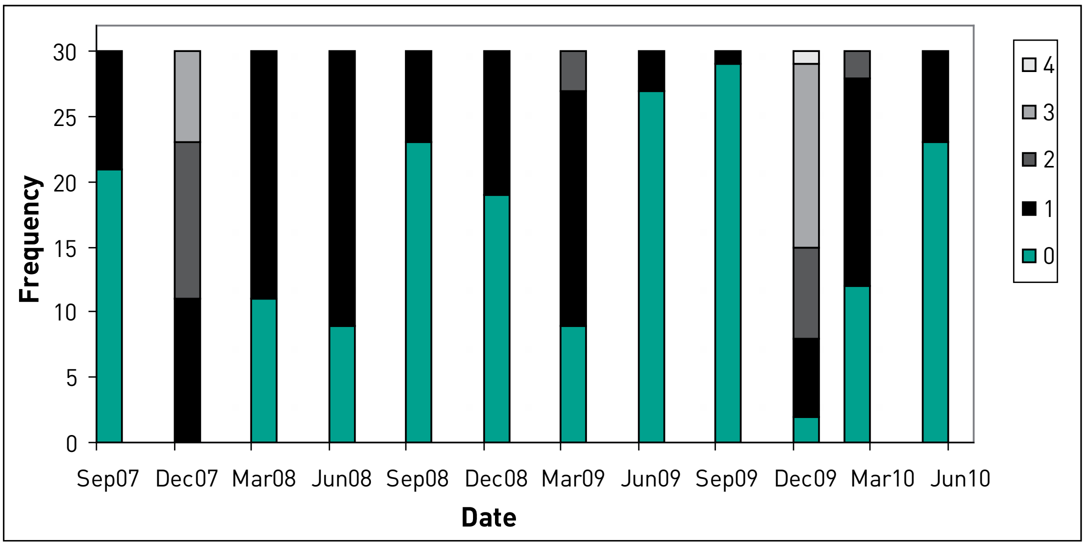


Figure 11. New growth of river red gum at Back Creek based on categories (see methods for description of the five categories).

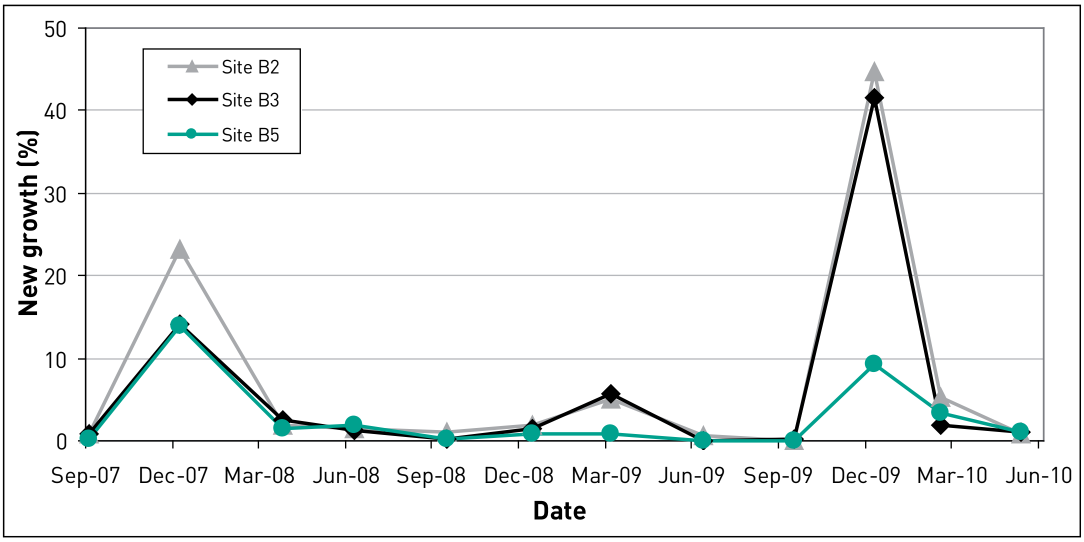


Figure 12. Mean new growth scores (%) for each of the three river red gum transects (n=10 trees per transect) at Back Creek.

Vegetation community

Trigger values

No rare or threatened plant species were recorded in the vegetation community of Back Creek. Hence, the trigger point of Wallace et al. (2007) relating to the maintenance of aquatic habitat for rare or threatened vegetation species, was not met.

The noxious weed arrowhead (*Sagittaria platyphylla*) was observed at Back Creek.

Thirty-two plant taxa from six functional groups were identified from 11 surveys. The abundance of each taxon for each sampling occasion and its functional group are presented in **Table 11**. Due to the steepness of the creek bank at site B5, the elevations -30 cm and +30 cm were not sampled as they overlapped with the -60 cm and +60 cm elevations, respectively. Abundances are the number of cells in which each taxon were recorded from a possible 195 cells (i.e. 2 sites x 5 elevations x 15 cells per quadrat plus 1 site x 3 elevations x 15 cells per quadrat).

Vegetation species richness ranged from nine to 20 taxa between surveys. The most abundant vegetation species sampled was river red gum (*Eucalyptus camaldulensis*) followed by common rush (*Juncus usitatus*). River red gum germinated on the creek bed following wetland drying and the seedlings developed into saplings over the study period, reaching a height of ≈3 m at site B2 in May 2010.

The abundance of understorey species at each elevation and monitoring time are presented in **Figure 13**. Abundances are the summed frequency of occurrence of plant species in the cells at each elevation. A relatively high abundance of plants occurred at and below the initial waterline in the first year of monitoring due primarily to the germination of river red gum seedlings on the exposed sediment during wetland drying. The increase in plant abundance in May 2010 at and above the initial waterline is due to the initial inundation of these quadrats when the wetland was first filled and the creation of moist soil conditions when the water levels decreased.

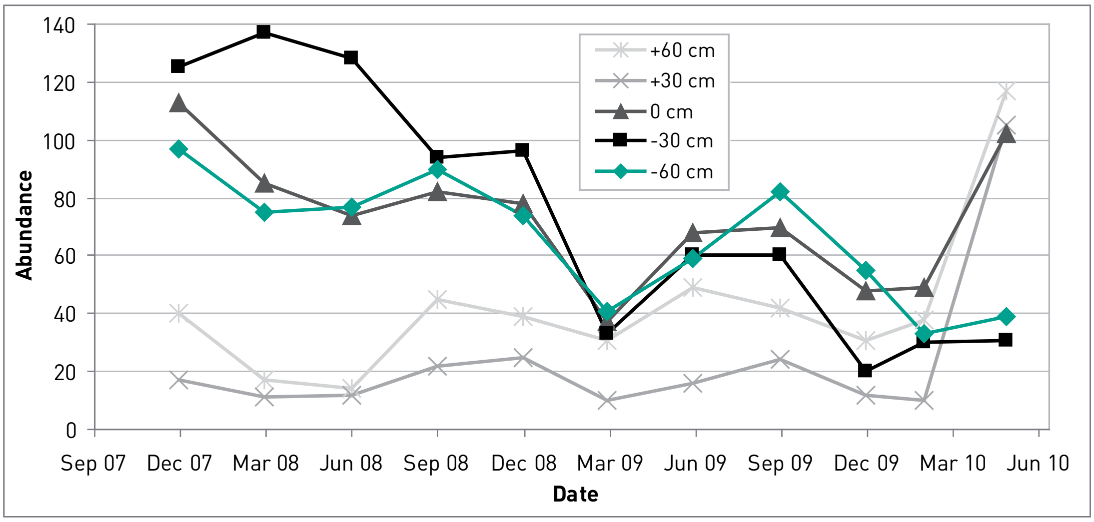


Figure 13. Abundance of understorey vegetation from fixed quadrats at five elevations at Back Creek.

