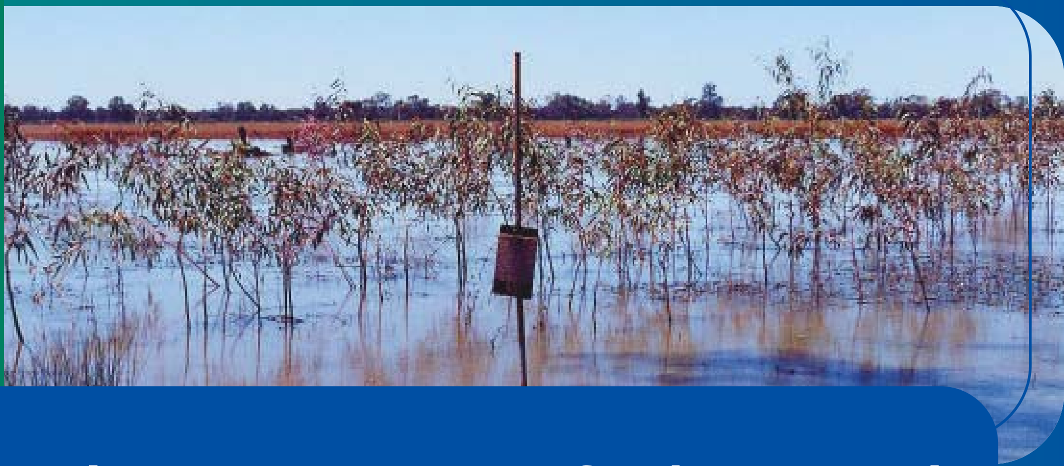

The Management of Lake Merreti:
Using Past Experiences to Guide Future Practices

Australian Landscape Trust
May 2003

Edited and Compiled by Tracey Steggles and Prudence Tucker

Acknowledgements

Over the past 20 years Lake Merreti has attracted funding for a number of management and monitoring programs. This report collates the findings from these studies, which were then used to develop guidelines for the future management and monitoring of Lake Merreti.

Environment Australia and the Australian Landscape Trust funded the production of this report. Various chapter authors developed the report, and the data presented in each chapter were collected and funded by various individuals and groups. A range of expert assistance and advice also supported the monitoring programs with the details summarised below.

Chapter 3 Water quality

1980 - 1995	Department of Water, Land and Biodiversity Conservation
1990 - 1993	Suter et al. (Engineering and Water Supply Department) funded by the Murray-Darling Basin Commission through the Natural Resources Management Strategy
1995 - 1997	Sonia Dominelli (Department of Environment and Heritage) funded by Bookmark Biosphere Trust
1998 – 2000	Prudence Tucker (Australian Landscape Trust) funded by Natural Heritage Trust MD-2001 and the River Murray Catchment Water Management Board
2000 - 2003	Scott Nichols (Australian Landscape Trust) funded by Natural Heritage Trust MD 2001 – Fish Rehabilitation Program

Statistical analysis by Tracey Steggles (Australian Landscape Trust).
Design of initial monitoring program advised by Associate Professor Keith Walker (Department of Environmental Biology, University of Adelaide).

Chapter 4 Groundwater

1984 – 2002	Department of Water, Land and Biodiversity Conservation
1995 – 2002	Jack Seekamp (local environmentalist) and Prudence Tucker (Australian Landscape Trust)

Reviewed by Ian Jolly (CSIRO).

Chapter 5 Vegetation

1995	Sonia Dominelli (Department of Environment and Heritage) funded by Bookmark Biosphere Trust
1998 – 2002	Prudence Tucker and Sonia Dominelli (Australian Landscape Trust) funded by Natural Heritage Trust MD-2001, the River Murray Catchment Water Management Board and the Australian Landscape Trust

Design of dry lake bed vegetation survey advised by Associate Professor Keith Walker and Mark Siebentritt (Department of Environmental Biology, University of Adelaide), and Deb Nias (NSW Department of Land and Water Conservation).

Design of submerged and emergent vegetation surveys advised by Margaret Brock.
Data analysis and interpretation by Jim George.

Soil analysis by Mardi van der Wielen and Louise Clark (Department of Soil and Water, University of Adelaide).

Contour map developed by SA Water and funded by the Renmark to the Border LAP.
Plant identification with assistance from Dennis and Janice Frahn, and staff at the South Australian Herbarium.

Acknowledgements

Chapter 6 Macroinvertebrates

1990 - 1993	Suter et al. (Engineering and Water Supply Department) funded by the Murray-Darling Basin Commission through the Natural Resources Management Strategy
1995 - 1997	Sonia Dominelli (Department of Environment and Heritage) funded by Bookmark Biosphere Trust
1998 – 2001	Prudence Tucker (Australian Landscape Trust) funded by Natural Heritage Trust MD-2001 and the River Murray Catchment Water Management Board

Statistical analysis by Dr. Sean White.
Reviewed by Tracey Steggles (Australian Landscape Trust).
The Aquatic Ecology and Biomonitoring Group, Australian Water Quality Centre, undertook macroinvertebrate identification.

Chapter 7 Fish

1990 – 1993	Suter et al. (Engineering and Water Supply Department) funded by the Murray-Darling Basin Commission through the Natural Resources Management Strategy
1996	Claire Stapleton
1998 – 2001	Prudence Tucker (Australian Landscape Trust) funded by Natural Heritage Trust MD-2001 and the River Murray Catchment Water Management Board
2000 – 2002	Scott Nichols (Australian Landscape Trust) funded by Natural Heritage Trust MD 2001 – Fish Rehabilitation Program

Statistical analysis by Dean Gilligan (NSW Fisheries).
Reviewed by Prudence Tucker (River Murray Catchment Water Management Board).

Chapter 8 Waterbirds

1985 – 1994	Bob Goodfellow (local ornithologist)
1987 – 2002	Mike Harper (Australian Landscape Trust)

Statistical analysis by Dr. Sean White.

Chapter 9 Management objectives and guidelines

Developed as part of the project funded by Natural Heritage Trust MD-2001 and the River Murray Catchment Water Management Board.

The monitoring that occurred between 1998 and 2002 was undertaken with assistance from many dedicated volunteers. The 53 volunteers, listed below, contributed 523 hours towards monitoring Lake Merreti between 1998 and 2000. A number of volunteers were also involved through the Australian Trust for Conservation Volunteers (ATCV). Volunteers included:

Nardia Baker, Michelle Ballestrine, Kirsty Bevan, Christian Birkle, Deborah Bogenhuber, Brenda Bornholm, Anthony Byrne, Steve Clarke, Sonia Dominelli, Robby Drew, Jarrod Eaton, Kirsty England, Renee Fielke, Sarah Fielke, Nick Flint, Dennis Frahn, Janice Frahn, Jurgen Hauschild, Anthony Hay, Tony Herbert, Rob Jury, Josephine Kelman, Debbie King, Cedric LeBloas, David Leedle, Karen Leske, Fran Marsh, Toula Meimeits, Kirsty Nattrass, Jason Nicol, Scott Nichols, Andrew O'Conner, Leanne Packer, Laura Phipps, Belinda Pinyon, Kay Richardson, Joseph Sanders, James Scheer, Vanessa Scott, Wayne Scrimshaw, Chris Small, Victoria Smith, Tracey Steggles, Jo-Anne Thyer, Ian Tucker, Jennifer Tucker, Sarah Tucker, Anna Vermooten, Rebecca Wallace, Scott Wedderburn, Bianca Weir, Elizabeth Wickens, Sarah Wilson.

Maps presented by Todd Goodman.

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Executive Summary

Under natural conditions Lake Merreti was a temporary wetland subject to fluctuating water levels and infrequent drying events, however, regulation resulted in permanent inundation of the wetland from the 1950s until 1994. In 1994 a wetting and drying regime was introduced to Lake Merreti with the aim of preserving and enhancing the vegetative habitats within the wetland. Between 1994 and 2003 there have been three complete drying, two partial drying and five refilling events. Various studies have been carried out at the wetland, both before and after management, relating to surface water quality, groundwater, vegetation, macroinvertebrates, fish and birds. The results have been compiled in order to provide an understanding of how each variable has been affected by past management actions, particularly the managed wetting and drying events. Not all parameters were surveyed during each event—where surveys were not undertaken no data is described in the summary below.

EVENT PATTERNS

Fluctuating water levels – Event 1 (July 1983 – September 1994)

Fluctuating water levels Event 1 spanned a period of 11 years during which there were four medium-to-large floods in the lower River Murray.

Surface water levels, salinity and turbidity in Lake Merreti all varied greatly throughout this event. Average salinity and turbidity calculated for this event were high. Both water level and salinity reflected changes in the river hydrograph and displayed a seasonal pattern, with water levels low and salinity high in summer. No patterns were evident for turbidity due to the limited data available.

While no quantitative surveys of vegetation were undertaken during this period, anecdotal evidence suggests that river red gums and lignum died due to extended periods of inundation. Regeneration of riparian species was prevented due to grazing. In the littoral zone, the variable water levels resulted in the expansion of spiny sedge up and down the elevation gradient. Limited aquatic plants were noted growing in the wetland.

The highest diversity and abundance of macroinvertebrates were recorded during Event 1. Peaks in abundance and diversity coincided with river floods, which may have been due to increased external colonisation or increased resource availability within the wetland.

Commercial fishing records for Ral Ral Creek indicate the most common species were callop and carp. Less common were bony bream, while redfin were caught occasionally and catches of cod were rare. The abundance of all fish species in Lake Merreti increased during flood events—again this may be due to external colonisation or increased resource availability within the wetland.

Complete drying – Event 2 (September 1994 – June 1995)

Complete drying Event 2 coincided with a period of low flows in the River Murray. After closing the main inlet structure it took approximately three months to evaporate 1 m of water in Lake Merreti (rate of drawdown <0.01m/day) and the lake then remained completely dry for a further five months.

Salinity and turbidity readings were very high due to evapoconcentration effects.

Non-permanent test holes drilled on the lake bed showed the depth to groundwater under the lake ranged from 0.42 m to 2.21 m below the natural surface and salinity was between 2 470 EC and 35 000 EC, indicating there is a fresh groundwater lens under the lake, although it is not evenly distributed.

A survey of the dry wetland bed vegetation found 30 species, which was the highest diversity recorded for a drying event. Despite the high diversity, vegetative cover was low.

All fish captured during drawdown were large carp, however, it is likely that this result was due to the sampling method used.

Refilling – Event 3 (June 1995 – July 1997)

Refilling Event 3 spanned 25 months and incorporated two medium river floods.

Executive Summary

This event recorded the highest mean wetland water level and lowest mean turbidity. There was a peak in salinity upon refilling due to the re-suspension of salts but the average for the event was similar to Event 1 indicating there was no cumulative increase in surface water salinity between the first and second refilling events. Water levels and salinity displayed a similar pattern in response to season and the river hydrograph as during Event 1. Turbidity remained low for approximately six months after refilling commenced due to sediment consolidation through drying. It then increased over time, as the sediments were gradually resuspended with duration of inundation.

Groundwater levels in the broad scale floodplain piezometers varied throughout the event and reflected changes in the river hydrograph and wetland water levels, peaking when floods occurred. These changes are likely to be due to hydraulic pressure from the surface water rather than recharge as the area around the piezometers was not inundated during this period.

No quantitative vegetation surveys were undertaken during this event but anecdotal evidence suggests there was no major change in the vegetation when compared to Event 1.

The diversity and abundance of macroinvertebrates was very low and neither responded to river flood events.

Gill nets and shrimp traps were used to sample the fish fauna and the most abundant species of fish caught were bony bream, gambusia and carp. No callop were caught in the wetland.

Complete drying – Event 4 (July 1997 – August 1998)

Complete drying Event 4 coincided with a period of low river flows. After the main inlet structure was closed it took approximately four months to evaporate 0.90 m of water (drawdown rate < 0.01 m/day) and the lake then remained completely dry for a further nine months.

Groundwater levels in the broad scale floodplain piezometers dropped over time due to reduced hydraulic pressure from the lake's surface water. Monitoring of the non-permanent test wells on the lake bed showed the groundwater levels had dropped (0.67 – 1.91 m below surface) and salinity had increased (1 730 – 44 400 EC) when compared to Event 2. The drop in groundwater levels was probably due to evapotranspiration as more plants were observed growing on the dry wetland bed during this drying event. Permanent nested piezometers installed on the lake bed during this event indicated the groundwater below the lake had an overlying freshwater lens that was between 1 m and 2 m in thickness. Water levels were higher under the lake bed than the floodplain indicating there was a groundwater gradient away from the wetland thus there was little risk of groundwater movement into the wetland basin during this drying event.

Although the diversity of dry wetland bed vegetation was lower than in Event 2, with only 18 species recorded, vegetative cover was higher. This increase in vegetative cover may have been due to between event differences in factors such as season and duration of drying. Vegetation mapping showed that plants with stunted growth covered a small area of the lake bed, and were located where there were pockets of groundwater with high salinity. During this event river red gums germinated at the edge of the wetland. Their growth was probably due to the reduction in grazing pressure with the de-stocking of Calperum Station.

Refilling – Event 5 (August 1998 – December 1999)

Refilling Event 5 ran for 16 months, during which there were no river floods.

Mean wetland water level and salinity were low and turbidity was high. Water level and salinity readings were less variable than in previous refilling events in response to the more stable river hydrograph. Turbidity showed a similar pattern to Event 3, with relatively clear conditions initially before increasing with duration of inundation, again due to sediment consolidation through drying and re-suspension during inundation.

Executive Summary

Broad scale floodplain groundwater levels rose upon refilling as the presence of surface water caused an increase in hydraulic pressure on the surrounding groundwater. Non-permanent test holes on the lake bed showed groundwater was closer to the surface than in Event 4 but there was no marked change in salinity, again due to changes in hydraulic pressure. Readings from the nested piezometers throughout Event 5 showed groundwater salinity decreased with duration of inundation, indicating recharge of the freshwater lens occurred.

Photographs show the river red gum regenerants became stressed during this event due to the extended period of inundation. A quantitative vegetation survey was undertaken 16 months after refilling. During this survey plants were only found growing over a relatively short distance and narrow elevation range. Littoral species were dominant (diversity, % cover and % flowering). Submerged vegetation was only growing in the shallow edge water and recorded low % cover and low % flowering. The growth of vegetation in the deeper water towards the centre of the wetland may have been prevented by the high turbidities recorded towards the end of this event.

The abundance and diversity of macroinvertebrates was higher than in the previous refilling event, and were more similar to numbers recorded in Event 1 during non-flood periods. The increase in macroinvertebrate abundance and diversity was probably due to the high cover of dry wetland bed plants during the preceding drying event, which increased resources upon refilling. Abundance and diversity were higher later in the event and peaked in spring/summer when aquatic vegetation had established.

Seine nets and shrimp traps were used to sample the fish fauna and the dominant fish species caught were gambusia, carp and smelt.

Complete drying – Event 6 (December 1999 – September 2000)

Complete drying Event 6 spanned nine months in total but the period for which the lake was drawing down or completely dry is unknown.

Salinity readings were high due to evapoconcentration.

Broad scale floodplain groundwater levels dropped over time, as did the lake bed groundwater levels, which was most likely a response to reduced hydraulic pressure. At one stage regional groundwater levels were slightly higher than lake bed groundwater levels but the difference was not sufficient to cause movement of groundwater to the wetland. The salinity of the lake bed groundwater increased over the course of the event indicating fresh water was being lost probably due to evapotranspiration.

The health of regenerating river red gums at the edge of the wetland improved due to drying. Sixteen species of dry wetland bed vegetation were found, which was similar to the number recorded in Event 4. Mapping showed the vegetation communities had similar boundaries as in Event 4 but community structure changed. No plants with stunted growth were found, plant density was reduced in some areas, and the species present were generally more tolerant of dry or salty conditions.

Fish caught were almost solely gambusia probably due to their tolerance of a wide range of adverse environmental conditions (e.g. high temperatures and salinity levels).

Refilling – Event 7 (September 2000 – March 2001)

Refilling Event 7 spanned six months during which time there was one medium river flood. The flood produced little response in wetland water levels possibly due to the short duration of the flood peak, low hydrological capacity of the inlet pipes or operation of the structure.

Mean wetland water level and turbidity for this event were low. Mean salinity was approximately the same as for Events 1 and 3 indicating there been no significant increase in salinity due to drying of the wetland. There were small fluctuations in water level, salinity and turbidity throughout, which were probably related to the method of filling with small volumes of water let in at a time.

Broad scale floodplain groundwater levels responded to changes in hydraulic pressure and rose when Lake Merreti was refilled and showed a minor peak when the river flood occurred.

A quantitative vegetation survey undertaken six months after refilling showed that although there was low species diversity, the area of plant growth was high. The community was dominated by submerged vegetation (high % cover, high % flowering), which was able to extend into the deeper sections of the wetland, as the turbidity of the water was low due to sediment consolidation during drying. The littoral species had similar cover but reduced diversity and flowering when compared to Refilling Event 5, which may have been due to frequent changes in water levels.

A single macroinvertebrates survey at the end of summer indicated abundance was similar and diversity higher than recorded the same time after refilling in the previous refilling event. Higher diversity may have been due to increased resources due to flooding or the increase in aquatic vegetation abundance.

Fish surveys employed fyke nets and showed that species richness but not catch rate increased over time. Carp were dominant initially then declined. Bony bream, rainbowfish, gambusia and smelt were not found until towards the end of the event. No redfin or callop were caught in the wetland. These results indicate carp are early colonisers while native species take longer to recolonise a wetland after drying.

Bird surveys recorded a similar species diversity to that found in Event 1 although in general abundance was higher, perhaps due to the increased abundance of aquatic vegetation and increased cover in the littoral zone.

Partial drying – Event 8 (March 2001 – September 2001)

During Partial drying Event 8 wetland water levels were maintained below 16.10 m AHD for six months to support the regenerating river red gums.

Surface water salinity was high and turbidity low during this event. The bed of the wetland may still have been relatively consolidated due to the short period that it had been inundated.

Groundwater levels remained fairly stable on the broad scale floodplain. A single survey of the nested lake bed piezometers showed the groundwater levels had risen and salinity decreased when compared to Event 6, indicating some recharge may have occurred during inundation.

A quantitative vegetation survey six months into Event 8 recorded the greatest species diversity, although the distribution and cover by vegetation had decreased. The growth of species with a range of water stress tolerances was supported by the gradual drawdown of water levels. Dry wetland bed vegetation was dominant (highest diversity, high cover, high % flowering for some species). Littoral and submerged vegetation also still recorded relatively high cover.

Fish surveys showed species diversity and abundance dropped over time and may have been due to increased predation by birds or harsher environmental conditions. Initially gambusia were dominant but later in the event the suite of gudgeon species and Australian smelt became dominant.

The diversity and abundance of birds increased when compared to Event 7. The lower water levels during this event would have increased the feeding area and loafing and roosting sites available to waterbirds.

Refilling – Event 9 (September 2001 – February 2002)

Refilling Event 9 ran for six months during which river and wetland water levels remained low.

Salinity readings were variable although no patterns were evident. Turbidity was high and increased over the course of the event as the wetland had not been completely dried for at least 12 months and the sediment had become unconsolidated.