Table 11. Understorey vegetation sampled at Back Creek on 11 occasions from 2007–2010, showing their categorisation per functional groups and measured abundance. The maximum possible abundance for each taxon at each time is 195 (i.e. 2 sites x 5 elevations x 15 cells per quadrat + 1 site x 3 elevations x 15 cells per quadrat). Shaded cells denote sampling trips following wetland refilling. Introduced species are highlighted with an asterisk.

Scientific name	Common name	Functional group	Abundance										
			Dec07	Mar08	Jun08	Sep08	Dec08	Mar09	Jun09	Sep09	Dec09	Feb10	May10
Alternanthera denticulata	Lesser joyweed	Tda						1	1		2		36
Asteraceae family			2	4	9	10	9	3			4	2	9
Avena spp.*		Tdr								24			6
Centipeda cunninghamii	Common sneezeweed	ATl	67	48	35	24	20	4	7	4	4		48
Chamaesyce drummondii	Caustic weed	Tdr							7				
Chenopodium pumilio	Small crumbweed	Tdr	3									3	
Cyperus difformis	Dirty dora	ATe	1		2								
Cyperus spp.		ATe				1							
Eleocharis spp.		ATe					1						
Erodium spp.													15
Eucalyptus camaldulensis	River red gum (tree or roots)	ATw	76	25	13	12	40	44	44	23	39	26	11
Eucalyptus camaldulensis	River red gum (seedlings)	ATw	48	78	81	87	83	81	79	90	68	85	95
Eucalyptus spp.		ATw			1								23
Geraniaceae family				1									
Glinus lotoides	Hairy carpet weed	Tda	1									2	19
Immature dicot			47	4	53	41	11	1	53	43	8	10	29
Immature monocot					70			2	24			10	5
Isolepis prolifera*	Budding clubrush	ARp	15	14	15	30	30						
Juncus spp.	Juncus	ATe											1
Juncus usitatus	Common rush	ATe	80	76	84	72	67	9	69	25	22	14	17
Lythrum hyssopifolia	Hyssop loosestrife	Tda	2				25						
Malva parviflora*	Small-flowered mallow	Tdr				1							1
Medicago spp.*	Medic	Tda			20	32	1		13	47			20
Paspalum distichum	Watercouch	Tda											2
Persicaria spp.				1	31		1	1		1	2	2	10
Poaceae family			33	12	1	54	24	3	24	60	11	19	81
Polygonum plebeium	Small knotweed	Tda	40	51	4				3				8
Pseudognaphalium luteoalbum	Jersey cudweed	Tdr	14	12	9	7	9	3	4	2			2
Salsola kali L. var. kali	Prickly roly-poly	Tdr						1					
Senecio spp.	Groundsel		4	2		2	3	1	1	2	14		
Solanum nigrum	Black-berried nightshade	Tdr		1	1								
Solanum spp.			3									2	2
Trifolium spp.*	Clover		3										
Abundance			**439**	**329**	**429**	**373**	**324**	**154**	**329**	**321**	**174**	**175**	**440**
No. taxa			**16**	**13**	**15**	**12**	**13**	**12**	**12**	**10**	**9**	**10**	**20**

Species richness ranged from two to 29 for each elevation and sampling occasion (**Figure 14**). Four taxa were recorded at all sampling occasions and eight taxa were sampled on only one occasion. In May 2010 there was a clear increase in species richness at elevations at and above the waterline (0 cm, +30 cm and + 60 cm) after these elevations were inundated and then water levels receded providing damp soil conditions. There was a general decrease in species richness at the -30 cm elevation over the study period. This may relate to the establishment of river red gum at this elevation and their outcompeting of other species through shading and possibly allelopathy.

The 32 plant taxa classified into six of a possible 10 functional groups (**Figure 15**). No submerged species were recorded within the vegetation quadrats, although ribbonweed (*Vallisneria* spp.) was observed growing at site B1 in November 2008 and March 2010.

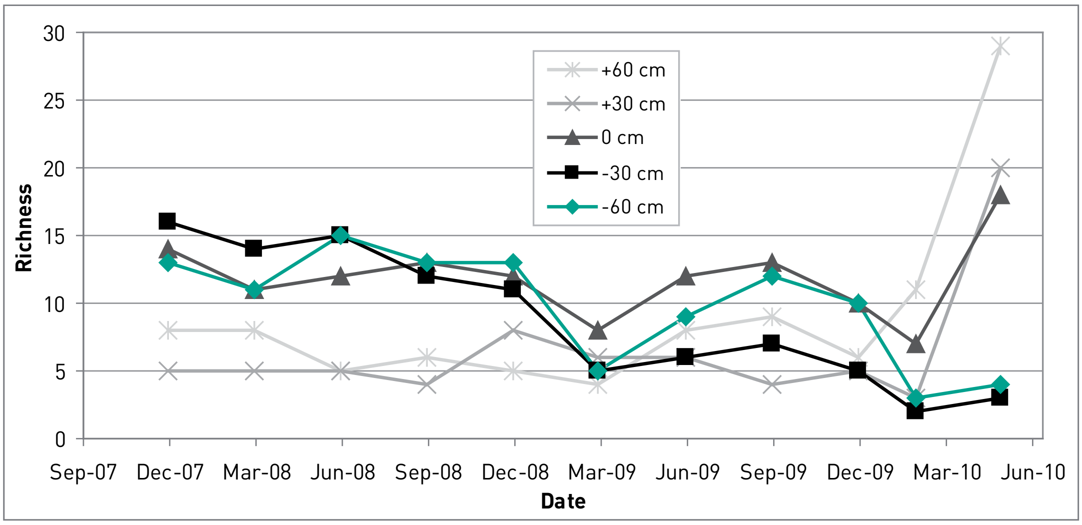


Figure 14. Richness of understorey vegetation from fixed quadrats at five elevations at Back Creek

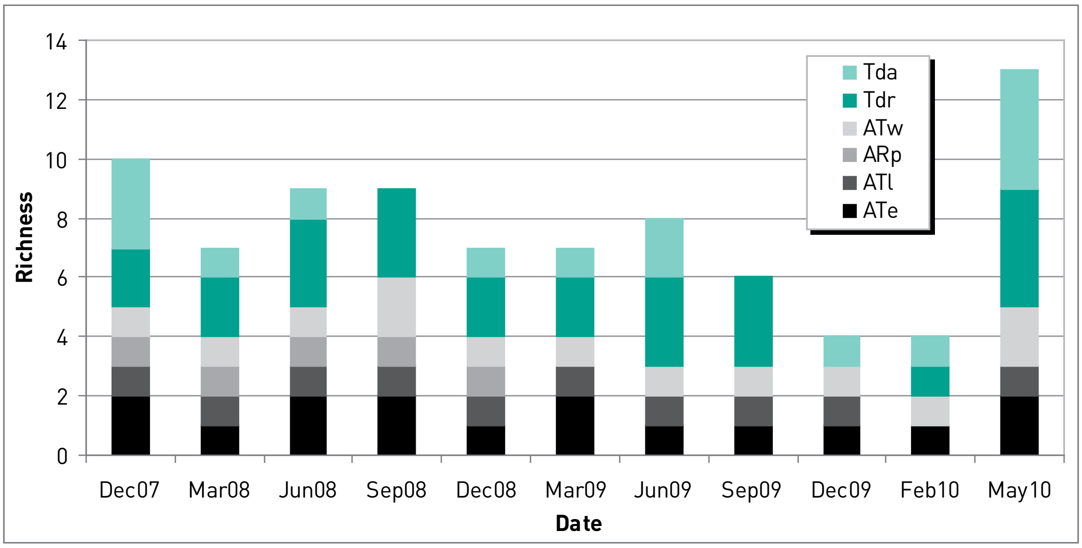


Figure 15. Species richness of the vegetation community by functional group at Back Creek at 11 sampling times

Introduced species

In October 2008, the weed arrowhead (*Sagittaria platyphylla*) was observed to be growing at a small section of Back Creek on the Yallakool Creek side of the regulator (**Figure 16**). The species was also observed in February 2009 and March 2010 at the same site. This species is declared in New South Wales under the *Noxious Weeds Act 1993* (Department of Primary Industries 2005).