There was little change in the groundwater levels on the broad scale floodplain as surface water depth, and hence hydraulic pressure, was relatively stable. A survey of the paired riparian piezometers indicated there was no fresh water overlying the saline groundwater in the riparian zone, with salinity ranging between 11 500 EC and 50 200 EC. A survey of the nested lake bed piezometers indicated the groundwater levels had risen and salinity had decreased from the previous event.

Executive Summary

Photographic evidence indicated spiny sedge had contracted and there had been an increase in terrestrial plant species and river cooba regeneration as conditions around the edge of the wetland became drier. The quantitative vegetation survey was undertaken four months into this refilling event and found the distribution of vegetation had increased when compared to the previous event. Littoral species were dominant (high diversity, high cover) indicating managed wetting and drying had favoured their expansion. Although cover by submerged vegetation was relatively high it was not as great as in Event 7, with growth possibly limited by high turbidity.

The structure of the fish community varied throughout the event. Initially smelt and carp gudgeons were dominant and carp low. Carp gudgeons remained high throughout while smelt declined and carp increased. Bony bream were not found until later in the event.

Similar abundance and diversity of birds were recorded in this event as in Event 8 indicating that habitat and resource availability may have been similar during these times.

Partial drying – Event 10 (February 2002 – March 2002)
Partial drying Event 10 spanned only two months.

Only the broad scale floodplain piezometers were surveyed during this event. Broad scale floodplain groundwater levels remained low, as there was little change in surface water volumes and hence hydraulic pressure.

A single bird survey recorded very high species diversity and abundance.

Refilling – Event 11 (March 2002 – ongoing)
Refilling Event 11 is ongoing.

Only the broad scale floodplain and nested lake bed piezometers have been surveyed. Broad scale floodplain groundwater levels remained low. Riparian groundwater levels had dropped and salinity increased slightly when compared to Event 9, indicating inundation of the riparian zone is required for recharge to occur. Lake bed groundwater levels fell and salinity increased when compared to Event 9.

Bird surveys indicated that abundance and diversity dropped during this event to levels slightly below those recorded in Events 8 and 9.

RECOMMENDATIONS

Hydrological management of Lake Merreti should continue, as it appears to have enhanced the wetland habitats by supporting the growth of submerged species, regeneration of riparian plants and expansion of the littoral zone. It is critical to carefully manage the water regime of Lake Merreti to achieve these outcomes. Features of the water regime that should be considered include the timing, frequency, rate and depth of drying and refilling (refer Chapter 9 Management Objectives and Guidelines).

High plant diversity and abundance during both the wet and dry phases can be supported by gradually changing water levels when drawing down or refilling.

Infrequent complete drying events are important components of the water regime as they result in the consolidation of the lake bed and allow dry wetland bed plants to establish. Subsequent clear water conditions upon refilling and the release of organic matter supports the growth of submerged plants.

Surface water levels in Lake Merreti should be drawn down and maintained below 16.10 m AHD over late summer/spring of each year to support the growth of the river red gum regenerants. The removal of water from their root zones during the hot months reduces water stress.

Groundwater recharge in the floodplain or riparian zones does not occur through hydrological management of the wetland at or below pool level. Increased frequency of inundation in these areas is required in order to prevent further loss of long-lived vegetation, and emphasises the need for environmental flows to South Australia. Small floods should also be let through to Lake Merreti in an attempt to support the mature long-lived riparian vegetation.

A diverse and abundant macroinvertebrate community will be supported by:
1. the growth of dry lake bed vegetation that provides resources on refilling
2. the growth of aquatic plants that provide nutrients and habitat
3. overbank flows that provide an influx of organic matter to the wetland and a means of recolonisation.

The use of attractant flows should be investigated further for use as a management tool to remove fish from the wetland prior to drying.

Works should be undertaken on the flow control structure on the main inlet to Lake Merreti. These works should focus on:
1. increasing the hydrological capacity of the structure so that small/short river flood peaks produce increases in lake water levels
2. reducing water velocities to facilitate fish movement out of the wetland.

Monitoring is essential for adaptive management at Lake Merreti and should be designed to assess management objectives, to ensure the golden rules of wetland management are not broken and to monitor other factors that may change due to management. The required frequency of monitoring will depend on the variable under consideration and may need to occur more frequently in response to a management event (refer Chapter 9 Management Objectives and Guidelines).

Suggested focus areas for future vegetation monitoring include:
1. During the wet phase
   a. between the elevations of 15.95 m AHD and 16.09 m AHD, as this is where the effects of hydrological management appears to be most pronounced
2. During the dry phase
   a. the central northern section of the lake bed, as this area has shown signs of higher subsurface soil salinity
   b. areas occupied by creeping monkey-flower, as this plant species may indicate salt affected areas

During drying events groundwater levels inside and outside the wetland basin should be closely monitored to ensure a gradient towards the wetland does not establish.

Chapter 1 ~ Introduction

Tracey Steggles, Australian Landscape Trust

BACKGROUND

As with most lower River Murray wetlands, Lake Merreti has undergone significant change since European settlement. In particular, regulation of the river, its anabranches and the wetland itself has resulted in a change in the hydrology of Lake Merreti. Under natural conditions Lake Merreti would have been a temporary wetland subject to fluctuating water levels and infrequent drying events, however, regulation has resulted in permanent inundation of the wetland for approximately 40 years, from the 1950s until 1994. The loss of the natural wetting and drying cycle, in turn, impacted on the physical and biological condition of the wetland, although to what extent is not known due to the lack of pre-regulation data. Since 1994, the hydrological management of Lake Merreti has had more of an ecological focus, with the introduction of a wetting and drying regime aimed at preserving and enhancing the wetland habitat.

The management objective for Lake Merreti now is to establish and maintain a range of habitats through time (including riparian, emergent, submerged and dry wetland bed vegetation) that, in turn, will support a diversity of native fish, invertebrate and bird species, and provide a summer and drought refuge for waterbirds.

Lake Merreti management objective
To establish and maintain a range of habitats through time, including:

- **a riparian zone with a range of species, in particular the newly established red gum fringe**
- **emergent vegetation**
- **dry wetland bed vegetation**
- **submerged vegetation.**

Outcome
Habitats to support a diversity of native invertebrate, fish, and bird species, and to provide a summer and drought refuge for waterbirds.

This report has been designed to provide managers with the necessary tools to achieve this objective by documenting:

- the history of management at Lake Merreti
- the results from monitoring, which demonstrate how the wetland has changed in relation to past management
- guidelines for future management and monitoring.

History of management
As part of the Calperum Station pastoral lease, Lake Merreti has a varied history. Past land use, surface water manipulations and conservation ratings of Lake Merreti have been described, all of which contribute to a general understanding of how the management focus and practices associated with the wetland have evolved.

Results of monitoring
More than 20 years of research and monitoring findings have been gathered at Lake Merreti on variables including surface water quality, groundwater, vegetation, macroinvertebrates, fish and birds. The information has been gathered by various individuals including local residents and scientists and comes in a variety of forms including anecdotal evidence, and qualitative and quantitative data. This report is a compilation of the results of monitoring and provides an understanding of how each variable has been affected by past management actions, particularly the managed wetting and drying events.

Future management
Using the results of research and monitoring, guidelines for the future hydrological management of Lake Merreti have been developed. These guidelines are not prescriptive but rather outline ways in which, based on existing knowledge, the water regime can be used to support the desired wetland habitats at

Chapter 1 ~ Introduction

Lake Merreti. Recommendations for future monitoring have been developed to facilitate adaptive management. Ongoing monitoring is essential for managers to recognize the ways in which conditions at Lake Merreti respond to management actions so that future wetting and drying regimes can be adjusted accordingly.

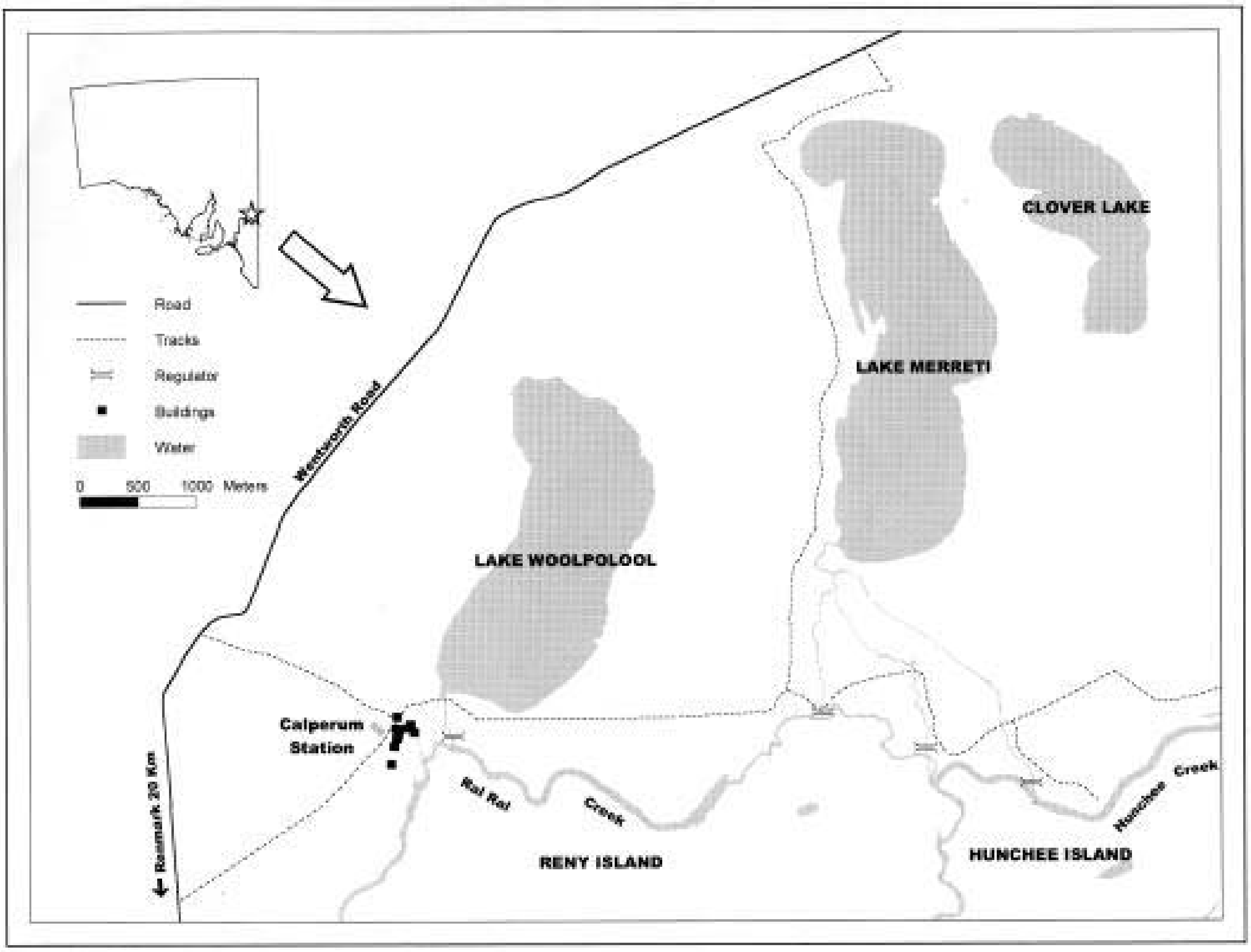
'Lake Merreti Hydrology Guidelines' aim to:

- **bring together over 20 years of data**
- **provide a tool for future hydrological management**
- **outline monitoring for adaptive management**
- **demonstrate the ability to learn from experiences.**

SITE DESCRIPTION

Lake Merreti is a freshwater wetland located on the northern side of the River Murray, approximately 20 km north of Renmark, South Australia. It is one of five wetlands in the Lake Merreti complex, which covers a total area of 3200 ha (Wetland Care Australia 1998). The other wetlands within the complex are Lake Woolpolool, Woolpolool Swamp, Clover Lake and Rotten Lake. Lake Merreti has an approximate wetland area of 391 ha at pool and, as such, is one of the largest regulated freshwater wetlands of the lower River Murray (Appendix 1.1).

Plate 1.1 Lake Merreti wetland complex



Water reaches the Lake Merreti wetland complex from the River Murray via the permanent anabranch system of Ral Ral Creek, which stems from the river between Weirs 5 and 6 (Plate 1.1). The main inlet to Lake Merreti is a 1.5 km long channel that extends from Ral Ral Creek to the wetland. This inlet has a sill level of 15.22 m AHD and connects the wetland to the creek at pool.

There are also two temporary inlets to Lake Merreti, both located upstream of the main inlet. The first is located on Ral Ral Creek and with a sill level of 17.29 m AHD does not flow until river flows reach 35 000 ML/day. The second temporary inlet is off Hunchee Creek and, as it has a lower sill (16.85 m AHD), begins to flow first when river flows reach 25 000 ML/day.

While the lake covers a large surface area, it is a relatively shallow water-body. The elevation of the lake bed at its lowest point has been surveyed at 15.30 m AHD. The water level is 16.30 m AHD when Lake Merreti is floating at pool, giving a water depth of approximately 1.0 m. The lake reaches capacity at river flows of approximately 80 000 ML/day when water levels are 18.00 m AHD. Once river flows exceed this rate, water spills from Lake Merreti into the other wetlands of the complex including Clover Lake, Woolpolool Swamp and Lake Woolpolool. Under current conditions, river flows of sufficient magnitude to cause overbank flows at Lake Merreti are predicted to occur once every eight years (Sharley and Huggan 1995), although such an event has not been recorded since 1993 (DWLBC 2002).

Flow control structures are present on the main inlet and both temporary inlets of Lake Merreti, each of which are also fitted with removable fish screens (Appendix 1.2). The presence of these structures provides the managers of Lake Merreti with an opportunity to manipulate water levels within the wetland, to a certain degree, exclusive of river flow conditions.

APPENDIX 1.1 SUMMARY OF BACKGROUND INFORMATION, LAKE MERRETI

Wetland type Location	**Regulated, freshwater** **Western side of the River Murray between Locks 5 and 6, approximately 20km north of Renmark, South Australia**
AMG (Zone 54) co-ordinates	**E 476918** **N 6235968**
1:50,000 Map Sheet	**Paringa 7029-1**
Wetland area	**391 ha**
Number of inlets	**1 permanent, 2 temporary**
Minimum lake bed elevation	**15.30 m AHD**
Water level at pool	**16.30 m AHD**
Water depth at pool	**0.8 – 1.0 m**
Water level at capacity	**18.00 m AHD**
Water depth at capacity	**2.5 – 2.7 m**
River flows required to reach capacity	**80 000 ML/day**
Owner	**Environment Australia** **GPO Box 787, Canberra ACT 2601** **ph (02) 6274 1111, fax (02) 6274 1666** www.ea.gov.au
Manager	**Austland Services Pty Ltd** **Calperum Station** **PO Box 955, Renmark SA 5341** **ph (08) 8595 7359, fax (08) 8595 7360** www.australianlandscapetrust.org

APPENDIX 1.2 INLET STRUCTURES, LAKE MERRETI

Main Inlet

Location: Permanent inlet creek near junction with Ral Ral Creek

Flows at: Pool

Sill level: 15.22 m AHD

Description: Two 900 mm diameter concrete pipes
One pipe fitted with a slide gate, one pipe fitted with a flap-valve at each end
Embankment to minimise overbank flows on western side with spillway sill 18.00 m AHD

Top of bank: 18.40 m AHD

Fish screens: Cement box (5.14 m wide x 1.53 m long x 1.55 m high) enclosing both pipes on creek side, fitted with aluminium structure holding six rotating fish screens

Second Inlet

Location: Off Ral Ral Creek (upstream of main inlet)

Flows at: 35 000 ML/day

Sill level: 17.29 m AHD

Description: Stainless steel frame with provision for placement of two stop logs (1 400 mm wide x 1 500 mm high)
Stone and earth embankment with 2.6 m long red gum sleeper walls on either side of structure

Fish screens: Four 700 mm x 1 100 mm rotating aluminium fish screens

Third Inlet

Location: Off Hunchee Creek (upstream of second inlet)

Flows at: 25 000 ML/day

Sill level: 16.85 m AHD

Description: Stainless steel frame with provision for placement of two stop logs (1 400 mm wide x 1 500 mm high)
Stone and earth embankment with 2.6 m long red gum sleeper walls on either side of structure

Fish screens: Four 700 mm x 1 400 mm rotating aluminium fish screens

Chapter 2 ~ Lake Merreti: A checkered history

Tracey Steggles, Australian Landscape Trust

BACKGROUND

European settlement and subsequent exploitation of the resources of the Murray-Darling Basin have brought about dramatic and extensive change to the ecosystem. Major changes include clearance of native vegetation for grazing and agriculture and, perhaps most importantly, an altered flow regime due to water diversion, water storage and regulation of the river and its anabranches (Close 1990). The impacts have not been confined to the main river channel. Wetlands have also been significantly impacted, largely through the altered river hydrology and by activities such as cropping and grazing by stock and feral animals, blockages to flowpaths caused by causeway, levee bank and track construction, and their use as sites for the disposal of stormwater, sewage and irrigation drainage effluent (Jensen 1998).

Signs of an ailing river ecosystem are now evident from reduced water quality, rising groundwater tables, poor recruitment in native fish (Pierce 1992), reduced habitat for waterbirds (Thompson 1986); (Pressey 1986), and reduced health and regeneration of key floodplain plant species (Sharley 1992). In recognition of this decline in health, management is now changing from a sole focus on the needs of the industries in the river region to include the conservation and rehabilitation of the river and its floodplain and wetlands.

As a lower River Murray wetland located on Calperum Station, a former pastoral lease, Lake Merreti has been exposed to many of the changes and impacts described. The property has been owned and managed by several individuals and organisations, each with their own priorities for land and water use. Background to how the management of Lake Merreti and its surrounds has changed through time is provided so as to contribute towards an understanding of the state of the wetland today.

LAND USE

The Calperum area has been inhabited by humans for over 12 000 years with the area occupied by the Maraura and Ngintait tribes, probably periodically, prior to European settlement (Morelli and de Jong 1996). Signs of their occupation remain today and include canoe trees, burial sites and middens.

The earliest recorded use of the area by European settlers was in 1838 when overland drovers used the site, then known as Ral Ral, as a campsite and watering point for livestock *en route* from New South Wales to Adelaide (ALT 2002). By 1839 large numbers of stock were being moved along this route, which likely resulted in the margins of Lake Merreti being periodically subjected to intensive grazing pressure.

In 1846 pastoral leases for the property were introduced, initially as one-year licenses then as 14-year licenses after 1851 (ALT 2002). These leases remained in operation for over 140 years with ownership transferring between several different parties (Table 2.1). The primary land use for Calperum Station throughout this time was grazing. In recent times, the deemed maximum stocking rate for the station was 24 100 sheep, although actual numbers varied and in 1991 only 17 000 sheep were being run on the station (McNaughton, pers. comm. in Nicolson and Carter 1994).

Impacts from the presence of stock around Lake Merreti included (Nicolson and Carter 1994):

- suppression of riparian vegetation regeneration due to grazing
- a shift in vegetation species composition as more palatable grasses in the littoral zone were removed and unpalatable species became dominant
- reduced habitat diversity due to changes in the vegetation community, which in turn impacted on native fauna
- increased soil erosion and compaction due to the removal of vegetation by grazing and trampling.

Infrequent cropping of the lunettes between Lakes Merreti and Woolpolool also took place when conditions were suitable. There is only one definite record of Lake Merreti being cropped, in 1943 when drought conditions dried the lake bed (Martin, pers. comm. in Jensen 1983). An attempt by the lessee to drain the lake in 1981 to enable a crop to be sown was prevented when the Engineering and Water Supply Department (E&WS) ordered that flows to the lake be reinstated (Jensen 1983).

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The Chicago Zoological Society and the Federal Government purchased the property in 1993, and ownership was subsequently signed over to Environment Australia (Director of National Parks). It was also during this year that grazing on the property ceased and Calperum Station became part of the Bookmark Biosphere Reserve. The objectives of UNESCO's Man and the Biosphere Programme have since guided the management of the property. These objectives focus on biodiversity conservation, ecologically sustainable development and community empowerment. Since 1998, management of Calperum Station has been contracted to the philanthropic, environmental organisation, Austland Services Pty Ltd (Australian Landscape Trust).

SURFACE HYDROLOGY

Under natural conditions Lake Merreti would have been a temporary wetland subjected to irregular wetting and drying events according to fluctuations in River Murray flows. Changes to the water regime of Lake Merreti have arisen over time through regulation of the river, its anabranches and the wetland itself.

Manipulation of water levels in the wetland may date back to as early as 1880 with an early map referring to Lakes Merreti and Woolpolool as reservoirs (Jensen 1983). Formal regulation of Lake Merreti commenced in 1914 so that water could be stored in the lake and used to maintain an adequate supply to the Chaffey Irrigation Area (Jensen 1983).

In 1927 Weir 5 was constructed on the River Murray creating stable levels in the reach of the river containing Ral Ral Creek and Lake Merreti. With more reliable river water guaranteed by the presence of the weir, the storage of irrigation water at Lake Merreti was no longer required. The inlet regulator was allowed to fall into disrepair, finally being destroyed in 1931 due to the effects of grazing, erosion and flooding (Jensen 1983).

While it is generally assumed that the presence of Weir 5 directly altered the surface hydrology of Lake Merreti from temporary to permanent, anecdotal evidence suggests otherwise. Photographs and recollections by naturalists and past lessees indicate the lake dried on at least four occasions after the weir was installed, in 1934-35, between 1939 and 1944, in 1950 and again in 1958. A photo taken in 1958 (Chapter 5 Vegetation, Plate 5.3a) clearly shows a dry lake bed containing healthy stands of lignum (*Muehlenbeckia florulenta*) and fringing river red gums (*Eucalyptus camaldulensis*). For this vegetation to survive it would have been necessary for the lake to dry more regularly than indicated by the above dates.

Around 1960 a levee was installed at the junction of Hunchee and Ral Ral Creeks (Shaddock, pers. comm. in Jensen 1983). The purpose of the bank was to maintain flow in the Ral Ral anabranch. This bank may have contributed to the permanent inundation of the wetland, as there is no record of Lake Merreti drying again for over 30 years. The permanent inundation of this wetland may also have been due to the presence of weirs, dams and barrages along the length of the River Murray that maintain higher summer flows to South Australia, and increases in the capacity of the Hume Dam in 1961. The regulation of the entire river has reduced the incidence of low-medium floods and created relatively stable water levels throughout. As a result of reduced flow variability, a large proportion of River Murray wetlands have generally become permanently inundated, rather than experiencing seasonal wetting and drying events.

In 1983 a regulatory structure was constructed on the inlet creek of Lake Merreti near its junction with Ral Ral Creek. The regulator was installed to enable water to be stored in the wetland and then released when salinity levels in Ral Ral Creek became elevated. Peaks in salinity generally occur immediately after the recession of high flow events as a result of the mounding and intrusion of saline groundwater into the creek. Low salinities must be maintained in Ral Ral Creek because it is the site of the Chaffey Irrigation Pumping Station and increases in water salinity above certain thresholds have a detrimental effect on crops.

The inlet structure was fitted with a one-way flap valve on one pipe that operated automatically to allow unidirectional water flow from the inlet to the wetland when water levels rose in Ral Ral Creek. A second pipe was fitted with a sluice gate that could be opened and shut manually to allow water to flow in either direction, depending on the relative level of the water in each waterbody. Under normal flow conditions the sluice gate remained open and water levels in the wetland fluctuated with Ral Ral Creek. The sluice gate could, however, be closed after high flow events to maintain high water levels in Lake Merreti for later release.

The Engineering and Water Supply Department outlined operating guidelines for the structure in consideration of the water needs of the irrigators. These guidelines stated that water was to be released via the sluice gate following river peaks:

- if there was a consistent upward trend in salinity in Ral Ral Creek
- if lake salinity exceeded 600 EC
- within 60 days to prevent the establishment of groundwater gradients from Lake Merreti to Ral Ral Creek.

Water stored in Lake Merreti for the purpose of flushing Ral Ral Creek has been of little use to irrigators because the conductivity of the lake generally exceeded that of Ral Ral Creek (Burns 1996). As a result of holding back flood events in consecutive years there was some die back of lignum and river red gums through drowning on the shoreline of the lake. Therefore, although the E&WS operating guidelines remained in place, alternative hydrological management was undertaken in autumn 1991 to enhance riparian vegetation. Lake water levels were lowered by 150 mm, resulting in the germination of hundreds of river red gums and the establishment of spiny sedge (*Cyperus gymnocaulos*) on the dried margins of the lake. Unfortunately, these young plants drowned over the following years as the lake was held at pool level. Following this, the Department for Environment and Natural Resources (Nicolson and Carter 1994) formulated management guidelines for the rehabilitation of the complex that included recommendations for partial drying of Lake Merreti, and carp control.

In 1994 the structure on the main inlet to Lake Merreti was modified to its current form. A second flap valve was fitted on the creek side of one pipe. With flap valves present on both ends, this pipe no longer operates to automatically allow water into the wetland when water levels in Ral Ral Creek rise. Instead, water levels in Lake Merreti are controlled through the manual operation of the sluice gate, the flap valves or both. The structure was also fitted with removable fish screens in an attempt to reduce carp numbers in the wetland. The screens prevent the passage of large fish but can be removed when flow conditions occur that will trigger the movement of adult native fish into wetlands.

In 1997 regulators were installed on the two temporary inlets to Lake Merreti. These remain in place today. Both structures are of a similar weir-type design with stop-logs used to control water levels in times of high flow. These structures are also fitted with removable fish screens. Greater details of the three structures are provided in Appendix 1.1.

Current hydrological management of Lake Merreti is designed to mimic more closely the conditions that occurred prior to regulation by reintroducing infrequent drying cycles to the wetland or by extending flood recession times. Closure of both the flap valve and the sluice gate on the inlet regulator means that water levels in Lake Merreti will not respond to changes in Ral Ral Creek. Instead, water levels in the lake will remain relatively steady, gradually dropping through evaporation and drying if the lake remains isolated for long enough. The first such manipulated drying event commenced in September 1994 with the lake completely drying from January to June 1995. Four subsequent drying events have followed, with the lake completely dried in 1997/1998 and 1999/2000, and partially dried in 2001 and 2002 (Table 2.2). The effects of drying and refilling the wetland on water quality and wetland flora and fauna have been monitored to ensure ongoing adaptive management.

CONSERVATION STATUS

Field naturalists, conservation groups and scientists have long recognised Lake Merreti as a site of environmental significance. Three separate assessments of wetlands along the River Murray in South Australia attributed a high conservation rating to Lake Merreti, largely due to the condition of the riparian vegetation and use of the wetland by birds (Krastins 1974); (Pressey 1986); (Thompson 1986).

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Several authors noted that Lake Merreti provided significant habitat for waders and waterbirds, particularly during times of drought, and also considered it an important breeding site for numerous species. Records of the number of bird species using Lake Merreti vary from 44 (SARMWWP 1989) up to a speculated 73 species (Jensen 1983). Species found breeding in the wetland included the white-faced heron, yellow-billed spoonbill, white-breasted sea-eagle, darter, and three species of cormorant (great, little black and little pied) (Mack, pers. comm. and Reid 1981 in Jensen 1983). Swans also nested in stands of lignum on the lake bed until being flooded out by high water levels (Jensen 1983). The importance of an ibis rookery on the western shore of Lake Merreti was noted from as early as 1937 (Foweraker in Jensen 1983). In 1981 three species of ibis were recorded breeding there, including the sacred ibis (*Threskiornis molucca*), the straw-necked ibis (*Threskiornis spinicollis*), and the rare glossy ibis (*Plegadis falcinellus*) (SARMWWP 1989). In general, bird activity at the site was influenced by both regional and local hydrology, with numbers peaking when river flows were low and limited wetland habitat was available. In comparison, a site visit during the 1986 high flow event found few birds at Lake Merreti apart from the ibis (Department of Environment and Planning 1986 in Jensen *et al.* 2002).

In terms of vegetation, Lake Merreti was considered to support relatively large areas of healthy riparian woodland, comprised of river red gum, black box (*Eucalyptus largiflorens*), river cooba (*Acacia stenophylla*) and lignum during the early 1970s (Krastins 1974). These riparian species are, however, adapted to the natural fluctuating water regime of the river system and by the early 1980s the permanent inundation of the lake had resulted in the loss of some of the fringing river red gums and stands of lignum from the southern lake bed (Jensen 1983). In addition, regeneration of long-lived plant species around the wetland was suppressed through grazing up until 1993 and the vegetative community became dominated by aging specimens (Nicolson and Carter 1994).

Krastins (1974) thought it likely that Lake Merreti had also once been an important breeding site for native fish until stable water levels had removed the stimulus to breed. It was suggested that artificial manipulation of water levels in Lake Merreti might reinstate fish breeding in the wetland (Krastins 1974).

The conservation focus for Lake Merreti has now shifted. Where previously the riparian vegetation and avifauna at the wetland were considered of primary importance, the lake itself is now recognised as significant. By focusing on the wetland system as a whole, rather than individual species or groups of species, management will support the establishment and survival of a diversity of plant and animal species.

Aside from its biological significance, the conservation of Lake Merreti has also long been considered important due to its popularity for tourism, recreation and educational activities.

Historically, there have been several attempts to have the conservation status of Lake Merreti formally recognised, with varying degrees of success. A push in 1958 to have the area listed as a sanctuary was eventually realised in 1960 when the Merreti-Chowilla Sanctuary was declared under the Animals and Birds Protection Act (1919-1963). However, with the passing of the National Parks and Wildlife Act (1972), sanctuary status was automatically revoked. The Nature Conservation Society advocated having Lake Merreti declared a national park, first in 1970, then again in a submission to the State Planning Authority in 1974. Neither attempt was successful.

In September 1987 the Lake Merreti complex, as part of the 30 600 ha Riverland Wetland Complex, was listed as a wetland of international significance under the Ramsar Convention. In particularly, the Convention recognised the large tracts of relatively undisturbed river red gums and unique birdlife in the area (Milliken 1995). Finally, in 1993, the Bookmark Biosphere Reserve, incorporating Calperum Station, was established as part of UNESCO's Man and the Biosphere Programme. Hence, the conservation significance of Lake Merreti and its surrounds is now recognised not only locally but at a global scale.

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Table 2.1 History of changes in ownership, land-use and conservation status of Calperum Station and Lake Merreti since European settlement

Timeline	Ownership and land use history
1838	Overland drovers first pass through Calperum area Used as a campsite and watering point for livestock
1839	Large numbers of sheep frequently moved to Adelaide via the overland route that passes through Calperum
1846	Annual licenses issued to pastoralists
1851	14-year pastoral leases introduced for Chowilla-Bookmark property, which incorporates the now Calperum and Chowilla Stations
1896	Calperum and Chowilla lease split
1896	*Lessee: John Holland Robertson*
1943	Lake Merreti cropped
1953	*Lessees: J Robertson's wife and daughters*
1960	Petition to the Premier to declare Lake Merreti a sanctuary Merreti-Chowilla Sanctuary declared under the Animals and Birds Protection Act (1919-1963)
1965	Lessees: Howard Martin and Colin Watson, then transferred to Martin's sons (Brenton, Eric and Chester)
1970	Push by Nature Conservation Society (NCS) to have Lake Merreti declared a national park
1972	Sanctuary status automatically revoked with passage of the National Parks and Wildlife Act (1972)
1974	Submission to State Planning Authority by NCS to have Lake Merreti declared a national park
1979	*Lessee: Chester Martin (bought out brothers)*
1981	*Lessee: Ken McNaughton*
1981	Lessee attempted to drain Lake Merreti for cropping, reinstatement of flow ordered by E & WS
1993	*Property purchased by Chicago Zoological Society and the Federal Government, ownership transferred to Environment Australia*
1993	Calperum Station became part of Bookmark Biosphere Reserve Grazing ceased
1995	Lake Merreti restoration program commenced First drying of Lake Merreti since 1958
1998	Management of Calperum Station contracted to Austland Services Pty Ltd (Australian Landscape Trust)

Table 2.2 History of hydrological management events at Lake Merreti

Management event	Management dates	Action
Pre ecological management (Before July 1983)	1880 1914 - 1927	Map indicates lake used as a reservoir Levees with weirs on inlets, lake used for storage of irrigation water
	1927 – 1930	Construction of Weirs 5 & 6 on River Murray, lake inlet levees breached as storage of water in wetland no longer required
	1934 – 1958	Evidence infrequent drying of lake still occurred, lake bed cropped in 1943
	1960	Levee constructed at junction of Hunchee and Ral Ral Creeks, Lake Merreti permanently inundated
Fluctuating water levels - Event 1 (July 1983 – September 1994)	July 1983	Structure built on inlet
	7/83 -20/3/91	Opening and closing of valve to store and release water for salinity management in Ral Ral Creek, water levels in lake fluctuated
	20/3/91-14/6/91	Flap valve to structure, water level lowered by 150 mm to dry lake margins
	14/6/91-13/9/94	Opening and closing of valve, water levels in lake fluctuated
Complete drying - Event 2 (September 1994 – June 1995)	13/9/94-27/6/95	Valve closed to fit inlet valve and install fish screens
	1/1/95 - 27/6/95	Lake completely dry
Refilling - Event 3 (June 1995 – July 1997)	27/6/95 – 7/97	Valve half opened to refill wetland
Complete drying – Event 4 (July 1997 – August 1998)	7/97 - 12/8/98 11/97	Valve closed Lake completely dry
Refilling - Event 5 (August 1998 – December 1999)	13/8/98 – 27/12/99	Valve opened, lake refilled
Complete drying - Event 6 (December 1999 – September 2000)	28/12/99 – 7/9/00	Valve closed, lake dried

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Management event	Management dates	Action
Refilling - Event 7 (September 2000 – March 2001)	8/9/00 – 28/9/00	Valve opened to refill wetland
	29/9/00 – 6/12/00	Valve closed to maintain low lake levels but opened on five occasions for fish monitoring
	7/12/00 – 2/2/01	Inlet opened to fill lake with rising river
	3/2/01 – 27/3/01	Inlet closed to dry lake margins and support growth of river red gum germinants, opened 6/3/01 for attractant flow
	27/3/01 – 30/3/01	Inlet opened to allow fish into wetland as food for birds
Partial drying - Event 8 (March 2001 – September 2001)	30/03/01 – 3/9/01	Inlet closed, lake levels lowered to dry margins
	11/4/01	Inlet opened to flush fish from pipe and for overnight attractant flow
Refilling - Event 9 (September 2001 – February 2002)	3/9/01 – 28/2/02	Inlet opened in spring to support germination of submerged plants
	30/10/01	Flap valves on second pipe opened completely to maximise flow
Partial drying - Event 10 (February 2002 – March 2002)	28/2/02-12/3/02	Inlet closed to dry wetland
Refilling - Event 11 (March 2002 – ongoing)	12/3/02 –	Inlet opened, lake refilled
	Early April 2002	Inlet channel deepened and second channel constructed on wetland side of inlet to increase flow to wetland

Chapter 3 ~ Water Quality

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BACKGROUND

Physicochemical processes and conditions play an important role in defining habitat structure and community composition of ecosystems. For wetland ecosystems, these physicochemical features are, in turn, influenced by factors such as hydrological regime, sediment type, vegetation cover and inputs from catchments (Bailey and James 2000). Almost all of these factors have been dramatically altered along the River Murray since European settlement, resulting in a significant change to the water quality of some wetlands (Pressey 1990). This is, however, largely restricted to a qualitative statement rather than quantitative measures, as there is little published information available regarding the water quality of floodplain wetlands, especially in South Australia (Suter *et al.* 1993), and a general lack of baseline data. Of particular interest are changes to salinity and turbidity, as these have been identified as good indicators of the general condition of wetland systems (Suter *et al.* 1993).

Changes to the salinity of wetlands on the lower River Murray are likely to have arisen from changes to the quality of the source water, the frequency of flushing events and interactions with the groundwater. Source water entering wetlands carries with it dissolved salts, which are left behind when the water evaporates. Salts, therefore, accumulate within wetlands unless they are periodically flushed from the system. River regulation has reduced the incidence of high flows in the lower River Murray and hence the frequency of flushing events. Lake Merreti does not receive flushing flows until River Murray flows exceed 70 000 ML/day (Suter *et al.* 1993). Flows to South Australia of this magnitude are predicted to have a return frequency of 15 in 100 years under regulated conditions, rather than 49 in 100 years under natural conditions (Sharley and Huggan 1995). River regulation, and the storage of the large volumes of water behind weirs, has also generated hydraulic pressure and a rise in the groundwater table (Walker 1992) and some wetlands have now become discharge points for saline groundwater.

Anecdotal evidence suggests that the turbidity of the River Murray system has increased since European settlement (van der Wielen in prep) and it is now considered a significant water quality problem (Mackay et al., 1988 in Walker 1992). Erosion and slumping of banks, particularly due to the rapid recession of floods, have contributed to turbidity increases (Walker 1992). For the lower River Murray, turbidity increases are largely a result of the operation of Lake Victoria, which is used to store water from the Darling River for release to South Australia in summer (Suter *et al.* 1993). In the early 1990s it was estimated that 70% of the daily River Murray flow to South Australia in summer originated from the Darling (Jacobs, 1989 in Walker 1992). Darling water is highly turbid as it carries a suspended load of very fine clay particles that only settle under conditions of extremely low flow (Shaffron *et al.* 1990); (Walker and Thoms 1993). Changes to the hydrology of lower Murray wetlands including Lake Merreti have also likely contributed to their increased turbidity. Prior to river regulation the wetlands would have dried infrequently, resulting in the aggregation of small particles and the formation of a crust on the sediment surface (Fox et al., 1977, in McComb and Qiu 1997). Recent studies have shown that the consolidation of clayey wetland sediments on drying lowers their re-suspension on refilling (van der Wielen in prep). Thus the reduced frequency of wetland drying events due to river regulation limits sediment consolidation increases the concentration of suspended particles in the water and results in increased turbidity.

Little information is available regarding the effect of hydrological management of wetlands on water quality conditions. Of particular concern is the potential for wetland salinity to increase through the accumulation of salts in the sediment and alterations to the underlying groundwater table upon drying. Water quality data has been collected at Lake Merreti since 1981 and provides an opportunity to compare pre and post hydrological management data and to examine the effects of managed drying events on water quality variables.