Managers were first notified of the occurrence of this declared noxious weed in the 18-month update report (Durant et al. 2009b).

Five other introduced plant taxa were recorded at Back Creek during the monitoring period, including *Avena* spp., *Isolepis prolifera*, *Malva parviflora*, *Medicago* spp. and *Trifolium* spp. and they generally occurred in low abundances.

Figure 16. The declared noxious weed arrowhead (*Sagittaria platyphylla*) located within Back Creek on the Yallakool Creek side of the regulator. Photograph: R Durant, 18 February 2009

River red gum

River red gum germinated upon the exposed sediment as water levels in Back Creek receded following wetland disconnection. These seedlings became established and developed into saplings over the 33 month study period. In March 2009, river red gum had reached an average height of ≈1.5 m and in May 2010 had an average height of ≈3 m.

The highest abundances of river red gum occurred at the -60 cm and -30 cm elevations (**Figure 17**). At site B3, river red gum cover in the quadrats increased from 4% in December 2007 to 57% in February 2010, while at site B2 river red gum cover increased from 12% in December 2007 to 77% in February 2010. Site B5 is not represented as -30 cm elevation was not sampled. The decrease in river red gum cover in May 2010 likely relates to the decrease in condition observed in river red gum after inundation of approximately five months.

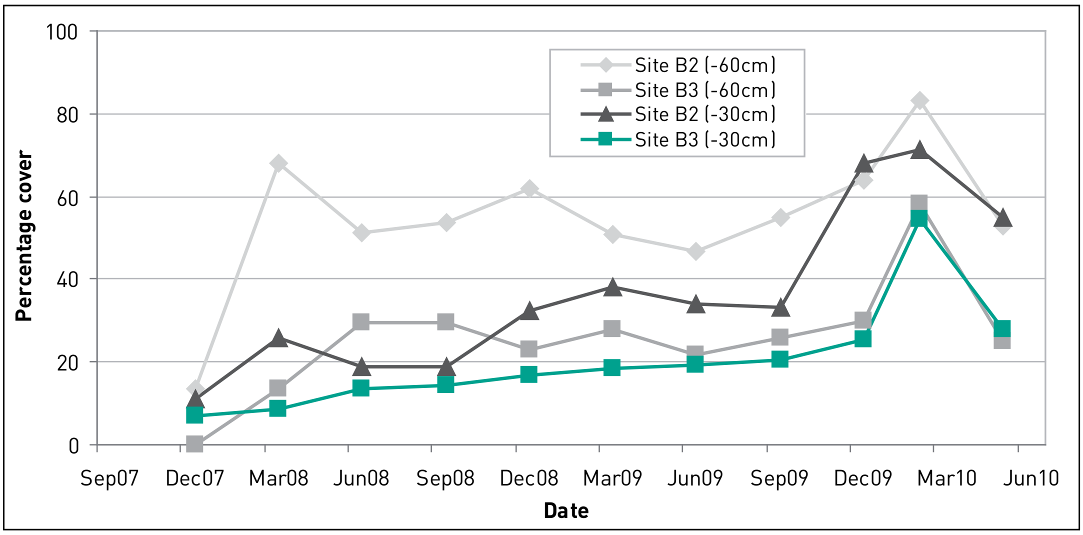


Figure 17. Growth of river red gum at -30 cm and -60 cm elevations at sites B2 and B3 of Back Creek

Birds

Trigger values

No trigger values were established for birds in Department of Water and Energy (2007) or Wallace et al. (2007).

No waterbirds or terrestrial birds recorded at Back Creek were listed as rare or threatened. However, the white-browed woodswallow (*Artamus superciliosus*) has a proposed listing of vulnerable by the New South Wales Scientific Committee (Department of Environment, Climate Change and Water 2009).

Bird surveys occurred at Back Creek on one occasion before the wetland dried (December 2007), and recommenced in December 2009 following the wetland receiving water in November 2009.

Waterbirds

A total of 77 individual waterbirds from 11 species were recorded at Back Creek from four surveys (**Table 12**). Waterbird richness was low, ranging from two to seven species for each sampling occasion. The highest abundance of waterbirds occurred in May 2010, when 40 individual waterbirds from seven species were recorded.

Table 12. Waterbirds recorded at Back Creek

Common name	Scientific name	Relative abundance					
		Prior to drying	Dec07	After refilling	Dec09	Mar10	Jun10
Australian wood duck	Chenonetta jubata					2	6
Australian reed-warbler	Acrocephalus australis				3	7	
Australasian grebe	Tachybaptus novaehollandiae					1	1
Black-tailed native hen	Tribonyx ventralis				1		
Dusky moorhen	Gallinula tenebrosa						3
Grey teal	Anas gracilis				6		3
Little grassbird	Megalurus gramineus					1	
Little pied cormorant	Microcarbo melanoleucos					5	11
Pacific black duck	Anas superciliosa					3	21
Whistling kite	Haliastur sphenurus		1				1
White-faced heron	Ardea pacifia		1				
Richness			2		3	6	7
Total count			2		10	19	46

Terrestrial birds

A total of 26 terrestrial bird species were recorded over the four sampling events (**Table 13**). Species richness ranged from 13 to 20 for each survey.

No threatened or rare terrestrial bird species were recorded at Back Creek. However, the white-browed woodswallow (*Artamus superciliosus*) has been proposed to be listed as vulnerable, under the NSW *Threatened Species Conservation Act 1995* by the New South Wales Scientific Committee (Department of Environment, Climate Change and Water 2009). The restless flycatcher (*Myiagra inquieta*) has been observed to be declining in numbers in areas north-east of this study site (Reid 1999).

Table 13. Terrestrial birds recorded at Back Creek

Common name	Scientific name	Occurrence					
			Dec-07		Dec-09	Mar-10	Jun-10
Australian magpie	Gymnorhina tibicen	Before drying		After refilling	X	X	X
Australian raven	Corvus coronoides		X			X	X
Black-faced cuckoo-shrike	Coracina novaehollandiae		X				
Brown treecreeper	Climacteris picumnus picumnus		X		X	X	X
Crested pigeon	Ocyphaps lophotes					X	
Galah	Cacatua roseicapilla		X		X	X	X
Grey fantail	Rhipidura albiscapa					X	X
Grey shrike-thrush	Colluricincla harmonica		X			X	X
Laughing kookaburra	Dacelo novaeguineae		X				X
Long-billed corella	Cacatua tenuirostris				X	X	X
Magpie-lark	Grallina cyanoleuca					X	
Peaceful dove	Geopelia placida		X			X	
Pied butcherbird	Cracticus nigrogularis					X	X
Red-rumped parrot	Psephotus haematontus		X		X	X	
Restless flycatcher[2]	Myiagra inquieta					X	
Sacred kingfisher	Todiramphus sanctus		X		X	X	
Striated pardalote	Pardalotus striatus		X		X		X
Sulphur-crested cockatoo	Cacatua galerita		X		X	X	X
Superb fairy-wren	Malurus cyaneus		X		X	X	X
Tree martin	Hirundo nigricans				X		X
Weebill	Smicrornis brevirostris					X	
Welcome swallow	Hirundo neoxena				X		
White-browed woodswallow[1]	Artamus superciliosus		X				
White-plumed honeyeater	Lichenostomus penicillatus		X		X	X	X
Willie wagtail	Rhipidura leucophrys		X		X	X	X
Yellow rosella	Platycercus elegens flaveolus		X			X	
Richness			16		13	20	15