METHODS

Monitoring frequency and site location

A number of water quality parameters have been recorded during various studies at Lake Merreti since 1981 including conductivity, turbidity, water depth, dissolved oxygen, temperature, total nitrogen, phosphorus, organic carbon and pH. This chapter focuses on water level, salinity (measured as electrical conductivity) and turbidity data collected at Lake Merreti.

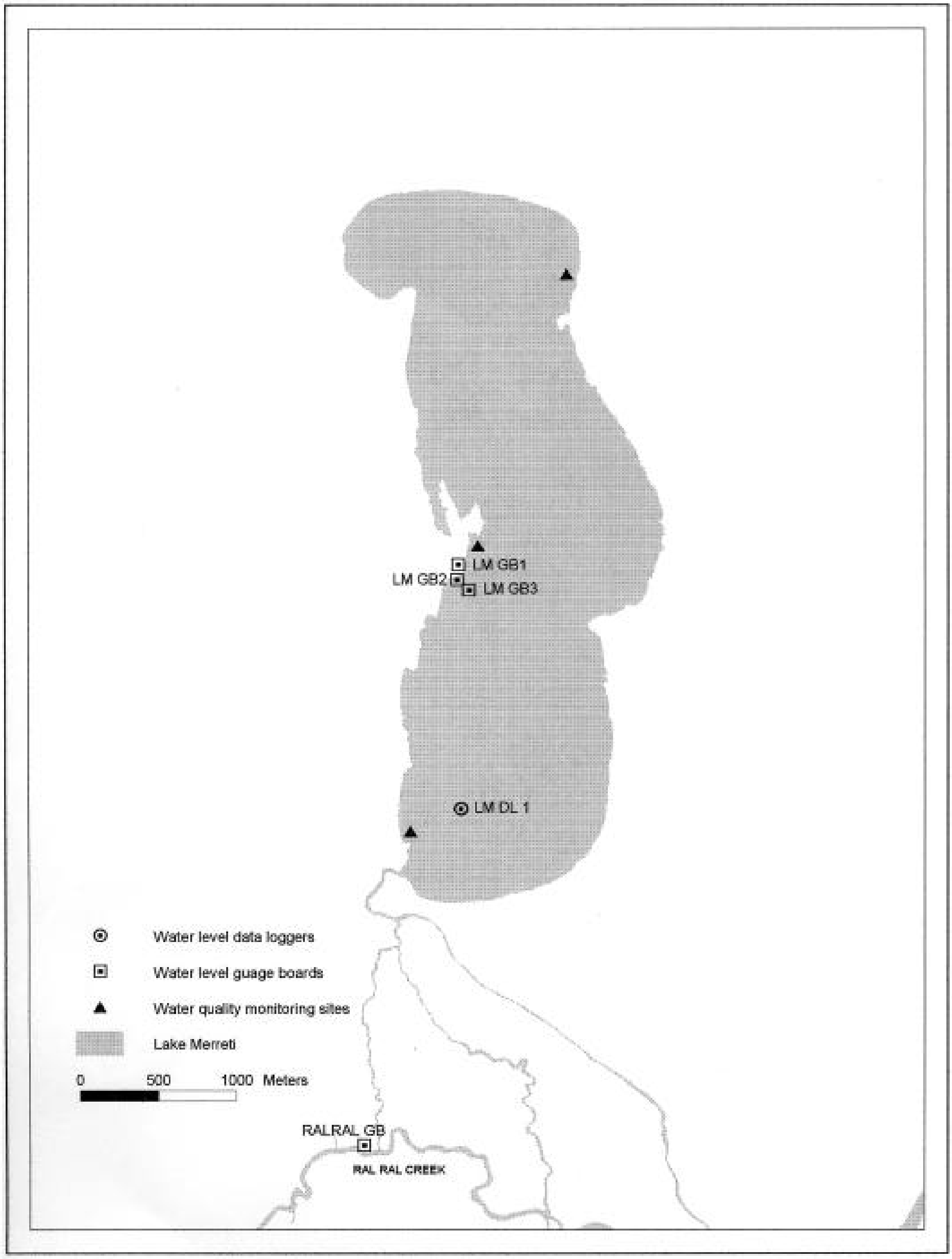
The parameters sampled and the survey effort varied between studies (Table 3.2). Conductivity and water levels were recorded most consistently beginning in 1981. The monitoring frequency for water level ranged from initial weekly readings to hourly logged water level data from July 1996. Fortnightly and monthly sampling of conductivity was carried out at between one and five sites in Lake Merreti (Table 3.2, Plate 3.1). Turbidity was recorded between 1995 and 2002 at a fortnightly to monthly frequency at three to five sites (Table 3.2). The conductivity and turbidity of Ral Ral Creek were also measured from 1995 to 2002. Further details of the parameters monitored, frequency of monitoring and number of sites surveyed are outlined in Table 3.2.

Table 3.1 Summary of water quality monitoring, Lake Merreti, 1981 – 2002

Study	Parameters monitored	Dates surveyed	No. of surveys	Frequency	No. of sites	Management event surveyed
(Herbert and Porter In prep)	Water level Conductivity	1981-1994	491	Weekly	Lake: 1	Fluctuating water levels – Event 1
(Suter *et al.* 1993)	Conductivity Dissolved oxygen pH Nitrogen, Phosphorous Organic carbon	Aug 1990 – Feb 1992	9	Monthly to three monthly	Lake: 4 (3 used in analysis)	Fluctuating water levels – Event 1
(Dominelli In prep)	Water level Conductivity Turbidity	Nov 1995 – Jan 1997	56	Water levels - daily Water quality – fortnightly	Lake: 2 Ral Ral Ck: 2	Refilling – Event 3
Tucker	Water level Conductivity Turbidity Temperature	Aug 1998 – Feb 2001	43	Water quality – monthly Water levels - daily	Lake: 5 (3 used in analysis) Ral Ral Ck: 2	Refilling – Event 5 Complete drying – Event 6 Refilling – Event 7
Nichols	Water level Conductivity Turbidity Temperature PH Dissolved oxygen	Nov 2000 – Jan 2002	12	Water levels - daily Water quality - seasonal then monthly in spring/summer	Lake: 4 (2 used in analysis) Ral Ral Ck: 4	Refilling – Event 7 Partial drying – Event 8 Refilling – Event 9 Partial drying – Event 10
Harper	Water level Conductivity Turbidity Temperature PH Dissolved oxygen	Oct 2000 – Feb 2002	17	Water levels - daily Water quality –monthly	Lake: 1	Refilling – Event 7 Partial drying – Event 8 Refilling – Event 9 Partial drying – Event 10

Chapter 3 ~ Water Quality

Plate 3.1 Water quality monitoring sites, Lake Merreti, 1983 - 2002



Monitoring techniques

Water levels in Lake Merreti were measured manually from gauge boards levelled to AHD (Australian Height Datum) until July 1996 after which water levels were logged using a data flow capacitance probe with a 392 data logger. Initially this data logger was located near the western shore of the lake and would become stranded once water levels dropped below approximately 16.10 m AHD. In March 2002 the data logger was moved to the lowest elevation point in the lake and has recorded water levels since until Lake Merreti was essentially dry. Readings from the logger were adjusted to manual readings of water level taken at the start and end of the logged period and recorded an accuracy of ± 5 mm (Bramford 2002).

Conductivity readings were collected by the Department of Water Resources between 1981 and 1994 using a WTW EC metre at a single location. Between August 1990 and February 1992, Suter et al., (1993) measured electrical conductivity (EC) using an ICI 303 ATC conductivity meter and results were verified in the laboratory using a Radiometer model CDM83 auto-ranging conductivity meter with automatic temperature compensation.

During the surveys undertaken by Dominelli, Tucker, Nichols and Harper between 1995 and 2002 water quality data were collected with the HORIBA U-10 automated water quality machine. The parameters measured included temperature (ºC), conductivity (EC) and turbidity (NTU).

Mean monthly River Murray flows to South Australia were obtained from the Department of Water, Land and Biodiversity Conservation (2002).

Data analysis

The water quality data were collected during several studies that varied in the:
1. type of data collected (see Table 3.1 Parameters monitored)
2. number of surveys conducted in a month (see Table 3.1, Frequency)
3. number of sites surveyed (see Table 3.1, No. of water quality sites).

Despite the variation in survey effort between studies, mean values were calculated in order to identify patterns in the data. Monthly means and standard deviations were calculated for water level, conductivity and turbidity. Maximum, minimum and mean values for water level, conductivity and turbidity were also calculated for each refilling event. In general, statistics were calculated using water level readings taken at one site in Lake Merreti from 1981 to 2002, conductivity readings taken at between one and three sites from 1981 to 2002, and turbidity readings taken at between one and three sites from 1991 to 2002. No statistics were calculated for complete and partial drying events due to the limited data available.

Statistical analyses were performed in the program JMP-IN (version 3.2: Sall and Lehman 1996). Data sets for each analysis were tested for normality using the Shapiro-Wilk W test. If data were not normally distributed then an attempt was made to transform the data in order to achieve a normal distribution. A non-parametric Kruskal-Wallis ANOVA (analysis of variance) was performed for data sets that did not have a normal distribution, or if there was a large difference in sample sizes (Zar 1984). The analysis was then repeated using a parametric ANOVA. Where the non-parametric and parametric analyses provided the same statistical result, statistics were cited from the parametric test. Tukey tests were used to identify significantly different means at $\alpha = 0.05$. The power of the analysis was determined for non-significant results.

As conductivity and turbidity readings were collected at different sites, the data were analysed to determine the feasibility of combining all data for each variable. One-way ANOVAs were performed to determine if mean conductivity and mean turbidity varied between sites. The between-site analyses failed to detect a significant difference in the mean conductivity (one-way ANOVA $F_{2,666}$; $P = 0.3490$) or the mean turbidity (one-way ANOVA $F_{2,139} = 0.2229$, $P = 0.8005$) recorded at different sites in Lake Merreti. However, there were insufficient samples to provide conclusive statistical results (power of test = 24% and 8% for conductivity and turbidity, respectively). Examination of the actual data confirms that the mean conductivity and turbidity values recorded at each site were fairly similar (Table 3.2), which suggests that there were no distinct within-lake gradients. Data collected from different sites were, therefore, combined for further statistical analyses.

Table 3.2 Mean surface water conductivity and turbidity per monitoring site, Lake Merreti, 1981 - 2002

	Conductivity (EC)			Turbidity (NTU)		
Site	Mean	Standard deviation	No. of samples	Mean	Standard deviation	No. of samples
1	1 059	506	48	290	330	54
3	1 034	2 634	553	231	220	21
5	905	247	68	240	319	67

One-way ANOVAs were performed to determine if the mean water level, mean conductivity and mean turbidity varied between refilling events. Given the potential effect of depth on conductivity, an attempt was made to standardise the data by using only readings taken when water levels were between 16.20 and 16.50 m AHD. However, a stable result could not be obtained due to the lack of data available at these depths during the latter refilling events (Events 7 and 9). An ANCOVA (analysis of covariance) was performed to determine if there was a difference in conductivity between phases with depth entered as a covariate, which allows for differences in wetland water level between events. A saturated model showed the relationship between depth and conductivity was the same across all events.

Regression analyses were used to examine the relationships between:

- conductivity in Lake Merreti and conductivity in Ral Ral Creek
- conductivity and the water level in Lake Merreti
- turbidity in Lake Merreti and turbidity in Ral Ral Creek
- turbidity and the water level in Lake Merreti.

The regressions were first performed using pooled data from all events, and then re-run on an event-by-event basis to determine if the relationships were consistent through time. Student's *t*-statistic was used to evaluate the likelihood that the slope of each regression line was significantly different from zero, which indicates a relationship between the variables. The relationships between the variables are also represented graphically in Figures 3.5, 3.6, 3.9 and 3.10. In order to simplify the graphs, each point represents the mean wetland conductivity and turbidity value calculated from readings taken on the same day at between one and three sites.

Hydrology during survey period

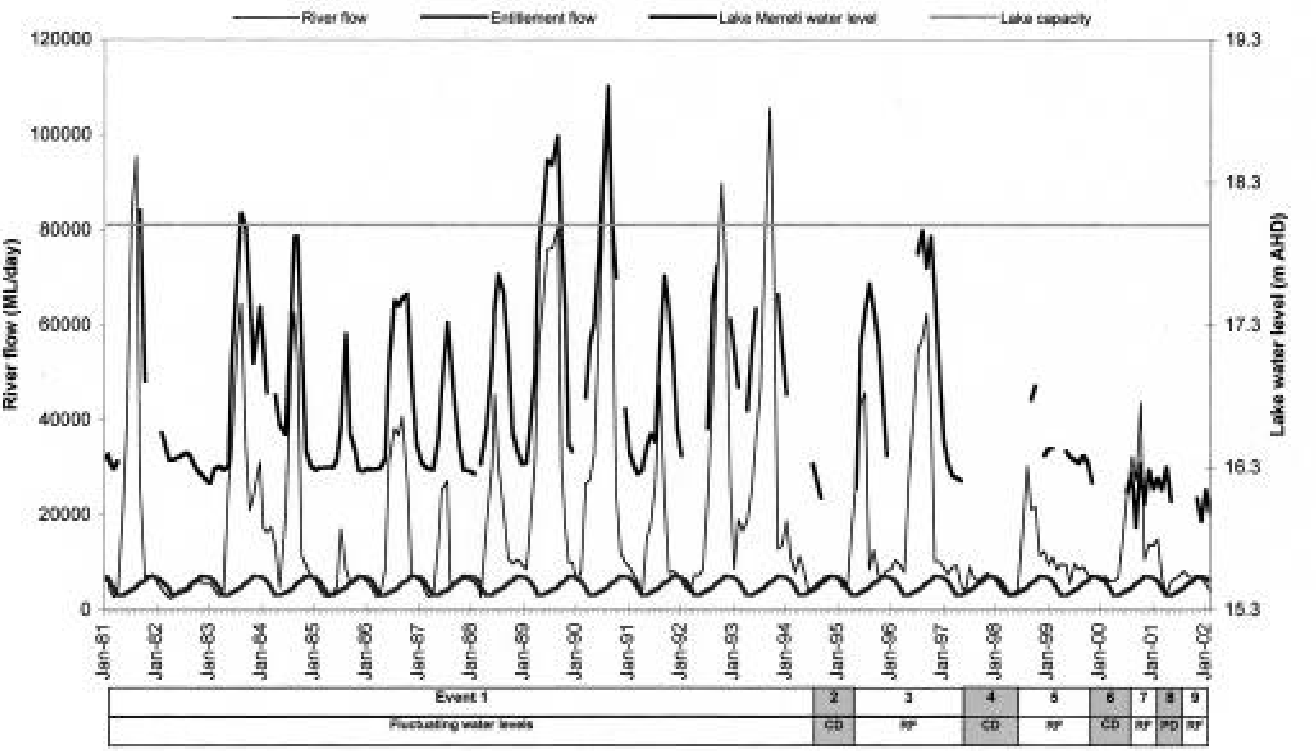
The water level in Lake Merreti is affected strongly by the variation in the River Murray hydrograph. Figure 3.1 shows the river flow conditions throughout the survey period and a brief description of key events is provided over the page.

Surveys undertaken during Fluctuating water levels Event 1 covered several periods of large and medium sized flooding in the lower River Murray. A large flood event in spring 1981 peaked at 95 000 ML/day in October. This was followed by a period of drought that produced low river flows, and corresponding low water levels in Lake Merreti from February 1982 to June 1983. Consecutive floods of a similar magnitude (50 000 – 60 000 ML/day) occurred in the spring of 1983 and the spring of 1984. Apart from some minor peaks in the hydrograph, there was no further flooding in the 1980s until late 1989 when flows exceeded 75 000 ML/day from August to October.

In September, October and November 1990, flow to SA exceeded 100 000 ML/day. Minor flooding occurred in the following year, with flow to SA ranging from 45 000 to 50 000 ML/day in October and November 1991. Two further significant flood events occurred in the early 1990s. The first occurred in late 1992 - early 1993 with flows peaking at 95,000 ML/day in December. A second large flood event later in 1993 produced flows to SA that exceeded 100 000 ML/day.

From August 1994 to September 1995 the lower River Murray experienced an extended period of low flow conditions, with flows remaining close to entitlement, and even dropping below entitlement in May 1995.

Figure 3.1 Mean wetland water level per month, Lake Merreti, 1981 – 2002



It was during this time that Lake Merreti was dried completely for the first time since the 1950s (Complete drying – Event 2). This marked the commencement of the managed wetting and drying of Lake Merreti.

There were two river floods during Refilling Event 3. The first occurred just after the wetland had been refilled and peaked at 65 000 ML/day in August 1995. In the following year, medium flooding again occurred with flow to SA ranging between 50 000 and 75 000 ML/day in September and December 1996, peaking in December.

The second managed complete drying of Lake Merreti (Complete drying – Event 4) coincided with a period during which river flows remained close to entitlement for almost a year.

River flows remained relatively low throughout Refilling Event 5 and Complete drying Event 6, with no flood events between August 1998 and August 2000. During Refilling Event 7, medium flooding occurred in the lower River Murray with flows to SA peaking at 63 000 ML/day in December 2000. River Murray flows to South Australia have remained relatively low since the 2000 flood until present, which incorporates Partial drying Event 8 and Refilling Event 9 at Lake Merreti.

MONITORING RESULTS

Depth

Overall

The mean (± standard deviation) water level in Lake Merreti across all management events was 16.86 (± 0.63) m AHD (Table 3.3). Given that the elevation at the lowest point in the lake is 15.30 m AHD, average water depth was approximately 1.5 m. This average was approximately 0.50 m above the pool level of 16.30 m AHD.