1 Proposed listing of vulnerable (Department of Environment, Climate Change and Water 2009)

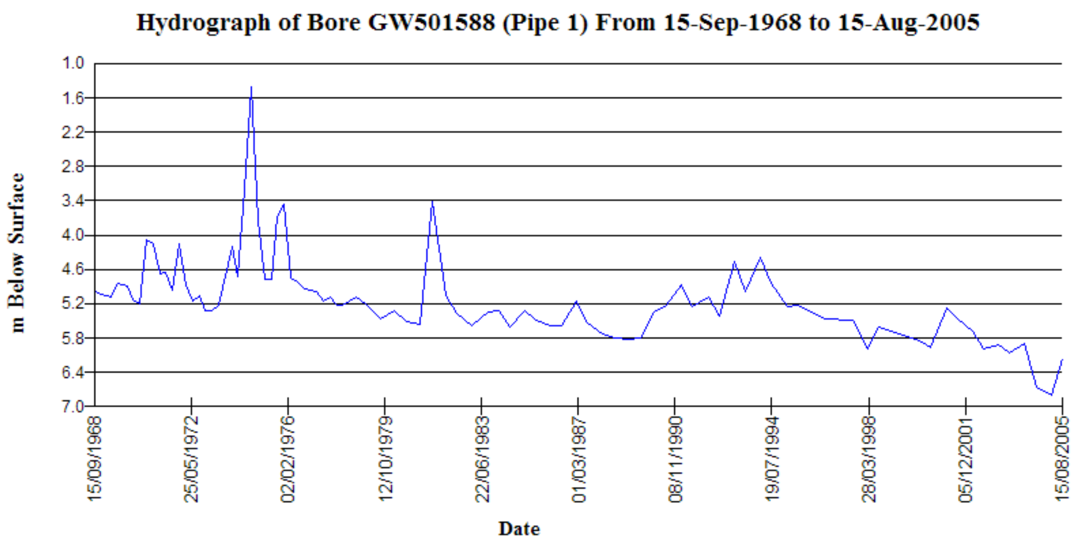
2 Species declining in numbers (Reid 1999)

Groundwater

Groundwater levels for bores GW501588 and GW501589 are presented in **Figure 18**. The latest information on the state database for these bores was 2005, when groundwater levels were approximately 5.8 m (GW501588) and 8 m (GW501589) below ground level. There was a general decrease in groundwater levels over the drought period. Given the continued dry conditions since 2005, it was predicted that regional groundwater levels would have continued to decrease over the past five years. The groundwater level was considered unlikely to intercept the creek bed of Back Creek and cause any salinity impacts. This prediction was supported by the complete drying of the wetland and the very low electrical conductivity of the water within Back Creek following its refilling.

The electrical conductivity of groundwater in the vicinity of Back Creek (located in the central region of the Murray Geological Basin) is typically in the range of 10,000 to 20,000 µS.cm^{-1} (Mitchell 2008).

A



B

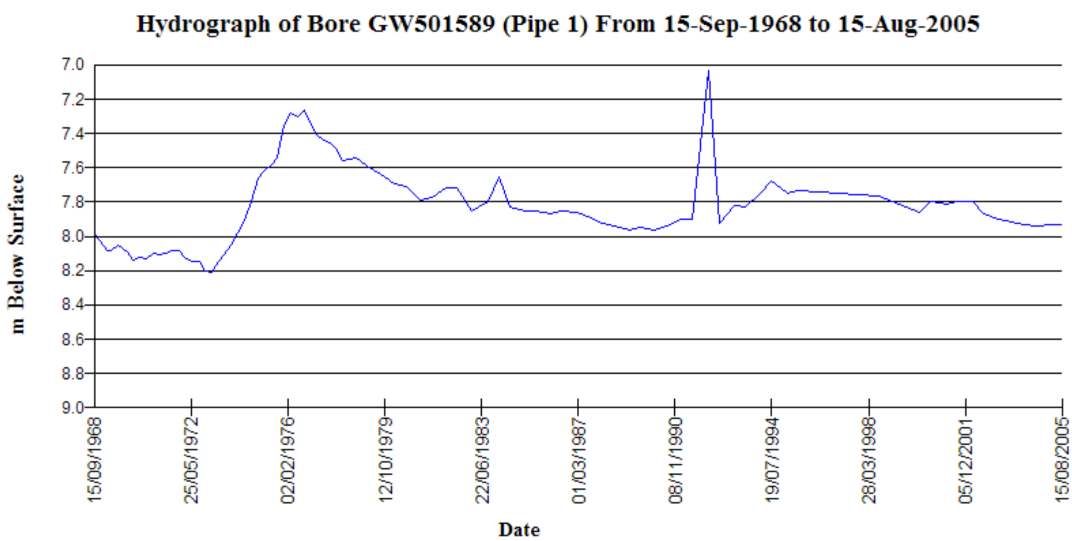


Figure 18. Groundwater hydrographs for bores (A) GW501588 and (B) GW501589 located approximately 6 km to the south-east of the confluence of Back Creek with Yallakool Creek.

Photo points

Photographs from a single photo point at each site are presented in figures 19 to 23. These images provide a photographic history of the site and highlight changes in water levels and vegetation over time.

A significant observation from the photo points was the establishment and growth of river red gum upon the dry creek bed. In March 2009, there was some mortality of river red gums — particularly at site B4 — that was likely due to the prolonged dry conditions and resource competition between the plants. In June 2009, there was clear growth in river red gum at sites B2 and B3. The photos also show a decrease in the condition of the river red gum saplings from December 2009 (shortly after refilling of the wetland occurred) to May 2010 when some inundated saplings had died.

Figure 19. Photo points at site B1 of Back Creek in (A) September 2007, (B) December 2007, (C) March 2008, (D) June 2008, (E) September 2008,(F) December 2008, (G) March 2009, (H) June 2009, (I) September 2009, (J) December 2009, (K) February 2010 and (L) May 2010.

Figure 20. Photo points at site B2 of Back Creek in (A) September 2007, (B) December 2007, (C) March 2008, (D) June 2008, (E) September 2008,(F) December 2008, (G) March 2009, (H) June 2009, (I) September 2009, (J) December 2009, (K) February 2010 and (L) May 2010.

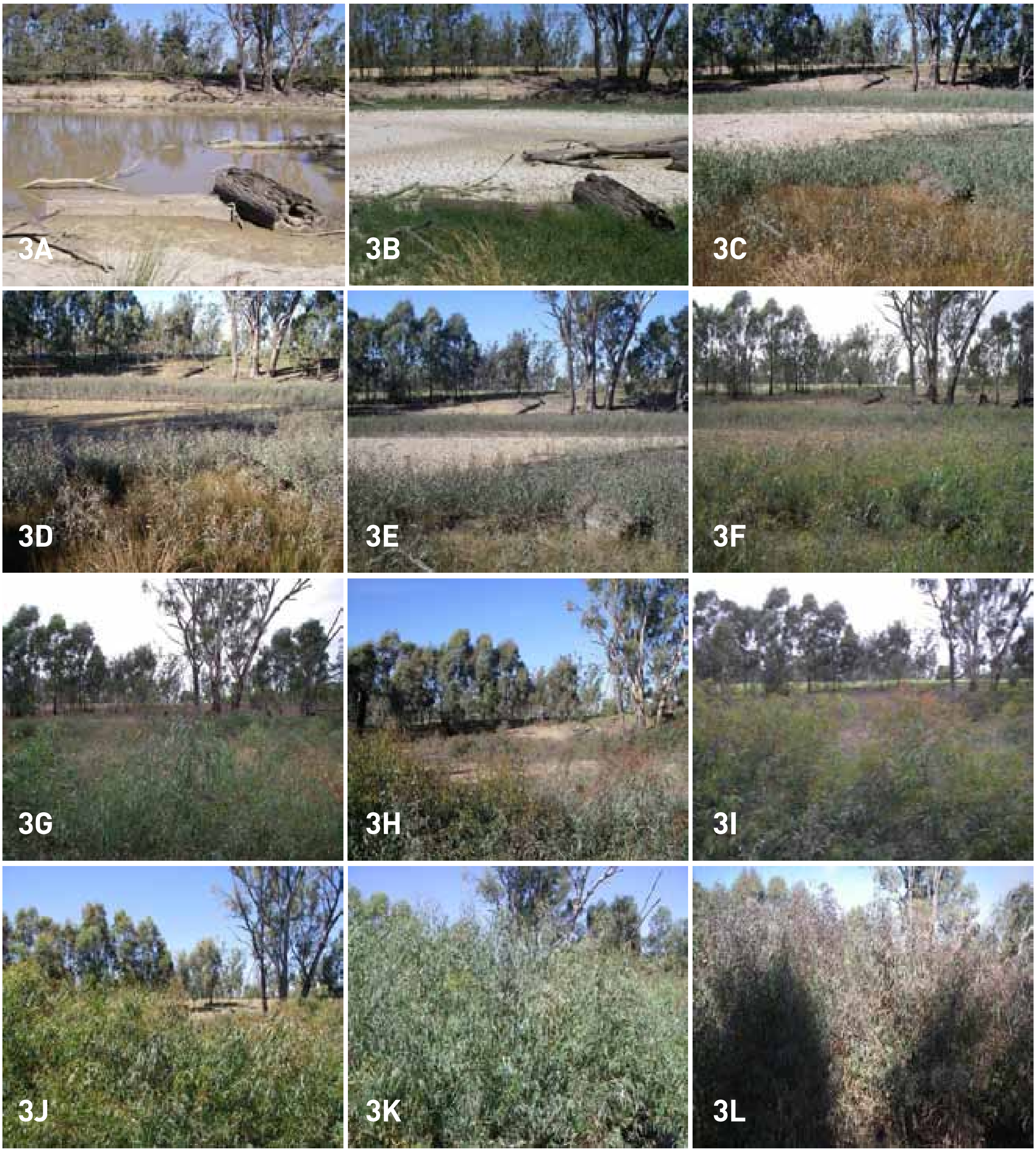


Figure 21. Photo points at site B3 of Back Creek in (A) September 2007, (B) December 2007, (C) March 2008, (D) June 2008, (E) September 2008,(F) December 2008, (G) March 2009, (H) June 2009, (I) September 2009, (J) December 2009, (K) February 2010 and (L) May 2010.

Figure 22. Photo points at site B4 of Back Creek in (A) September 2007, (B) December 2007, (C) March 2008, (D) June 2008, (E) September 2008,(F) December 2008, (G) March 2009, (H) June 2009, (I) September 2009, (J) December 2009, (K) February 2010 and (L) May 2010.

Figure 23. Photo points at site B5 of Back Creek in (A) September 2007, (B) December 2007, (C) March 2008, (D) June 2008, (E) September 2008,(F) December 2008, (G) March 2009, (H) June 2009, (I) September 2009, (J) December 2009, (K) February 2010 and (L) May 2010.

Discussion

The monitoring program met its objective of assessing the ecological condition of Back Creek during the study period. Monitoring results for the ecological indicators of sulfidic sediments, water quality and water levels, blue-green algae, fish, river red gum, understorey vegetation, birds and groundwater were interpreted against pre-determined trigger values (Wallace et al. 2007; Department of Water and Energy 2007; Baldwin et al. 2007) and communicated to managers on a tri-monthly basis, to ensure that management decisions could be based on recent and appropriate environmental data.

Sulfidic sediments

The occurrence of sulfidic sediments in inland wetlands is not uncommon (Baldwin et al. 2007). Acid sulfate soils are formed after iron sulfides oxidise upon exposure to air and form sulfuric acid. Upon rewetting of the sediments, the acid is released and the wetland has the potential to become acidic (depending upon its buffering capacity), resulting in adverse effects including fish deaths, reduced food resources and altered plant communities (McCarthy et al. 2006). The best option to manage sulfidic sediments is to implement a wetting and drying cycle, so long as sulfidic sediments have not formed already in the soil layer (Baldwin et al. 2007).

The pH of sediment at all sites of Back Creek was below the acceptable pH 4.5 threshold of the decision-support tool of Baldwin et al. (2007), raising concerns that the wetland may contain sulfidic materials at levels that could cause ecological damage if the wetland dried. The protocol of Baldwin et al. (2007) recommended that a more detailed investigation of sulfidic sediments be undertaken by directly analysing sediments.

The subsequent analysis of sediment cores found only small amounts of reactive sulfide in the sediment but relatively high net acidities (Baldwin et al. 2008). The study concluded that there was a low risk of net acidification related to sulfidic sediments if the creek was dried (Baldwin et al. 2008). However, the study recommended that if Back Creek was dried, any refilling event should be accompanied by a monitoring program with an emphasis on water column pH and electrical conductivity. The pH range of 6.3–7.3 and electrical conductivity range of 52–61 $\mu S.cm^{-1}$ following refilling, provides good evidence that the wetland did not acidify or intercept saline groundwater during its dry phase.

Water levels and quality

Back Creek was partially dry at the beginning of this project and had dried completely seven months into the monitoring program. The wetland remained dry for over 18 months until managers made the decision to refill the wetland and the regulator was opened in November 2009. The loss of aquatic habitat resulting from the decreasing water levels following wetland disconnection had clear impacts upon water-dependent biota such as fish. The only fish deaths observed were of some common carp in the final isolated pool (approximately 5 m x 5 m) when water depth was <10 cm, indicating that predators such as piscivorous birds likely consumed the isolated fish community.

Water quality is an important determinant of the aquatic flora and fauna that can occur within a wetland. During the period of monitoring that Back Creek contained surface water, several water quality variables were on occasion outside of the acceptable range stipulated in Department of Water and Energy (2007) and Wallace et al. (2007). However, in no instance could we attribute any deleterious effects upon aquatic biota, such as fish, to poor water quality.

Electrical conductivity of the surface water in Back Creek increased greatly as the wetland dried, and this pattern conforms to the model of salts concentrating as water evaporates. The relatively high electrical conductivity reading in March 2008 is attributed to the concentration of salts within the small volume of water remaining in the shallow pool, just before drying. After the wetland was refilled, electrical conductivity was low and well below the Department of Water and Energy (2007) and Wallace et al. (2007) trigger values.

The pH at Back Creek was generally slightly acidic and did not exceed pH 8 during the study period, likely reflecting the high net acidities of the sediments (Baldwin et al. 2008). The finding that pH did not fall below 6 following wetland refilling provides supportive evidence that sulfidic sediments are not a concern at Back Creek.

Dissolved oxygen levels were extremely low following wetland refilling. This is attributed to the dense stands of river red gum becoming established on the creek bed during the dry phase. Thick layers of leaf litter and established vegetation contributed carbon to the water column, fuelling microbial decomposition of the organic material and thereby consumption of dissolved oxygen from the water column. The dense stands of river red gum also likely limited wind and wave action within the wetland, resulting in lower rates of diffusion of atmospheric oxygen into the water column.

Surface water temperatures before complete drying were within the Department of Water and Energy (2007) acceptable range of 6–30°C at all sites and times, with the exception of March 2008 when water temperature was recorded at 34.4°C. The high water temperature at this time is attributed to the shallow water depth (<10 cm) and high daytime temperatures at the time of sampling (air temperature was 37°C), and the consequent low thermal buffering capacity of the surface water.
After Back Creek refilled, surface water temperatures were within the Department of Water and Energy (2007) acceptable range at all sites and times.