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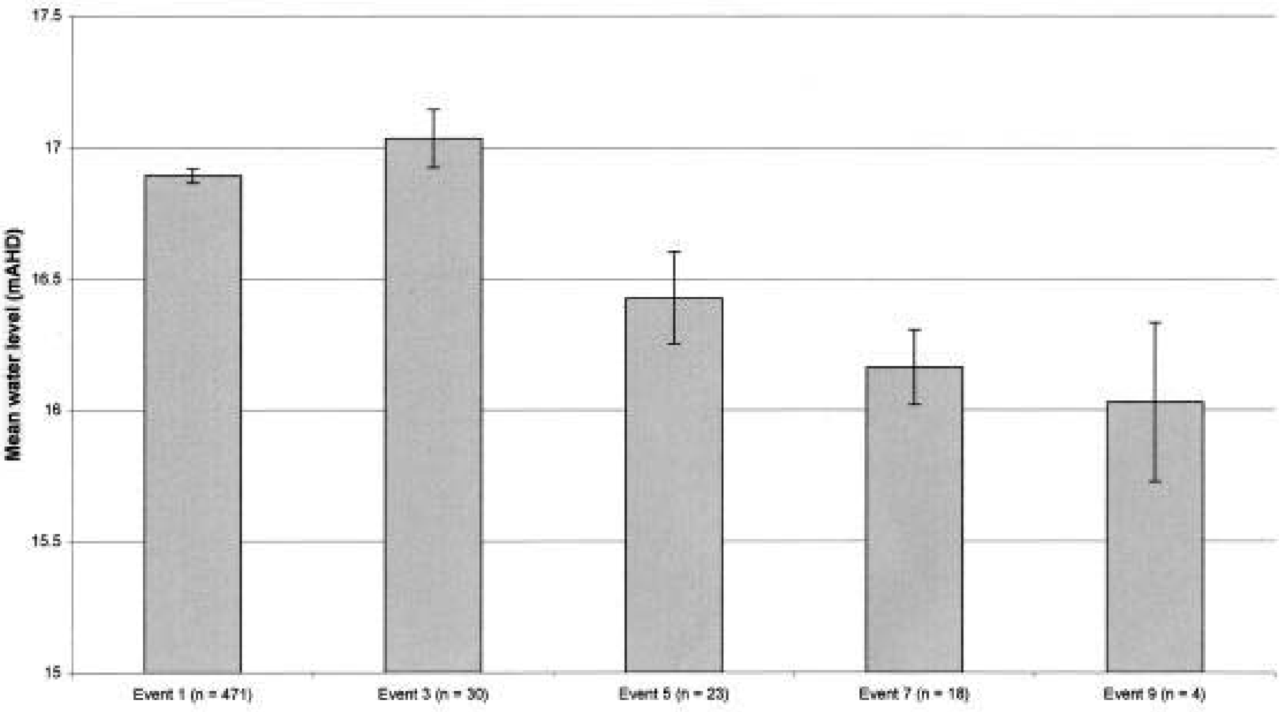
Table 3.3 Minimum, maximum and mean water quality value per refilling event, Lake Merreti, 1983 - 2002

	Water level (m AHD)			Conductivity (EC)			Turbidity (NTU)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Fluctuating water levels - Event 1	16.08	18.99	16.89	294	7000	1056	40	1800	556
Refilling - Event 3	16.10	18.36	17.03	308	2120	1019	6	579	105
Refilling - Event 5	16.07	16.93	16.42	370	1060	733	85	999	445
Refilling - Event 7	16.09	16.69	16.16	166	2050	1011	6	430	118
Refilling - Event 9	15.92	16.09	16.03	362	3780	819	105	816	408
Overall			16.86			999			258

There was a significant difference in the mean water levels of Lake Merreti between refilling events (Figure 3.2; one-way ANOVA $F_{4,530} = 10.3188$, $P < 0.0001$). Mean water levels were up to one metre higher in the earlier events (Fluctuating water levels – Event 1 and Refilling – Event 3), than in the later events (Refilling Events 7 and 9). This variation in the depth of the water in the lake is largely a reflection of river conditions during the respective events (Figure 3.1).

Figure 3.2 Mean surface water level per refilling event, Lake Merreti, 1983 - 2002



Patterns over time

Fluctuating water levels – Event 1 (1983 – September 1994)

Mean (± standard deviation) water level for Event 1 was 16.89 (± 0.61) m AHD (Figure 3.2). Water depth was highly variable, changing by over 2.90 m over the course of the event (Table 3.3). Lake Merreti remained connected to Ral Ral Creek throughout management Event 1, and variations in lake water levels were affected strongly by season and the river hydrograph (Figure 3.1).

The lowest water levels were recorded in the early stages during a period of drought when river flows remained at or below entitlement. The greatest water depths for this survey period were recorded in October 1989 and in October 1990 when levels peaked at 18.99 m AHD. These high wetland water levels coincided with high flow events in the lower River Murray. Floodwaters were held up in Lake Merreti after flood peaks due to the operating guidelines in place between 1983 and 1991 (refer Chapter 2 Lake Merreti: A checkered history) and resulted in the lake having elevated water levels for extended periods.

In general, there was a seasonal pattern of low wetland water levels in summer and relatively high levels in winter and spring. Reduced wetland water levels in summer were due to a combination of low river levels and reduced inflow to the wetland, and high water loss through evaporation.

Complete drying – Event 2 (September 1994 – June 1995)

The first managed complete drying of Lake Merreti commenced on 13/9/1994. The wetland was completely dry by 1/1/1995 indicating that it took approximately three months for the water to evaporate.

The water level in the wetland at the time the regulator was closed was 16.32 m AHD. Therefore, the maximum water depth was approximately 1.00 m, as the elevation of the lake bed at its lowest point is 15.30 m AHD. Based on the depth of the water and the time it took to dry, the estimated mean rate of drawdown was less than 0.01 m per day.

Lake Merreti remained completely dry for five months until the regulator was opened on 27/6/1995.

Refilling – Event 3 (May 1995 – July 1997)

Refilling after the complete drying event (Event 2) resulted in a rapid increase in the depth of the water in Lake Merreti, although no daily data were available over the first few months to indicate the actual refill rate. The mean water level for Refilling Event 3 was 17.03 ($\pm$ 0.61) m AHD (Figure 3.2). This was the highest event mean recorded, perhaps because there were two large river floods in a short time frame. Water levels varied by over 1.80 m during Refilling Event 3 (Table 3.3) and followed a similar pattern to that of Event 1 (Figure 3.1). A maximum depth of 18.36 m AHD was reached in December 1996 during a flood event. During this flood event and an earlier event of similar magnitude in 1995, water levels in Lake Merreti rose at a relatively rapid rate of between 0.02 and 0.07 m/day.

Complete drying – Event 4 (July 1997 – August 1998)

The second managed complete drying of Lake Merreti commenced in July 1997 when water levels were approximately 16.20 m AHD. It took approximately four months for the wetland to dry via evaporation and Lake Merreti was recorded as completely dry in November 1997. The drying of Lake Merreti took longer in this event than the previous complete drying event (Event 2) despite the initial water level being lower. Drawdown may have been slower as the wetland was dried over winter when evaporation rates are lower.

Lake Merreti remained dry for a further nine months until the regulator was reopened on 13/8/1998.

Refilling – Event 5 (August 1998 – December 1999)

The mean water level for Refilling Event 5 was 16.43 ($\pm$ 0.84) m AHD (Figure 3.2). Generally the depth of the water in Lake Merreti remained relatively low throughout Refilling Event 5, with water levels only varying by 0.86 m overall (Table 3.3). The reduced variability in wetland water levels is a reflection of river flow conditions as there were no floods during Refilling Event 5 (Figure 3.1). The maximum lake water level of 16.93 m AHD coincided with a minor peak in river flow of approximately 30 000 ML/day in December 1998.

As no daily level data were available for the first two months of Refilling Event 5, the initial rate of refill is not known, but the water depth in the wetland rose by 0.01 – 0.03 m/day during the river peak in spring 1998.

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Complete drying – Event 6 (December 1999 – September 2000)

The regulator was closed to commence drying of Lake Merreti on 28/12/1999 when the water level was 16.31 m AHD. Daily logger data shows that the water level was 16.08 m AHD by the 26/1/2000 after which no further readings were available as the logger became stranded. These readings indicate that the initial rate of drawdown through evaporation was less than 0.01 m/day.

Complete drying Event 6 spanned nine months in total, from 28/12/1999 to 7/9/2000. There is no record of when Lake Merreti dried completely but, based on the results from Complete drying Event 2, it can be estimated to have taken approximately three months. The wetland would then have been completely dry for six months, from April to September 2000.

Refilling - Event 7 (September 2000 – March 2001)

Refilling of Lake Merreti in Event 7 occurred over an extended timeframe, with small volumes of water intermittently let through to the wetland. Refilling Event 7 recorded a mean water level of 16.16 (± 0.61 m AHD), which is less than lake pool level (Figure 3.2). Actual water levels were frequently below pool level (16.30 m AHD), with total variation in water level throughout the event only 0.60 m (Table 3.3).

A medium flood, which peaked at 63 000 ML/day in December 2000 (Figure 3.1), produced little response in lake water levels (maximum = 16.69 m AHD). While all gates on the inlet structure were open at the time the river peaked (17/12/2000), they had been closed for approximately two months while river levels were high (28/9/2000 to 6/12/2000). This period incorporated a smaller peak in mid-October 2000 of 41 500 ML/day and three weeks of rising river levels for the second peak. The operation of the structure may, therefore, have contributed to the lack of response to the flood event in wetland water levels, although it is likely to be due largely to the short duration of the flood peak and the small capacity of the inlet pipes.

The December 2000 flood failed to result in the much-needed inundation of the riparian zone around Lake Merreti. Inundation is required to support the long-lived vegetation (e.g. river red gums) around the lake and to freshen the underlying groundwater (refer Chapter 4 Groundwater). It is, therefore, recommended that works be undertaken to increase the hydrological capacity of the inlet structure, which will increase the volume of water that reaches the lake during small floods.

Partial drying – Event 8 (March 2001 – September 2001)

Initially the main inlet structure was closed on 3/2/2001, however, it was reopened for several days at the end of March causing water levels to rise. The regulator was then closed on 30/3/2001 for approximately five months until refilling commenced on 3/9/2001. Limited water level data were available to indicate the minimum water level obtained during Partial drying Event 8, although the last manual gauge board reading taken showed the water level was 16.06 on 13/7/2001.

Refilling - Event 9 (September 2001 – February 2002)

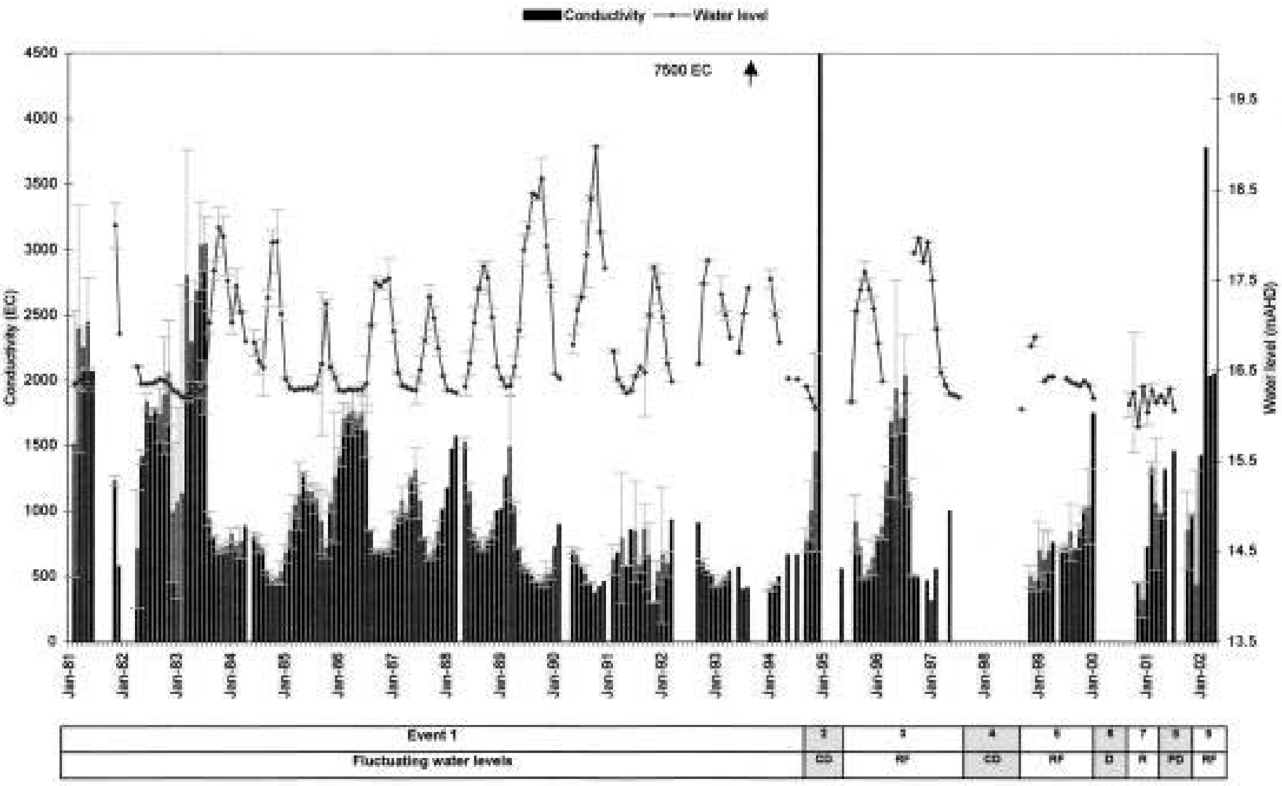
Mean water level for Refilling Event 9 was 16.03 (± 0.61) m AHD (Figure 3.2), which was the lowest event mean recorded over the survey period. Water levels remained below lake pool level throughout Refilling Event 9 with minimal fluctuations in water depth overall (Table 3.3; 0.17 m). These results are a reflection of river flow conditions, as river levels remained at or below entitlement throughout Refilling Event 9 (Figure 3.1).

Conductivity

Overall

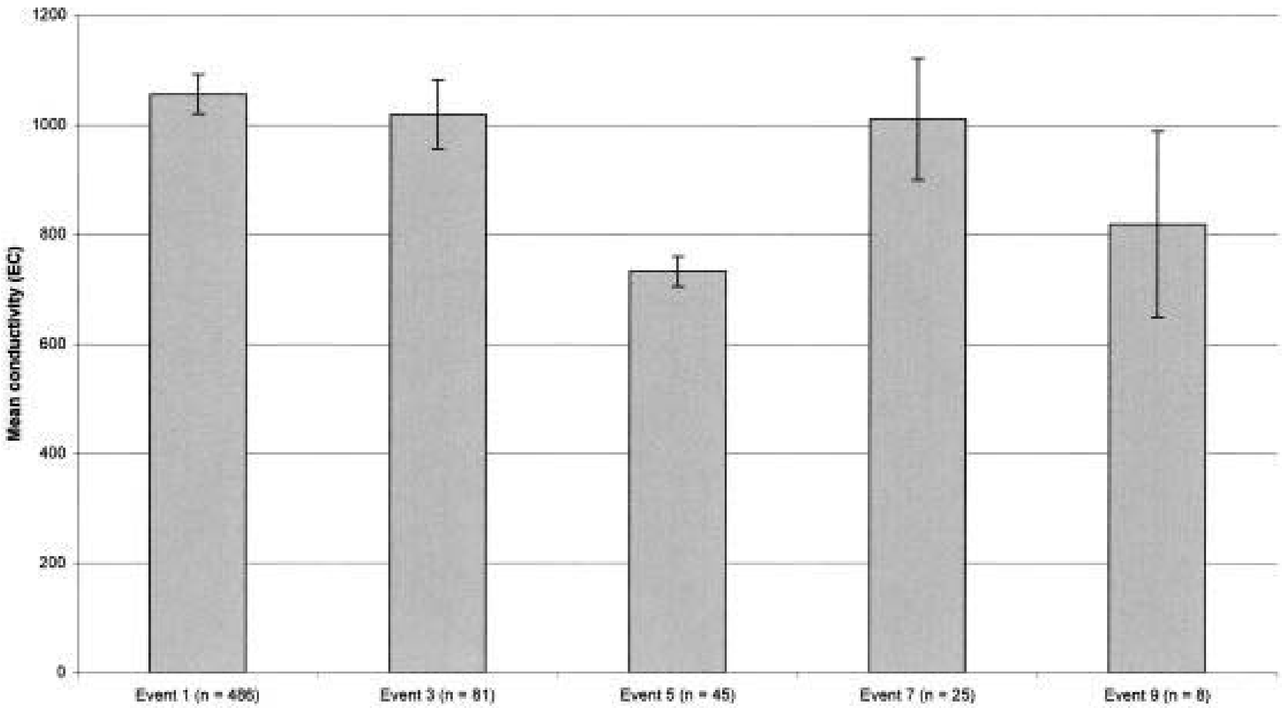
Overall, the mean (± standard deviation) conductivity of Lake Merreti was 999 (± 710) EC (Table 3.3), which is below the limit at which salinity is known to have toxic effects on freshwater macroinvertebrates and plants, although it may result in some sub-lethal, adverse effects (Hart *et al.* 1990). As indicated in Figure 3.3 and by the large standard deviation value, salinity at Lake Merreti is highly variable.

Figure 3.3 Mean surface water conductivity per month, Lake Merreti, 1981- 2002



On an event basis, mean conductivity was highest in Fluctuating water levels Event 1 (1056 ± 792 EC) and lowest in Refilling Event 5 (733 ± 184 EC) (Figure 3.4). However, water levels in Lake Merreti varied significantly between these events and wetland salinity is known to be affected by changes in water volume through the evapoconcentration and dilution of salts (Suter *et al.* 1993).

Figure 3.4 Mean surface water conductivity per refilling event, Lake Merreti, 1983 - 2002

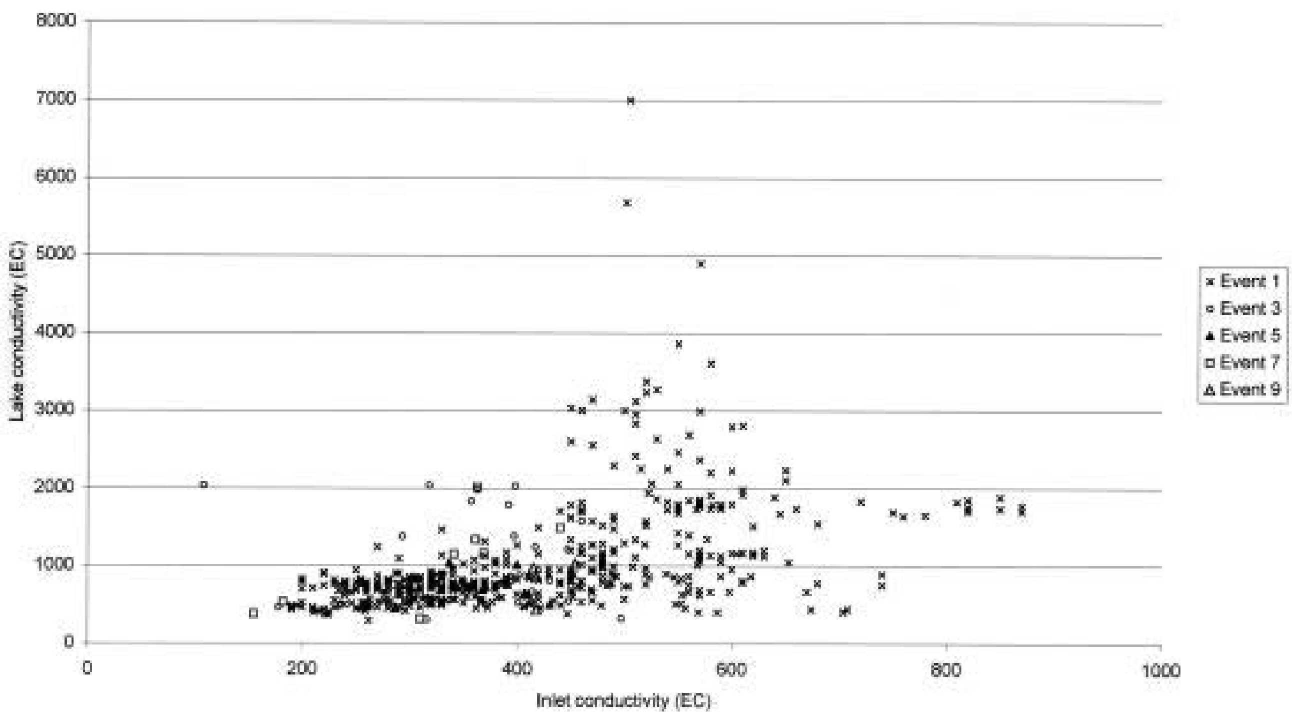


A comparison of the mean conductivity per event that allowed for differences in water level was, therefore, carried out using an ANCOVA analysis. This analysis showed that there was a significant difference in the mean conductivity of Lake Merreti between refilling events once differences in depth were taken into account (ANCOVA $F_{4,504}$ = 72.9390: P < 0.0001). Wetland conductivity was lowest in Refilling Event 3 and highest in Refilling Event 9. There was no significant difference in mean conductivity between Fluctuating water levels Event 1 and Refilling Event 7. Refilling Event 5 was excluded from the analysis due to a lack of corresponding conductivity and water level data. These results show that there has been no gradual and consistent increase in conductivity, which indicates that drying phases have not produced an accumulation of salt within the survey period.