The high turbidity before complete drying of the wetland is attributed to the suspension of sediment due to shallow water depths and their consequent susceptibility for resuspension through wind and wave action. It is likely that the low turbidity levels since refilling are due to (a) greater water depths and (b) the establishment of river red gum across the creek bed and the consequent reduction in wind and wave action.

Blue-green algae

Blue-green algae growth rate is influenced by a number of variables, including temperature, light, mixing regime, nutrient concentration and nutrient stoichiometry. Only site B2 in February 2010 had a potential toxin producer that exceeded the 15,000 cells.mL^{-1} trigger value of Wallace et al. (2007). In contrast, the count for this species was considerably lower at site B3 for the same time (1730 cells.mL^{-1}) highlighting the variability in phytoplankton concentrations across small spatial scales.

Fish

The six native and four exotic fish species sampled at Back Creek are widespread and abundant throughout the Edward–Wakool River system. All of the fish species sampled were small-bodied with the exception of two exotic species common carp and goldfish. At the time the regulator was installed, Back Creek had already become disconnected from Yallakool Creek and the falling water levels signalled fish had to move from the wetland to the deeper waters of Yallakool Creek. This could potentially explain the absence of large-bodied native fish such as bony bream, golden perch, silver perch or Murray cod from the sampling. As the creek dried, it is probable that small-bodied fish species were preyed upon by piscivorous birds and possibly other predators given that only dead common carp were observed as the final small pool of surface water became very shallow.

The abundance and diversity of fish within Back Creek changed considerably in response to the wetland disconnection and drying. Before drying, native fish comprised 95% of the fish sampled due to high numbers of carp gudgeons being sampled. Following refilling, exotic fish comprised 97% of the fish sampled with high numbers of juvenile common carp being sampled.

Allowing wetlands to experience a wetting and drying regime has the potential to improve the quality of habitat and trigger breeding responses in many aquatic species such as fish. However, upon refilling there is the risk of exotic fish such as common carp and Eastern gambusia breeding and dominating the fish community. The high abundance of late larvae and early juvenile common carp within Back Creek 25 days after the wetland commenced refilling, provides evidence that Back Creek is providing good habitat for this species. However, it is unclear whether these fish were spawned within Back Creek or whether they were washed in from Yallakool Creek. Growth rates of young-of-the-year common carp in South Australia by Vilizzi (1998) indicate a mean standard length of 14.6 mm for four-week-old fish. Based on this rate of growth, the common carp of Back Creek had likely washed into the creek after spawning in Yallakool Creek. However, an otolith-based study by Smith (2004) at Walker Flat South in South Australia indicates higher growth rates of common carp, with standard lengths of approximately 21 mm at 25 days old. Given that the mean standard length of the common carp within Back Creek was 20 mm, there is the possibility that these common carp were spawned within the wetland.

Regardless of the origin of these fish, the rapid growth rates in the cohort of common carp after wetland refilling indicates that Back Creek is providing good nursery habitat for the species. Common carp and Eastern gambusia are tolerant of very low dissolved oxygen levels relative to native fish species (Koehn and O'Connor 1990; Pusey et al. 2004; McNeil and Closs 2007), which is likely providing them with a competitive advantage at Back Creek given the very low dissolved oxygen conditions since wetland refilling. It is predicted that as dissolved oxygen levels increase, an increase in the diversity and abundance of native fish species will occur. However, the time required to increase dissolved oxygen levels within Back Creek is unclear.

River red gum

The condition of the river red gum trees fringing Back Creek was generally maintained over the study period. Based on visual assessments, most river red gum had a 'moderate' crown condition on each sampling occasion, with some trees having a 'healthy' crown condition on some sampling occasions. This pattern was generally reflected in the photographs of the crowns of each tree taken at the start and end of the study. This comparison revealed an increase in the amount of foliage within the crown for 11 trees, no clear change in foliage for 18 trees and a decrease in foliage in one tree. These photographs provide a record of the crown condition of each tree between surveys and were particularly useful for determining whether a change in crown condition based on the field visual assessments was real or due to intra- and inter-observer variation inherent within the field survey methodology. Together, the results from both techniques demonstrate that the disconnection and drying of Back Creek over an 18 month period did not result in deterioration of river red gum health. Rather, the photographic records indicate that over half of the trees showed at least some increase in crown condition based on the amount of foliage present within the crown.

The greatest amount of new growth of river red gum was recorded on 18 December 2009, approximately three weeks after refilling of the creek commenced. The considerably higher amount of new growth at sites B2 and B3 compared to B5 suggests that the inflows may have generated the large growth response because site B5 was the only site still dry at the time of the December 2009 survey. However, other factors such as recent rainfall (56 mm rainfall in November 2009 at nearby Deniliquin) and seasonality may also account for the increase in new foliage. Regardless of the driver causing the response, the recording of new growth is a positive sign for the sustainability of the river red gums adjacent to Back Creek.

Vegetation community

The plant species recorded at Back Creek are common to wetlands and river systems located within the Edward–Wakool River system. No rare or threatened plant species were recorded from the fixed quadrats at Back Creek, or from general observations within the area surrounding the creek. However, the noxious weed arrowhead (*Sagittaria platyphylla*) was observed in Back Creek on the Yallakool Creek side of the regulator. This species has the potential to form dense, monospecific patches and to obstruct water flows. The species is declared a noxious weed in New South Wales under the *Noxious Weeds Act 1993* (Department of Primary Industries 2005). Given that the identified stand of arrowhead was not removed before refilling Back Creek, there was the potential for its seeds to flow into other sections of Back Creek during refilling and provide further opportunity for its establishment and growth. However, there were no sightings of arrowhead on the monitored side of the regulator at Back Creek at any time during the monitoring period. New South Wales Department of Primary Industries states that there is a legal requirement for the control of arrowhead whereby 'The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority' (Department of Primary Industries 2009). Managers were notified of the occurrence of this declared noxious weed in the tri-monthly reports (Durant et al. 2009b; Durant et al. 2010a; Reid et al. 2009a,b).

The reintroduction of an appropriate wetting/drying cycle can promote an increase in the diversity and abundance of the vegetation community. Drying events desiccate aquatic plants and initially provide moist soil conditions that support the germination and growth of other plants upon the bed of the wetland. These changes were observed at Back Creek as plants became established at below-waterline elevations as the wetland dried (including river red gum seedlings). Flooding events can drown flood-intolerant vegetation established on the bed of the wetland and provide moist soil conditions to support plant establishment at higher elevations. These changes were recorded at Back Creek following refilling where a decrease in abundance and diversity of the vegetation community occurred below the waterline and an increase occurred above the waterline. This latter change was most notable when water levels peaked at the +30 cm elevations in February 2010 and a decrease in water levels provided opportunities for amphibious and terrestrial species to germinate on the moist soils.

An outstanding change at Back Creek as a result of the disconnection and drying of the wetland was the germination and establishment of river red gum upon the creek bed. This occurred along the length of Back Creek, with trees achieving heights of over 3 m during the 33 month monitoring period. A similar growth response in river red gum was observed upon lakebeds at Hattah Lakes following long periods of wetland drying (McCarthy et al. 2009a). The future of the river red gum saplings at Back Creek is dependent upon water regime. River red gum with their foliage above the waterline can generally tolerate continuous flooding for up to 18 months (Scott & Grant 1997). If Back Creek remains inundated for a prolonged period it would be expected that the river red gum on the creek bed will die. There was evidence of this occurring at some sites of Back Creek in May 2010 after six months of inundation, and large trees were observed to rapidly lose condition and die after one year of continuous inundation at Hattah Lakes (McCarthy et al. 2009a).