Figure 3.5 shows the conductivity of Lake Merreti recorded at a given conductivity in Ral Ral Creek and indicates that wetland conductivity tended to increase with that of Ral Ral Creek. This was supported by a regression analysis, which showed that there was a significant relationship between the two variables, and that 19% of the variation in wetland conductivity was described by changes in the conductivity of Ral Ral Creek (r^2 = 0.1857; t_{646} = 12.18; P < 0.0001).

Ral Ral Creek is the primary source of water in the wetland, therefore, the quality of the inlet water will determine the initial quality of the water entering the wetland. In general, the conductivity of the water in the wetland was two-to-three times greater than that of the water in the inlet, indicating that there is not a direct relationship between these variables and in-situ processes elevate wetland conductivity.

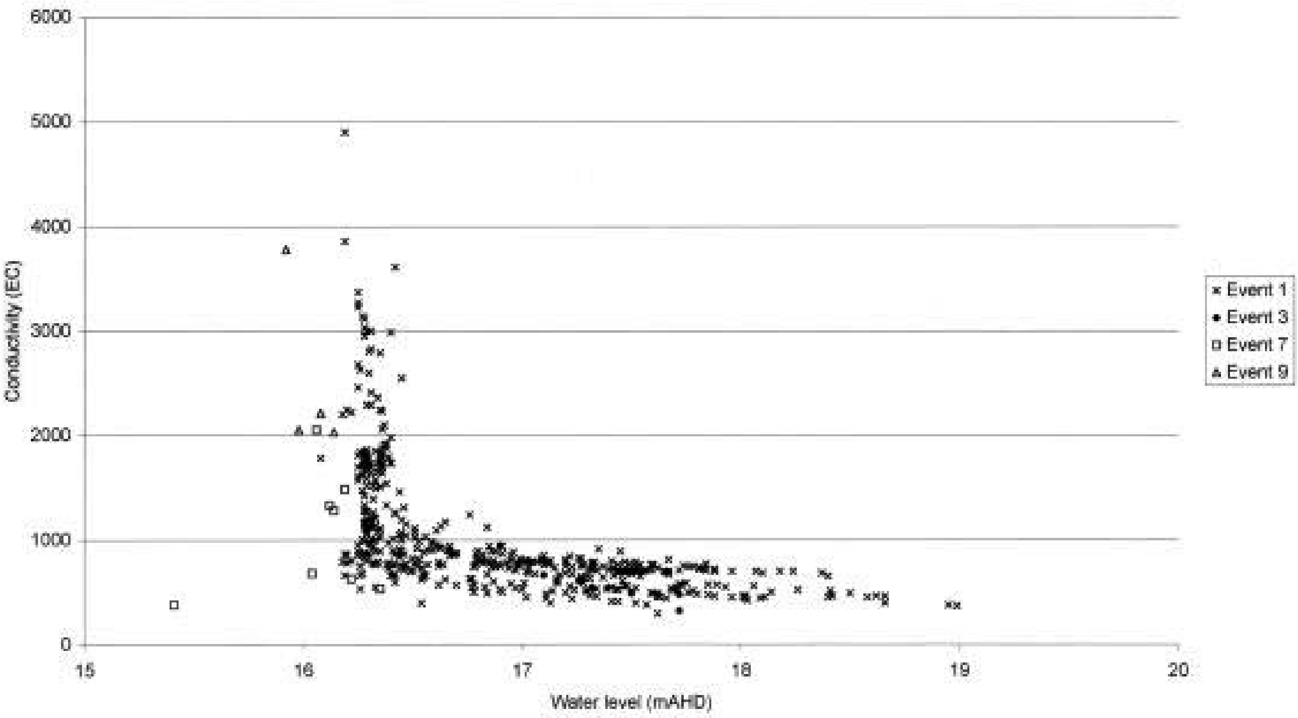
Figure 3.5 Variation in wetland conductivity with Ral Ral Creek conductivity, Lake Merreti, 1983 – 2002



There was also a significant relationship between the conductivity in Lake Merreti and the water level in the wetland at the time, as indicated by regression analysis (r^2 = 0.3169; t_{510} = -15.37; P < 0.0001). The variation in water level explained 32% of the variation in wetland conductivity. Figure 3.7 shows that conductivity increased as water levels dropped, although the relationship changed at 16.30 m AHD. When water levels were less than 16.30 m AHD, changes in depth had a dramatic effect on wetland conductivity. However, when water levels were greater than 16.30 m AHD the effect of a change in depth on conductivity was limited.

As conductivity is a measure of the total dissolved salts in a given volume of water, a decrease in volume will effectively increase the salt concentration. Generally, wetland water levels are reduced in summer when evaporation rates are high and river flows are low, resulting in the evapoconcentration of salts. When wetland water levels rise, particularly during flood events, the salt concentration becomes diluted and conductivity declines.

Figure 3.6 Variation in wetland conductivity with wetland water level, Lake Merreti, 1983 - 2002



The results from the regression analyses indicate that both water level and the conductivity of the inlet water have a significant effect on the conductivity of Lake Merreti. However, the influence of water depth is greater than that of inlet conductivity.

When analysed on an event-by-event basis, the correlation of Lake Merreti conductivity with Ral Ral Creek conductivity and with water level was not consistent across each event (Table 3.4). These results indicate that the overriding influence on the conductivity of the wetland varied between events. Variations in the degree to which water depth and inlet conductivity affected wetland conductivity may be dependent on the volume of water entering the wetland relative to the volume that was already present. During some management events these two variables had little or no correlation with wetland conductivity, which indicates that alternate factors also influence the quality of the water within the wetland. Such factors may include:

- river flows and rate of wetland inflow
- climatic conditions (rainfall and evaporation)
- duration of wetting and drying events
- frequency of flushing events.

Table 3.4 Correlation of wetland conductivity with Ral Ral Creek conductivity, and with wetland water level per refilling event, Lake Merreti, 1983 - 2002

Management Event	Wetland conductivity significantly correlated with Inlet Conductivity	Wetland conductivity significantly correlated with Water Level
All refilling events	Y	Y
Fluctuating water levels – Event 1	Y	Y
Refilling – Event 3	N	Y
Refilling – Event 5	N	n/a
Refilling – Event 7	Y	N
Refilling – Event 9	N	N

Patterns over time

Fluctuating water levels - Event 1 (1983 – September 1994)

The mean (+ standard deviation) conductivity for Fluctuating water levels Event 1 was 1056 (+ 792) EC (Figure 3.4). This was the highest event mean recorded during the survey period although, in general, conductivity readings fluctuated widely throughout this event as indicated by the high standard deviation.

It is probable that high conductivities in Lake Merreti during Event 1 (fluctuating water levels) resulted from the combined effect of both low water level and high inlet conductivity. The highest conductivities for Lake Merreti were recorded between February 1981 and August 1983 when conductivities were generally above 1 500 EC (Figure 3.3). During this period, water levels were at their lowest and inlet conductivities at their highest, peaking at 846 EC in June 1982. The high conductivities coincided with a period of drought and low river flows.

The lowest conductivities were recorded in November 1991 (299 EC), October 1990 (368 EC) and September 1989 (460 EC). These dates corresponded with high water levels in the wetland due to high river flows, and low conductivities in Ral Ral Creek (minimum = 190 EC in November 1991).

These results were supported by the regression analyses and are demonstrated in Figures 3.5 and 3.6. Figure 3.5 shows that wetland conductivity increased with inlet conductivity during Fluctuating water levels Event 1, and the regression analysis indicated that 21% of the increase in conductivity in Lake Merreti was due to increases in the conductivity of Ral Ral Creek ($r^2 = 0.2145$; $t_{486} = 11.51$; $P < 0.0001$). Figure 3.6 shows that the conductivity of Lake Merreti decreased as water depth increased, with 33% of the variation in wetland conductivity explained by variation in water depth ($r^2 = 0.3277$; $t_{466} = -15.06$; $P < 0.0001$).

During this management event, variations in the conductivity of Lake Merreti reflected patterns in the river hydrograph, perhaps because the wetland remained connected to the inlet throughout. The highest conductivities were recorded in 1982 and 1982, which coincided with a period of drought and low river flows. From 1984 to 1988 there were minor spring peaks in river flows each year. During these years, conductivity would slowly increase over summer and autumn then decrease in late winter/early spring when river levels rose. In 1989 and 1990, two large River Murray flood events occurred and conductivity remained relatively low.

Complete drying – Event 2 (September 1994 – June 1995)

A mean monthly conductivity of 999 EC was recorded in October 1994 and a mean of 6 560 EC recorded in December 1994, after which the wetland was dry. This dramatic increase in conductivity demonstrates the evapoconcentration effects on salt concentration in the surface water of Lake Merreti.

Refilling - Event 3 (May 1995 – July 1997)

A mean (+ standard deviation) conductivity of 1019 (+ 570) EC was recorded in Refilling Event 3 (Figure 3.4). The mean and standard deviation were comparable to the values recorded in Fluctuating water levels Event 1, indicating conditions were similar in these two events.

There was an initial peak in conductivity upon refilling of the wetland, which was likely due to the re-suspension of salts that had been deposited on the lake bed during the drying phase. After reaching 910 EC in August 1995, two months after refilling commenced, conductivity declined to 482 EC in October 1995 despite there being little change in water levels. The change in conductivity then assumed a pattern similar to that which occurred in Fluctuating water levels Event 1 (from 1984 to 1988), and conductivity gradually rose over summer and autumn before dropping in spring when a peak occurred in the river hydrograph (Figure 3.3).

Conductivities remained low (300 – 500 EC) from September 1996 to January 1997. These conditions corresponded with relatively high lake levels (> 17 m AHD) due to a river flood event, and low inlet conductivities of between 180 and 315 EC.

Conductivity in Ral Ral Creek remained relatively low (< 450 EC) throughout Refilling Event 3, even between April and July 1996 when lake conductivity exceeded 1500 EC. Unfortunately, no water level data were available for these months, although a drop in the river hydrograph indicates that lake levels may have been low due to reduced river flows. It appears, therefore, that during Refilling Event 3 the conductivity of Ral Ral Creek had little influence on the conductivity of Lake Merreti, and that variations in lake conductivity were largely due to fluctuations in water levels and river flows.

These results were supported by the regression analyses, which showed that wetland conductivity was not influenced by variations in the conductivity of Ral Ral Creek (Figure 3.5: $r^2 = 1 \times 10^{-6}$, $t_{81} = 0.01$, $P = 0.9928$) but was strongly affected by variations in water depth (Figure 3.6: $r^2 = 0.8533$; $t_{24} = -11.57$, $P < 0.0001$). During Refilling Event 3, 85% of the increase in conductivity in Lake Merreti could be explained by a decrease in the depth of the water.

Refilling - Event 5 (August 1998 – December 1999)

Mean ($\pm$ standard deviation) conductivity for Refilling Event 5 was 733 ($\pm$ 184) EC, which was the lowest event mean recorded during the survey period (Figure 3.4). Conductivity remained relatively stable throughout the event as indicated by the low standard deviation.

There was a progressive increase in conductivity with duration of inundation during Refilling Event 5, increasing from 497 EC in November 1998 to 1035 EC in December 1999. Both inlet conductivity and water levels remained fairly stable throughout, however, river flows gradually declined from approximately 20 000 ML/day to 7 000 ML/day. These results indicate that factors other than inlet conductivity and water depth were affecting the conductivity of the wetland.

The regression analysis also indicated that there was no significant relationship between the conductivity in Lake Merreti and the conductivity of Ral Ral Creek ($r^2 = 0.0124$; $t_{44} = -0.74$; $P = 0.4658$). Unfortunately, depth and conductivity readings were not collected on corresponding dates, therefore, it was not possible to perform a regression analysis to assess statistically if there was a relationship between these two variables.

Complete drying – Event 6 (December 1999 – September 2000)

A monthly mean in January 2000 (one month into drawdown) of 1 748 EC again demonstrates the effect of evapoconcentration on elevating salt levels. Readings were only taken in January 2000 during this event.

Refilling - Event 7 (September 2000 – March 2001)

Mean ($\pm$ standard deviation) conductivity in Refilling Event 7 was 1011 ($\pm$ 554) EC, which was similar to values recorded in Refilling Event 3 (Figure 3.4). Unlike the two previous managed refilling events where there was a gradual or seasonal increase in conductivity, conductivity levels fluctuated throughout Refilling Event 7 (Figure 3.3). Inlet conductivities, water levels and river flows also fluctuated during this management event. Seasonal patterns may not have been evident due to the short timeframe of this event, which only spanned six months.

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The regression analyses indicated that the conductivity in Lake Merreti was influenced by the conductivity of the water in Ral Ral Creek (r^2 = 0.3737; t_{24} = 3.70; P = 0.0012), but not the depth of the water in the lake (r^2 = 0.1296; t_{14} =1.39; P = 0.1875) during Refilling Event 7. Figure 3.5 shows that wetland conductivity increased with inlet conductivity, with 37% of the increase in conductivity in Lake Merreti due to increases in the conductivity of Ral Ral Creek. The greater effect of inlet conductivity on wetland conductivity may have been due to the method of filling the wetland, as only small volumes of water were let in intermittently.

Partial drying – Event 8 (March 2001 – September 2001)

Conductivity increased over time during Partial drying Event 8. Mean monthly conductivity was 978 EC in April 2001, 1 317 EC in May 2001 and 1 457 EC in July 2001. This gradual increase was likely to have been due to the drawdown of water levels in the wetland. In addition, as the structure was closed, the wetland would not have received any freshening inflows.

Refilling - Event 9 (September 2001 – February 2002)

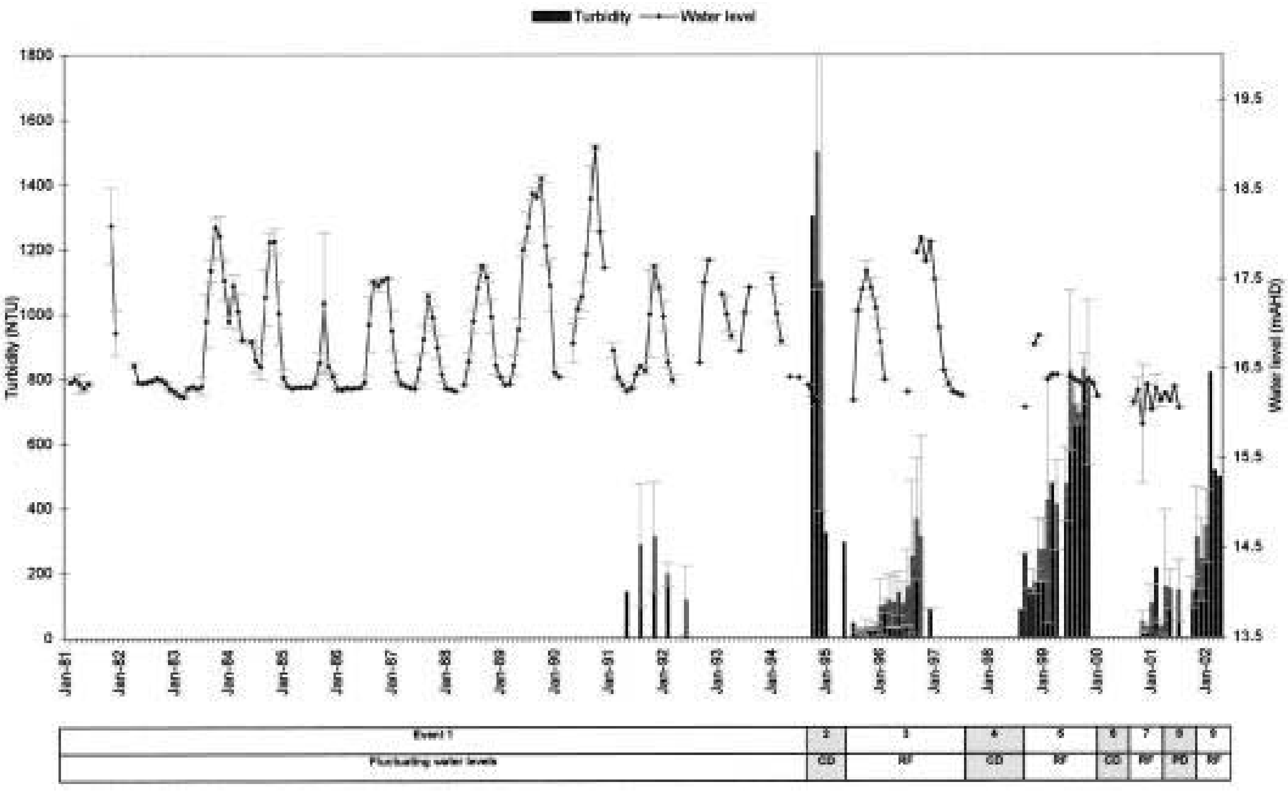
Mean (± standard deviation) conductivity for Refilling Event 9 was 819 (± 480) EC (Figure 3.3). Conductivity levels fluctuated during this management event but were generally higher during the summer months, when river flows were lower. Again this refilling event spanned only six months and, due to the limited data available, it is difficult to identify patterns or look for relationships between variables. Likewise, regression analyses indicated that neither water level (r^2 = 0.5436; t_3 = -1.54, P = 0.2627) nor inlet conductivity (r^2 = 0.0578, t_7 = 0.61, P = 0.5663) had a significant effect on the conductivity of Lake Merreti.

Turbidity

Overall

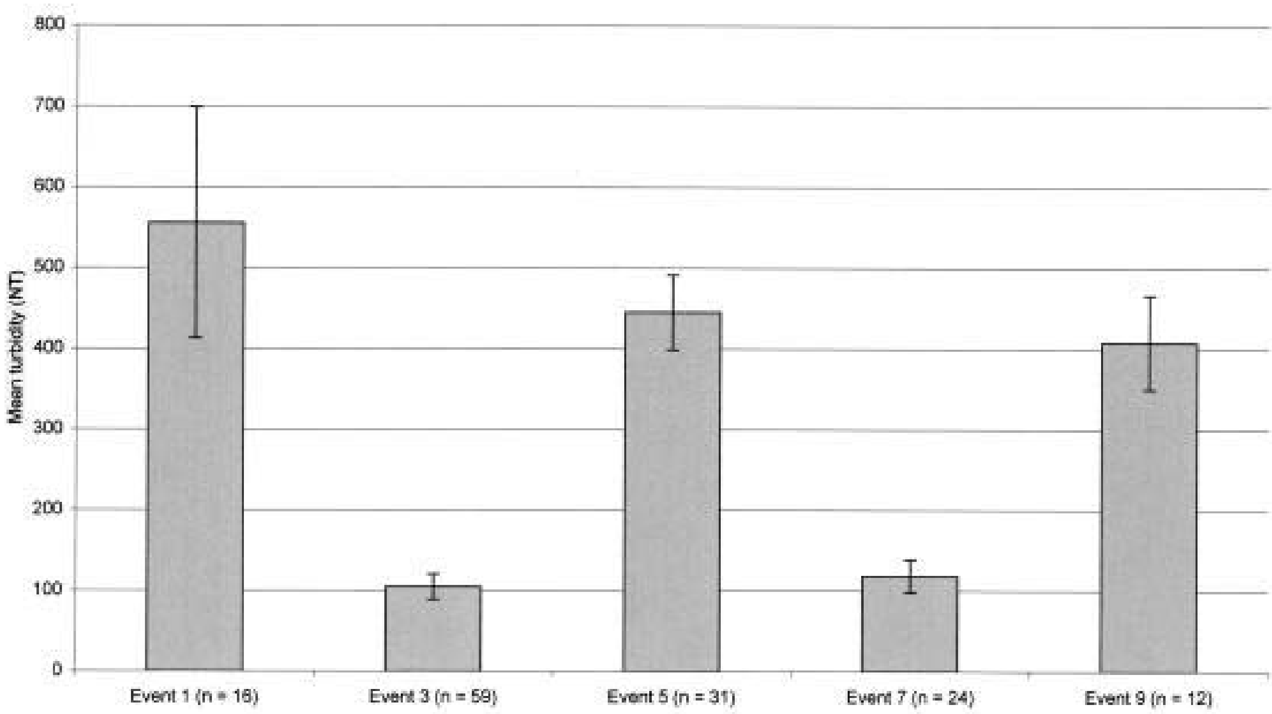
The mean (± standard deviation) turbidity of Lake Merreti across all management events was 258 (± 290) NTU. This is a relatively high turbidity reading indicating the water is quite opaque, although turbidity varied widely throughout the survey period (Figure 3.7).

Figure 3.7 Mean surface water turbidity per month, Lake Merreti, 1991 - 2002



The mean turbidity of Lake Merreti varied significantly between refilling events (one-way ANOVA $F_{4,139}$ = 29.4598, P < 0.0001). Mean turbidity was greater during Fluctuating water levels Event 1 and Refilling Events 5 and 9 (400 –500 NTU) than in Refilling Events 3 and 7 (~100 NTU) (Figure 3.8).

Figure 3.8 Mean surface water turbidity per refilling event, Lake Merreti, 1991 - 2002



Figures 3.9 and 3.10 show the turbidity of the water in Lake Merreti recorded at a given turbidity in Ral Ral Creek (Figure 3.9) and at a given water level (Figure 3.10) during all refilling events. Regression analyses were used to assess the relationship between these variables and found that there was no correlation between the turbidity of Lake Merreti and the turbidity of Ral Ral Creek (r^2 = 0.0132; t_{119} = 1.26; P = 0.2114). There was, however, a significant relationship between wetland turbidity and water levels (r^2 = 0.1911; t_{31} = -2.66; P = 0.0123). Changes in water depth described 19% of the variation in the turbidity of Lake Merreti, with turbidity increasing as depth decreased. As turbidity is a measure of the amount of suspended solids in a given volume of water, a decrease in water volume will effectively increase the concentration of the solids (Scholz *et al.* 1999). In addition, the depth of the water is likely to determine the capacity for wind to disturb sediments on the lake bed.

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Figure 3.9 Variation in wetland turbidity with Ral Ral Creek turbidity, Lake Merreti, 1991 - 2002

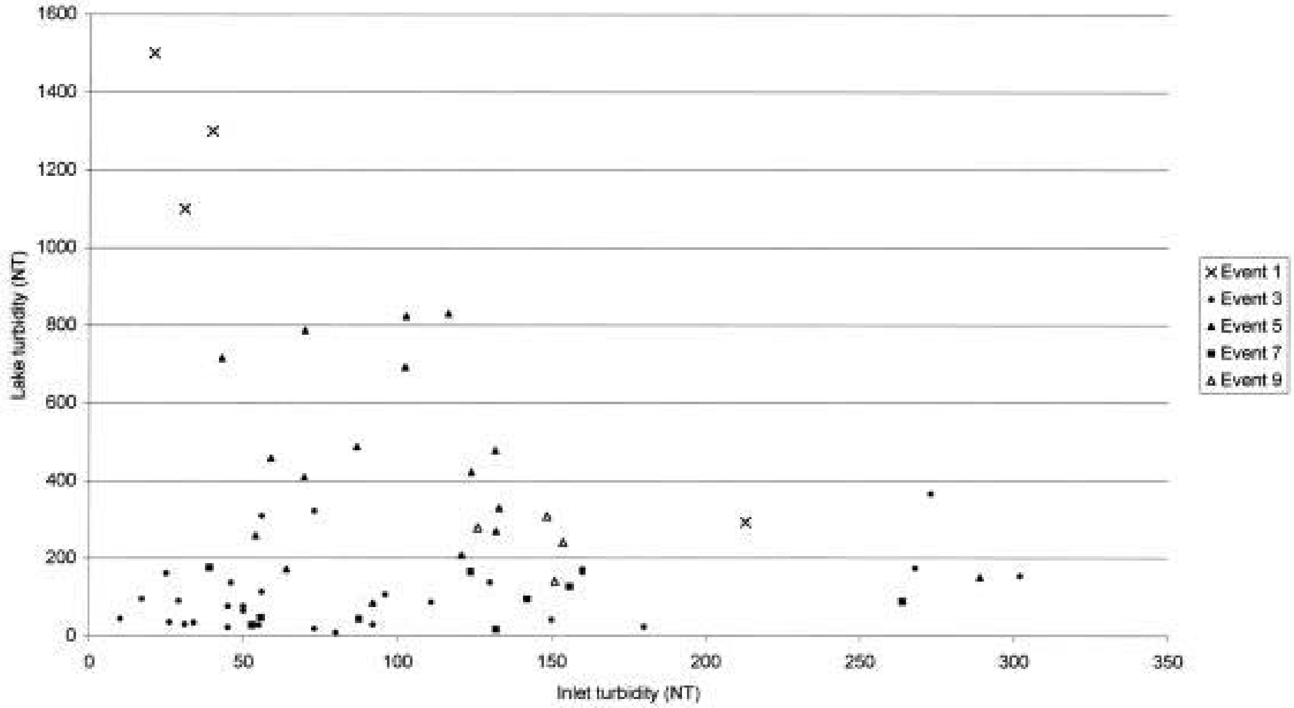
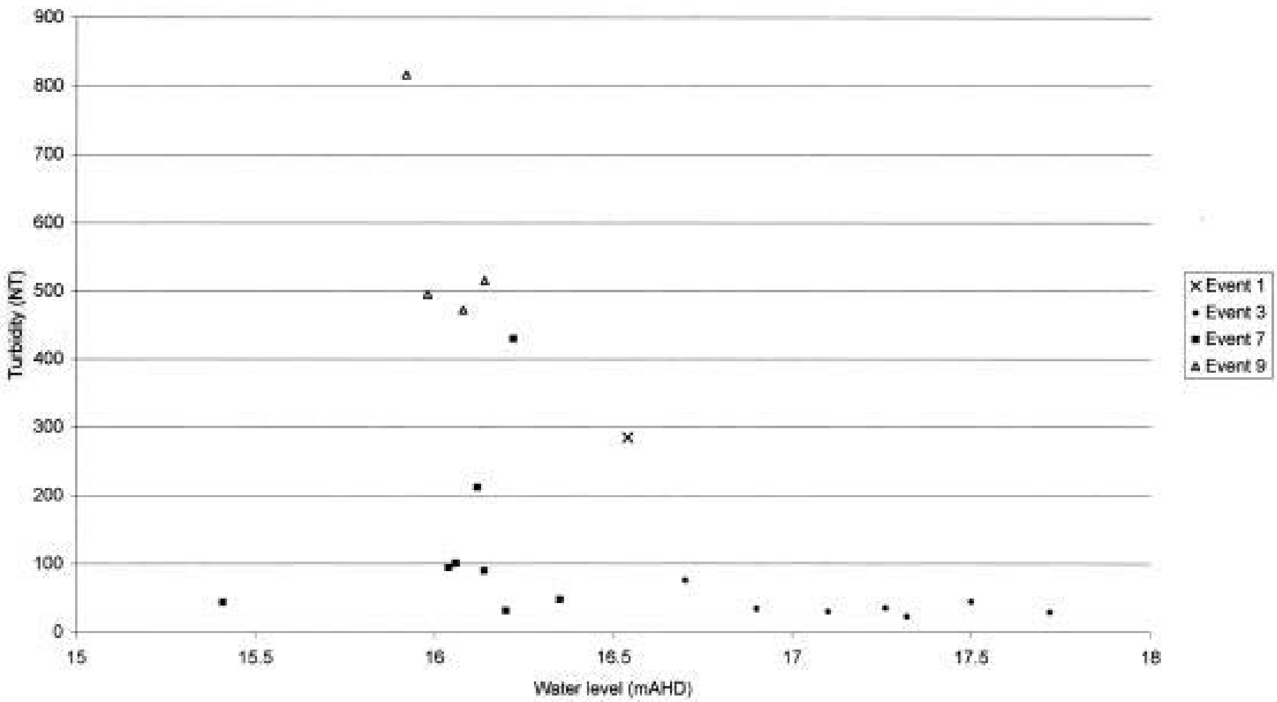


Figure 3.10 Variation in wetland turbidity with wetland water level, Lake Merreti, 1991 - 2002



When each refilling event was examined separately, the analyses indicated that the strength of the relationship between the turbidity of Lake Merreti and that of Ral Ral Creek varied between events. Similarly, the correlation between wetland turbidity and water levels also differed between events (Table 3.5). Limited data precluded analyses for some management events, however, the results show that the variable having the greatest effect on wetland turbidity differs between events. Given that during some events wetland turbidity was not correlated with either variable (Table 3.5), alternate factors must also have a significant influence on the water quality of the wetland. High conductivity is known to reduce turbidity as it causes the aggregation of colloidal particles (Suter *et al.* 1993), therefore, variations in conductivity will influence corresponding turbidity readings. The effect of wind is high in Lake Merreti due to the orientation of the wetland and its shallow nature. Prevailing winds can cause extremely high fetch in Lake Merreti, which would contribute to the high turbidities. Other factors that may influence turbidity include:

- degree of consolidation of the lake bed
- presence/absence of bottom-feeding fauna e.g. carp
- presence/absence of aquatic vegetation
- presence/absence of algae and detritus.

Table 3.5 Correlation of wetland turbidity with Ral Ral Creek turbidity, and with wetland water level per refilling event, Lake Merreti, 1991 - 2002

Management Event	Wetland turbidity significantly correlated with: Inlet Turbidity	Water Level
All refilling events	N	Y
Fluctuating water levels – Event 1	Y	n/a
Refilling – Event 3	Y	N
Refilling – Event 5	N	n/a
Refilling – Event 7	N	N
Refilling – Event 9	N	n/a

Patterns over time

Fluctuating water levels - Event 1 (1983 – September 1994)

The mean (± standard deviation) turbidity during Fluctuating water levels Event 1 was 556 (± 572) NTU, which was the highest event mean recorded for the survey period (Figure 3.8). As only nine readings were taken between May 1991 and June 1995, there is insufficient data to identify patterns. However, it does show that turbidity fluctuated widely over these 13 months, ranging from a minimum of 40 NTU to a maximum of 1800 NTU (Figure 3.7).

While the regression analysis showed that wetland turbidity was negatively correlated to inlet turbidity ($r^2 = 0.7113$; $t_5 = -3.14$, $P = 0.0349$), this is unlikely to be a true representation of the relationship given the short duration of monitoring and limited data available for this event.

High turbidity during this event was probably due to the extended period for which Lake Merreti had been inundated, as the wetland had not been dried since 1959 (i.e. >20 years). Both low water levels and reduced aquatic plant growth may have contributed indirectly to elevated turbidity because lake bed sediments were then more exposed to stirring by the wind. Corresponding water levels were not available for analysis but, as described in the '*Depth*' section above, low water levels were experienced at times due to drought and seasonal variations in river flow. Anecdotal evidence also suggests that there was little aquatic vegetation present in Lake Merreti during Fluctuating water levels Event 1 (refer Chapter 5 Vegetation).

Complete drying – Event 2 (September 1994 – June 1995)

High mean monthly turbidities were recorded in October 1994 (1300 NTU), November 1994 (1500 NTU) and December 1994 (1100 NTU), after which Lake Merreti was completely dry. These elevated turbidities may have been linked to the drop in water levels as the lake water was being evaporated dry.

Refilling - Event 3 (May 1995 – July 1997)

The mean (± standard deviation) turbidity of Lake Merreti was reduced to 105.5 (± 123) NTU in Refilling Event 3, which was the lowest event mean recorded during the survey period (Figure 3.8). After the wetland was refilled in June 1995, turbidity remained relatively low (<50 NTU) for approximately the first six months. Turbidity then began to increase steadily, peaking at 579 NTU in August 1996 and remaining relatively high until the final readings for this event were taken in December 1996 (Figure 3.7).

The low turbidity recorded in Refilling Event 3 is likely to have been largely due to the complete drying of Lake Merreti from January 1995 to June 1995 during the previous event (Complete drying – Event 2). The drying of wetlands has been shown to consolidate sediments, reducing their re-suspension on refilling and hence lowering the turbidity of the surface water (van der Wielen in prep). The gradual increase in turbidity six months into the event may indicate that after this time period, the sediments were becoming less consolidated with duration of inundation.

High turbidities between August and October 1996 coincided with a river flood event, high turbidity in Ral Ral Creek (maximum = 300 NTU) and a relatively rapid increase in lake water levels. High wetland turbidities during the flood event probably reflected the quality of the source water, which would have entered the wetland in large volumes. The possible effect of the turbidity of Ral Ral Creek on wetland turbidity was supported by the regression analysis ($r^2 = 0.0814$; $t_{56} = 2.21$, $P = 0.0314$), which indicated that wetland turbidity increased with inlet turbidity (Figure 3.9), although variations in inlet turbidity only explained 8% of the variation in lake turbidity. There was no significant correlation between wetland turbidity and water level during this event ($r^2 = 0.0930$; $t_{13} = -1.11$, $P = 0.2892$).

Refilling - Event 5 (August 1998 – December 1999)

A similar pattern was recorded upon refilling of Lake Merreti in Event 5 as in the previous refilling event (Event 3), with turbidity increasing over time (Figure 3.7). However, actual turbidity readings were much higher and the mean (± standard deviation) turbidity of the wetland during this event was 445 (± 260) NTU (Figure 3.8).

It is not known why turbidity was higher in this refilling event (Event 5) when compared to the previous refilling event (Event 3) as conditions in these two events were very similar, including the duration of the preceding complete dry, the duration of inundation and the lack of aquatic vegetation growth. Lower turbidity readings may actually have been anticipated, as this was the first refilling event after fish screens had been installed on all inlets to Lake Merreti. The primary purpose of these screens was to exclude adult carp from the wetland, as this introduced species has been linked to many problems, including the loss of aquatic plants and increase in turbidity. While the screens may have reduced the density of adult carp in Lake Merreti, fish monitoring in the wetland found that the carp population had consisted mostly of small individuals and numbers were generally not high enough to contribute to elevated turbidities (Nichols 2003).

The gradual increase in turbidity over the course of the event was not a reflection of the water quality in Ral Ral Creek, as turbidity there fluctuated between approximately 50 and 300 NTU throughout. Similarly, the regression analysis found that there was no correlation between wetland and inlet turbidity (Figure 3.9: $r^2 = 0.0534$; $t_{30} = 1.28$, $P = 0.2110$). No corresponding water level data were available for a regression analysis to determine if this was affecting wetland turbidity but depth remained fairly stable throughout and there were no river flood events during Refilling Event 5.

Refilling - Event 7 (September 2000 – March 2001)

Overall, the turbidity of Lake Merreti was low during this refilling event with a mean (± standard deviation) of 118 (± 99) NTU (Figure 3.8) and no gradual increase in turbidity over time (Figure 3.7). There were small fluctuations in the mean monthly turbidity throughout the event, which may have been related to the method of refilling wetland by allowing small volumes of water in intermittently. This management event was unique in that the turbidity of Lake Merreti was generally lower than that of Ral Ral Creek (53 – 264 NTU), which also fluctuated throughout. Regression analyses showed that there was no significant correlation between the turbidity of Lake Merreti during Refilling Event 7 and inlet turbidity (Figure 3.9: $r^2 = 0.0029$; $t_{17} = 0.22$, $P = 0.8316$) or water level ($r^2 = 0.0945$; $t_{11} = 1.02$, $P = 0.3309$).

Water levels in the wetland remained at or below pool level throughout this event, therefore, it would be expected to be more susceptible to high turbidity due to the disturbance of sediments by wind. However, generation of extensive amounts of aquatic vegetation upon refilling (refer Chapter 5 Vegetation) would have aided low turbidities by reducing the effects of wind. Also the low turbidity may have been related to the short duration of this refilling event, which spanned only six months. Results from Refilling Event 3 indicated that turbidity remained relatively low for approximately the first six months before beginning to increase.

Partial drying – Event 8 (March 2001 – September 2001)

The turbidity of Lake Merreti was monitored during April, May and July 2001 of Partial drying Event 8 and returned relatively low mean monthly values ranging between 143 and 154 NTU. A vegetation survey in July 2001 showed that aquatic vegetation was still abundant in the open water areas of the wetland, which may have assisted in keeping turbidity low.

Refilling - Event 9 (September 2001 – February 2002)

The turbidity of Lake Merreti was elevated during Refilling Event 9 when compared to the previous refilling event (Event 7), resulting in a significantly higher event mean of 408 ($\pm$ 203) NTU (Figure 3.8). A pattern of increasing turbidity with duration of inundation was again evident, similar to Refilling Events 3 and 5 (Figure 3.7).

Refilling Event 9 followed on from a partial rather than complete drying event and so, in effect, Lake Merreti had been inundated since September 2000. Given that the wetland had not been completely dried and there was no opportunity for the lake bed sediments to consolidate, higher wetland turbidity was not unexpected. Water levels remained below pool level and the shallow water may have contributed to the high wetland turbidity due to the effects of wind.

The turbidity of Ral Ral Creek again fluctuated throughout, ranging from 126 - 198 NTU, and was not significantly correlated with the turbidity of the wetland (Figure 3.9: $r^2 = 0.1098$; $t_7 = -0.86$, $P = 0.4227$). Water depth remained stable and hence was unlikely to have contributed to the pattern of increasing turbidity over the course of the event, although no corresponding water level data were available to perform a regression analysis.