Birds

The diversity of 11 species of waterbirds at Back Creek was low when compared to other New South Wales wetlands disconnected for water savings, including Euston Lakes (42 species; McCarthy et al. 2010) and Tareena Billabong (28 species; McCarthy et al. 2009b), but was the same as Tumudgery Creek (Durant et al. 2010b).

A more diverse and abundant waterbird community may have been expected at Back Creek in response to the drying and refilling of the wetland. However, the first survey occurred in December 2009 and a large decrease in fish abundance occurred in the three months before this sampling. Therefore, waterbird diversity and abundance may have been higher at an earlier stage of wetland drying that was not recorded in the monitoring program.

The spatial distribution of nomadic waterbirds is determined by influences at the landscape scale. An analysis of flood patterns within the Murray–Darling Basin suggests that waterbird habitat is nearly always available somewhere in the Basin (Scott & Grant 1997). The availability of food, ultimately determined by rainfall and/or flooding, is the major factor that controls the movements of nomadic species of waterbirds (Scott & Grant 1997). While the condition of a creek system is important in determining the diversity and abundance of waterbirds it can support, the occurrence of suitable habitat elsewhere will influence whether waterbirds will occupy a particular wetland. It is therefore difficult to assign a level of condition to an individual wetland based on a recording of low waterbird abundance or diversity as occurred at Back Creek.

No waterbird or terrestrial bird species recorded at Back Creek were classified as rare or threatened under the New South Wales *Threatened Species Conservation Act 1995* (TSC Act) or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Of the terrestrial bird species recorded, the white-browed woodswallow (*Artamus superciliosus*) has a proposed listing of vulnerable status. The proposed listing was based on a population decline for the species that was potentially due to limitations of food supply and foraging substrates as a result of clearing and degradation of suitable habitat (Department of Environment Climate Change and Water 2009).

A study by Reid (1999) examined bushbirds of the New South Wales sheep-wheat belt, which included large parts of the interim biogeographic regionalisation of the Riverina where Back Creek is located. The restless flycatcher (*Myiagra inquieta*) recorded at Back Creek was considered by Reid (1999) as a species that was possibly declining. The brown treecreeper recorded in this study is the subspecies *Climacteris picumnus picumnus* and not the subspecies *C. picumnus victoriae* that is listed as vulnerable on the Threatened Species Conservation Act and most likely the subspecies considered to be declining in status according to Reid (1999).

Groundwater

Based on a review of groundwater trends in the region, it was predicted that the groundwater level would be unlikely to cause any salinity impacts on Back Creek (Mitchell 2008). This prediction was supported by the complete drying of the wetland and the recording of very low electrical conductivity of the surface water within Back Creek following its refilling.

Mitchell (2008) also predicted that groundwater levels near Back Creek would decline if the wetland were dry for an extended period, with established trees and deeper rooted vegetation still able to access groundwater in the region. While data on the groundwater levels in the vicinity of Back Creek during the monitoring period was not available, the maintenance of condition in river red gums indicates that these trees were able to draw upon groundwater resources during the period of disconnection.

Past water regime

Based on 60 years of records at the Yallakool Creek offtake, water levels were variable over an annual cycle with the highest levels recorded over the summer months and lowest (at zero discharge) for around one to three months each year in June/July/August (Appendix A). Before the construction of the Back Creek regulator, water levels in Back Creek were responsive to changes in water level in Yallakool Creek which typically varied over 1 m annually. As such, water levels in Back Creek would have reached low levels for approximately one to three months on an almost yearly cycle due to much of the water draining from Back Creek when water levels in Yallakool Creek decreased (New South Wales Murray Wetlands Working Group 2008).

For the 60 years before construction of the regulator at Back Creek, the water regime at the wetland was considered to be 'almost permanent' (New South Wales Murray Wetlands Working Group 2008). However, it remains unclear (a) what the natural water regime was, or (b) how the current flow regime differs to the natural water regime.

Synthesis of ecological indicators

Based on the monitoring results of the above ecological indicators, the ecological condition of Back Creek was generally maintained during the 33 month study period. No significant ecological damage was recorded or observed in response to the wetland disconnection. Sulfidic sediments and groundwater interactions were not considered significant threats at Back Creek, blue-green algae were mostly non-toxic taxa, the condition of mature river red gum fringing the wetland was maintained or slightly increased, the wetland-edge vegetation community was dynamic in response to the changed water regime and the low diversity and abundance of waterbirds does not necessarily reflect the ecological condition of Back Creek. However, the extensive establishment of river red gum upon the bed of Back Creek from the imposed drying event has contributed to the development of low dissolved oxygen levels within the surface water after wetland refilling and the length of time these conditions will persist is unclear. Possibly linked to these water quality conditions was the shift from a native-dominated fish fauna prior to wetland drying, to an exotic-dominated fish fauna following wetland refilling, where large abundance of juvenile common carp are currently occurring within Back Creek. It is predicted that an improvement in dissolved oxygen levels will lead to an increase in native fish diversity and abundance within Back Creek.

Future management and recommendations

The flow regime is a critical driver of the ecological processes and functions that occur at a wetland. As such, an understanding of the natural water regime of a wetland can provide managers with a guide for developing a management plan for that wetland. One approach may be to mimic the natural water regime to best support the flora and fauna adapted to that particular environment.

Given the unclear status of the natural water regime at Back Creek, it is difficult to provide specific water regime recommendations relating to the future management of the site. However, it is probable that before receiving regulated flows, Back Creek was an ephemeral wetland that received winter/spring flooding and waters drained from the wetland upon flood recession. Given the ecological responses during the recent drying and rewetting of Back Creek and the unclear status of the natural water regime for the site, it is recommended that:

A management plan is developed for Back Creek to maximise the ecological values of the wetland that incorporates:

- investigation of the natural flow regime of the wetland
- comparison of the natural flow regime with the current regulated flow regime
- development of an optimal water regime for the wetland that provides for:
    - o the two-way exchange of water between the wetland and Yallakool Creek
    - o the elimination of river red gum that have established upon the creek bed
    - o preventing river red gum from re-establishing upon the creek bed
- consideration of the potential benefits of delivering an optimal water regime to the wetland and the infrastructure required
- adaptive management principles, and
- development of a monitoring program to record ecological responses to any changed water regime.

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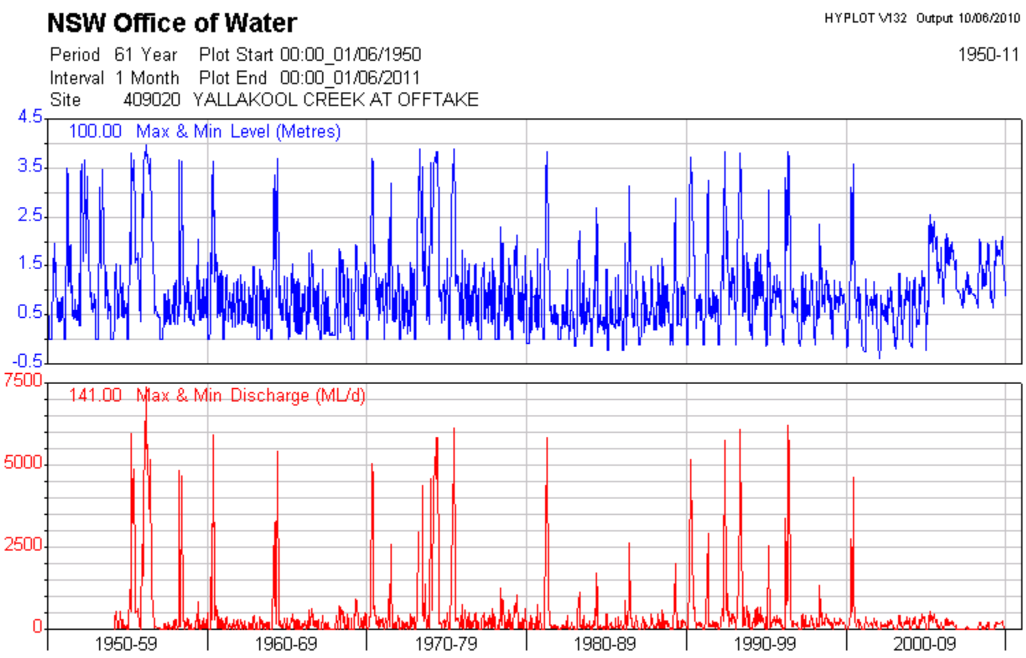
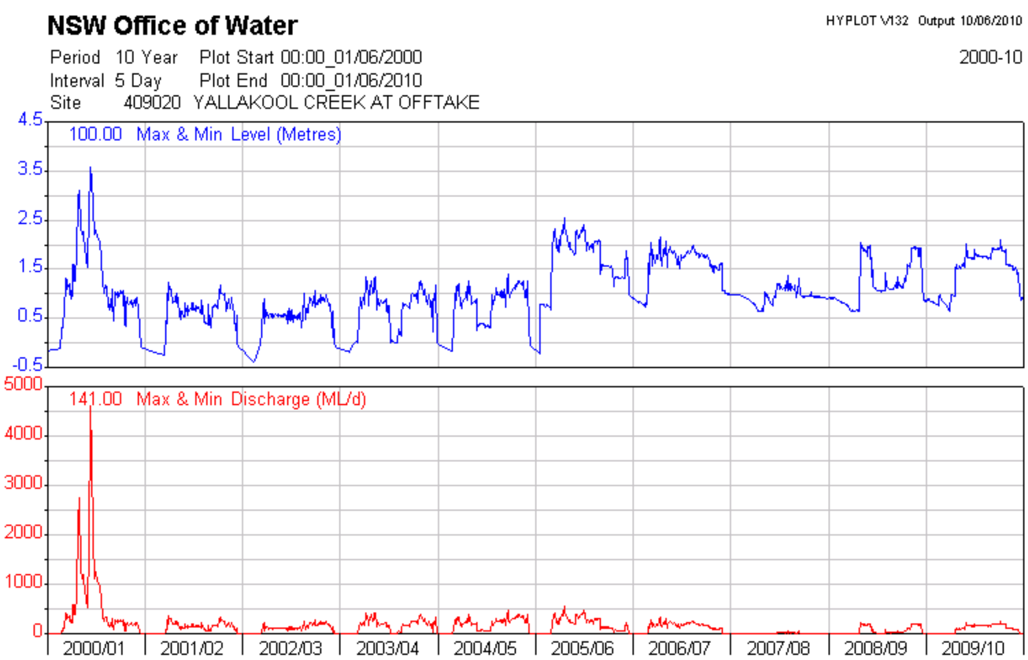
Appendix A.

Water levels and discharge at the Yallakool Creek offtake for(i) a 60 year period from 1950–2010 and (ii) 10 year period from 2000–2010

(i)



(ii)



Appendix B.

Blue-green algae taxa recorded at Back Creek

Anabaena circinalis !!!

Anabaena sp.

Anabaena spiroides f spiroides !!!

Aphanizomenon sp.

Aphanocapsa sp.

Cuspidothrix sp.

Cyanodictyon sp.

Cylindrospermum licheniforme !!

Geitlerinema sp.

Merismopedia sp.

Phormidium sp.

Planktolyngbya sp.

Planktolyngbya subtilis !!

Pseudanabaena sp.

Romeria sp.

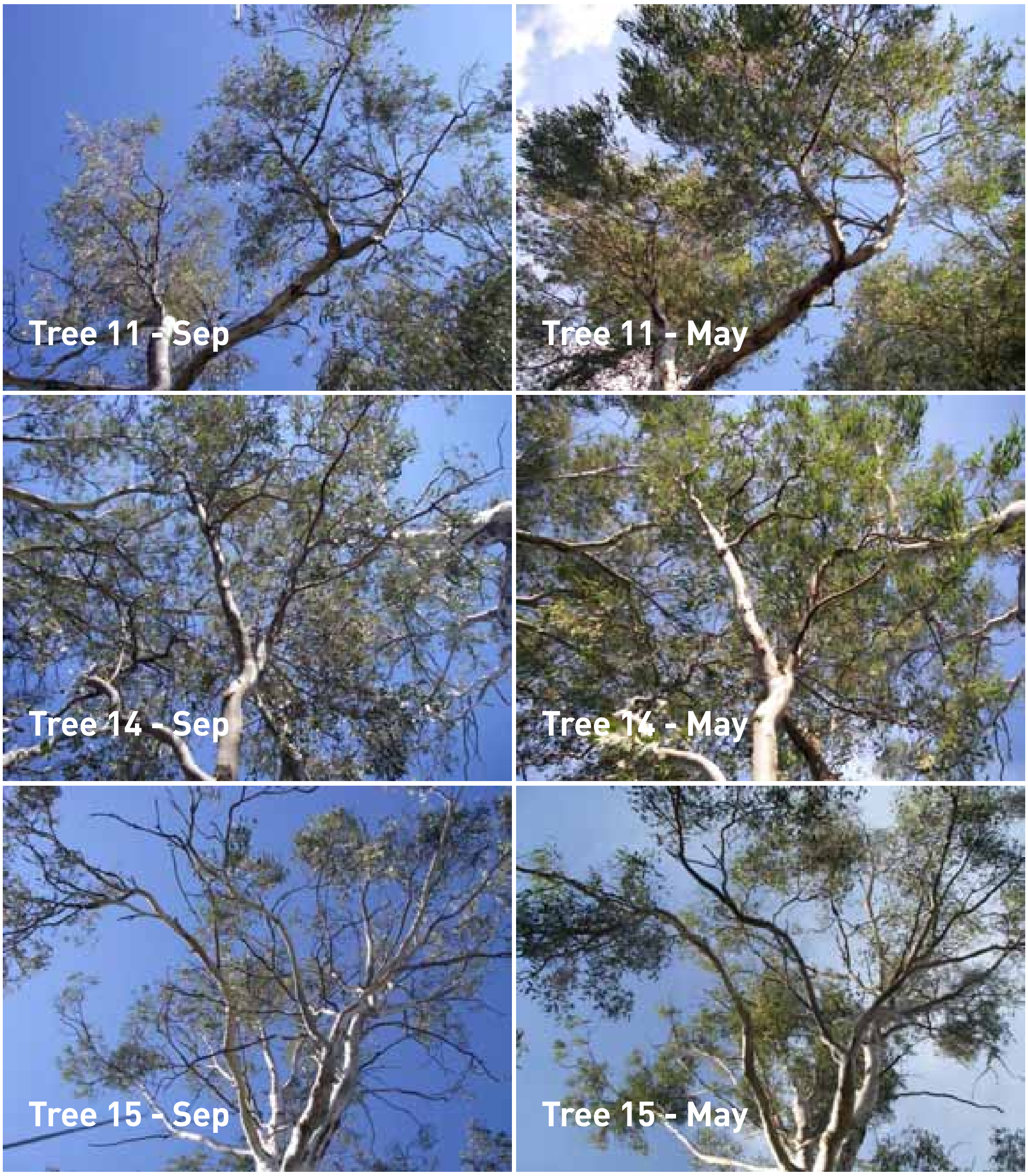
!! - Suspected but unconfirmed potential toxin producer

!!! - Potential toxin producer

Appendix C.

Photographs highlighting changes in river red gum foliage density between (A) September 2007 and (B) May 2010

Increase in foliage density



No change in foliage density

Decrease in foliage density

Australian Government

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BASIN AUTHORITY