Chapter 3 ~ Water Quality

SUMMARY

- Water levels in Lake Merreti were strongly related to river flow conditions and during the earlier refilling events generally showed a seasonal pattern of greater depths in winter and spring and lower depths in summer when river flows were lower and evaporation rates higher. No seasonal pattern was evident in the later refilling events, perhaps due to their short duration and relatively stable river flows.
- Water levels in Lake Merreti were significantly lower and less variable during the later refilling events (Events 7 and 9) than the earlier events (Events 1 and 3), which was largely a reflection of river flow conditions during the respective events.
- High river flow events generally produced peaks in lake water levels, except in December 2000, probably because of the short duration of the flood peak and the size of the inlet pipes. This highlights the need to increase the hydrological capacity of the main inlet structure and to allow small floods into Lake Merreti in order to increase the frequency of inundation of the riparian zone.
- The complete drying of Lake Merreti (Events 2, 4 and 6) took approximately three to four months to evaporate dry from around pool level.
- It took approximately three to four months to dry Lake Merreti completely through evaporation in Events 2 and 4. The rate of drying is affected by season and this should be taken into account when planning future drying events.
- The overall mean conductivity of Lake Merreti was 999 EC, which falls within the tolerance range of freshwater organisms but may have adverse effects on some salt sensitive species.
- There was a difference in mean wetland conductivity between refilling events with the highest recorded in Fluctuating water levels Event 1 (1056 EC) and the lowest in Refilling Event 5 (733 EC). There was no gradual and consistent increase in conductivity over the survey period, indicating that the managed drying and refilling of Lake Merreti did not cause an accumulation of salts.
- After being dried there was an initial peak in conductivity upon refilling Lake Merreti, probably due to the re-suspension of salts deposited during drying. During the earlier refilling events (Events 1 and 3) a slight seasonal pattern in conductivity was evident where conductivity would increase over summer and autumn, then decrease in late winter or early spring. This pattern appeared to be related to the seasonal variation in river flows and wetland water levels. No seasonal pattern was evident in the later refilling events (Events 7 and 9), which were of shorter duration and had more stable water depth conditions.
- The conductivity of Lake Merreti was influenced by both water level and inlet conductivity although, generally, water depth had a greater effect. Wetland conductivities appeared to be dominated by evapoconcentration effects, with salt concentration generally increasing when wetland water levels dropped (e.g. Complete drying – Event 2).
- The overall mean turbidity of Lake Merreti from May 1991 to January 2002 was 258 NTU although turbidity varied widely between refilling events. This variation was not, however, due to a consistent increase or decrease over the survey period with the lowest event mean (105 NTU) recorded in Refilling Event 3 and the highest (556 NTU) in Fluctuating water levels Event 1.
- Turbidity levels were generally low on refilling creating clear water conditions that could have supported the germination of submerged aquatic plants. This initial low turbidity was likely to be due to the consolidation of the lake bed during drying and, after approximately six months turbidity, began to increase with duration of inundation.
- The turbidity of the inlet and the wetland water level were not good determinates of the turbidity of Lake Merreti.
- In general turbidity was lower in events when there was extensive growth of aquatic vegetation (e.g. Refilling – Event 7 and Partial drying – Event 8) and higher in events when the wetland had been inundated for extended periods (Fluctuating water levels – Event 1 and Refilling – Event 9). These results indicate that the turbidity of Lake Merreti is affected by the extent of sediment consolidation and aquatic plant cover which, in turn, determines how readily the sediment is disturbed by wind.

Although it is not possible to analyse statistically, there appears to be a correlation with the catch of callop and carp and rises in the hydrograph (Figures 7.1, 7.2, and 7.3). This is especially evident for the large flood that peaked in November 1993 at 110,711 ML/day, where catches for the above species increased with increasing flow to South Australia, similarly decreasing with decreasing flow to South Australia.

Although the catch per effort figures are very low for redfin, it appears that this species has the reverse trend to callop and carp catches, with catch declining as flows rose in 1993 (Figures 7.5 and 7.6).

The last commonly caught large species, bony bream, does not show any correlation – appearing to be largely independent of flow (Figure 7.4 and 7.5). Catches for this species usually remain much lower than those for callop and carp, probably reflecting the smaller adult size of these fish. Catches of bony bream peaked in March 1994, October 1994 and January 1996, with only the March catches coinciding with a slight peak in the hydrograph.

Figure 7.2 Hydrograph for SA 1993-1996.

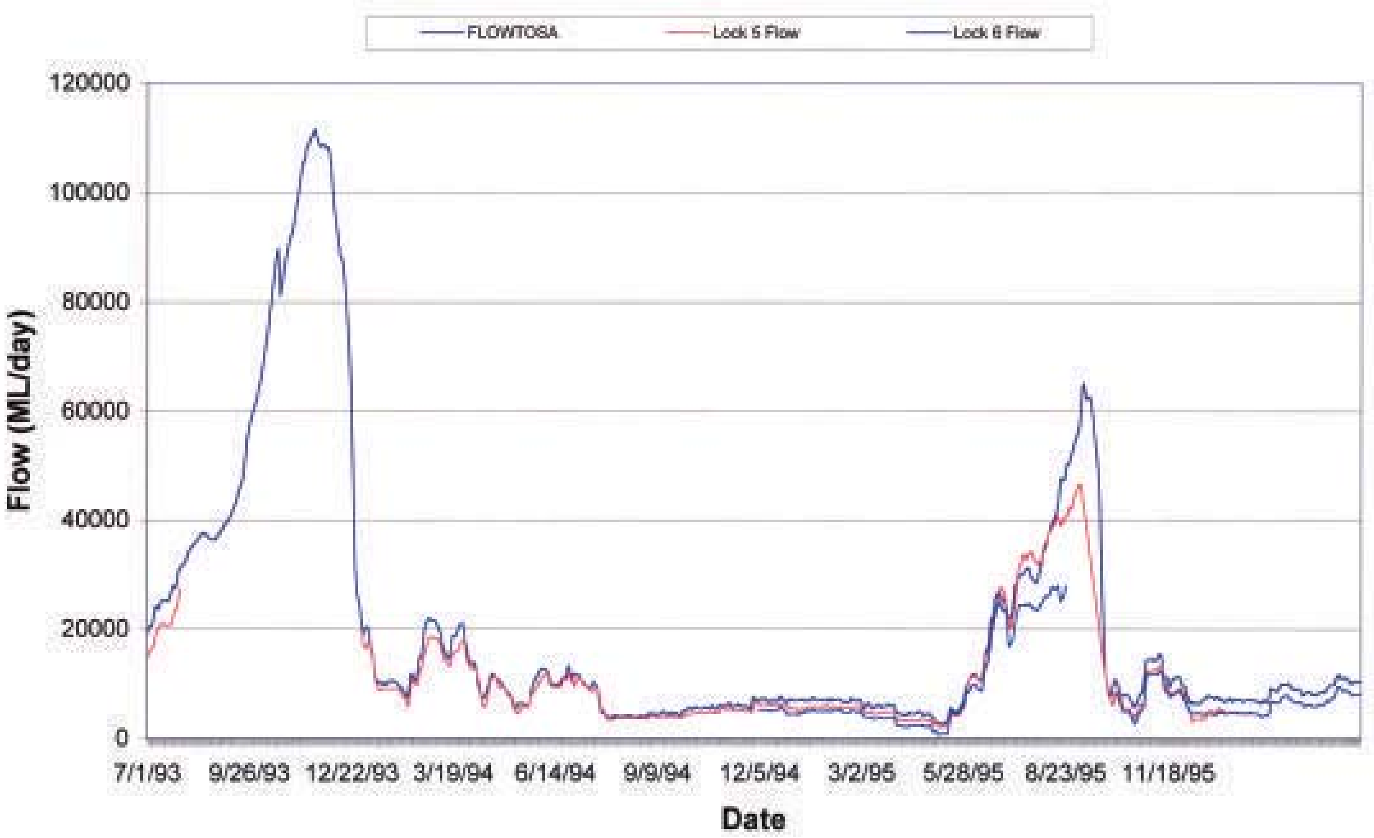


Figure 7.3 Carp (whole weight) catch per effort data for Reach M58 (Ral Ral Creek), shaded columns indicate nets were not set.

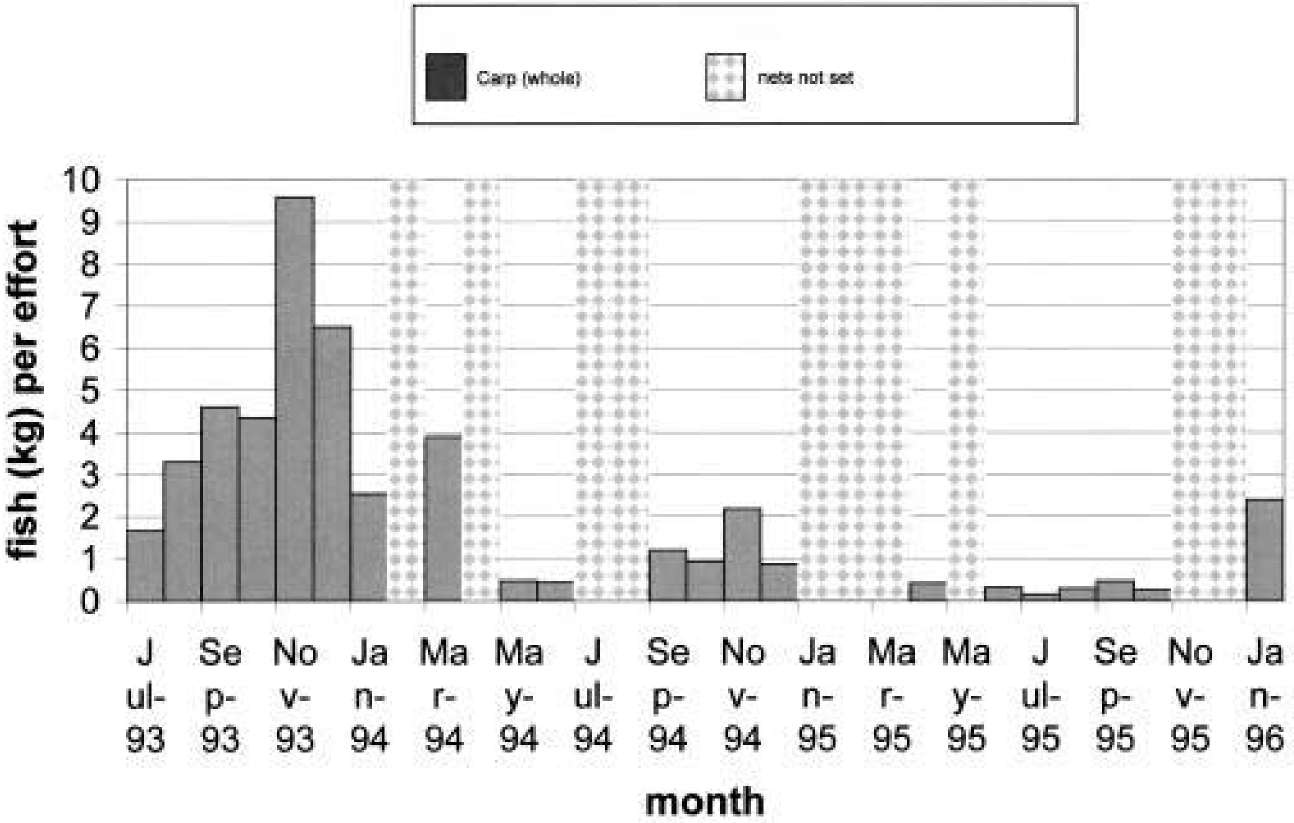


Figure 7.4 Bony bream (whole weight) catch per effort data for Reach M58 (Ral Ral Creek), shaded columns indicate nets were not set.

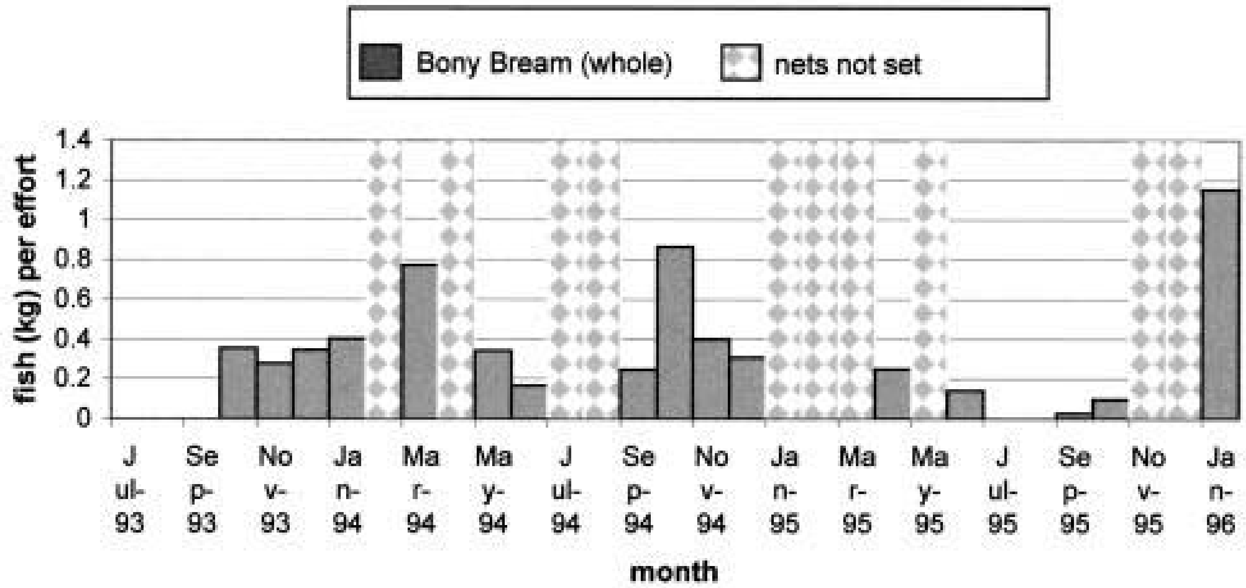


Figure 7.5 Hydrograph for SA 1993-1996.

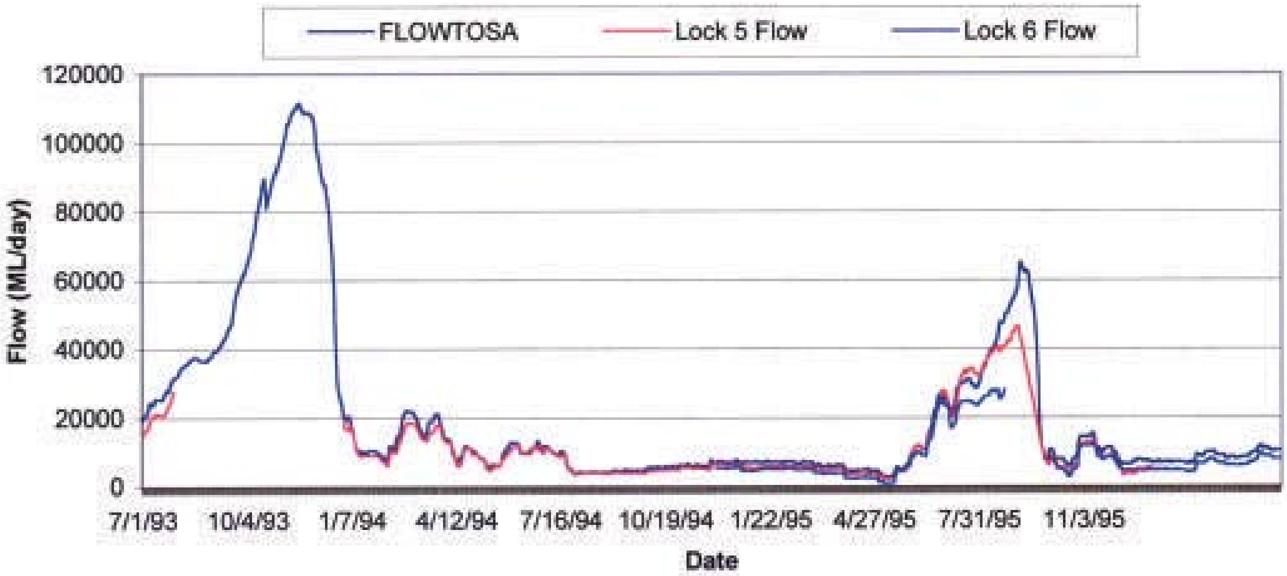
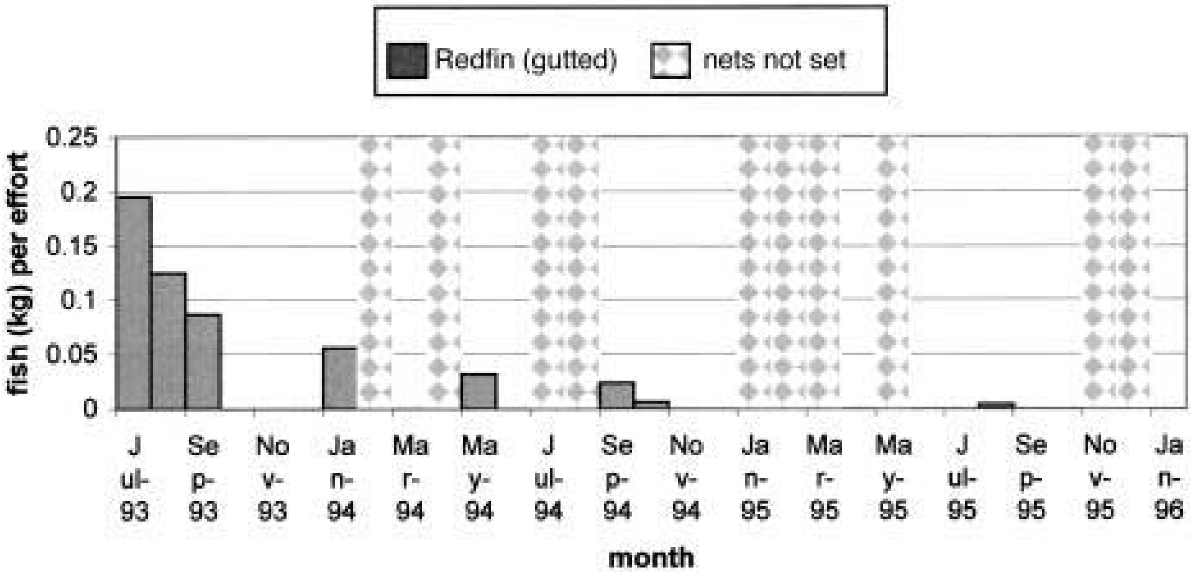


Figure 7.6 Redfin (gutted weight) catch per effort data for Reach M58 (Ral Ral Creek), shaded columns indicate nets were not set.



Lake Merreti

Fluctuating water levels – Event 1 (1983 – September 1994)

Suter et al. (1993) sampled small fish populations in eight wetlands from Mannum to Chowilla, including Lake Merreti, from October 1992 to March 1993 (Suter *et al.* 1993). Six species were recorded from Lake Merreti including the native hardyhead (*Craterocephalus* sp.), carp gudgeon spp., Australian smelt, and bony bream, and introduced gambusia and carp. Juvenile fish were also recorded, but were not able to be identified to species level.

During their study, Australian smelt, carp gudgeon spp., and hardyheads were found to be the most widely distributed and abundant natives, whereas bony bream and flathead gudgeon were only occasionally recorded (Suter *et al.* 1993). Suter et al. (1993) noted the complete absence of rainbowfish from their samples with concern (Suter *et al.* 1993).

It was noted that all species increased in abundance during spring floods, with gambusia and carp being most widely distributed and particularly common during flood events, and displaying prolific breeding at every wetland except Lake Woolpolool during these times. Carp numbers were highest in November each year, although dropped to low numbers at other times. Australian smelt, carp gudgeon spp., hardyhead, and bony bream were regularly observed breeding.

During the same study, it was found that macroinvertebrate numbers also increased at the peak of spring floods (Suter *et al.* 1993), probably in response to inundated vegetation providing a source of food, shelter and nutrients. It is possible that the macroinvertebrates themselves may have aided the increase in fish numbers through the availability of additional food resources.

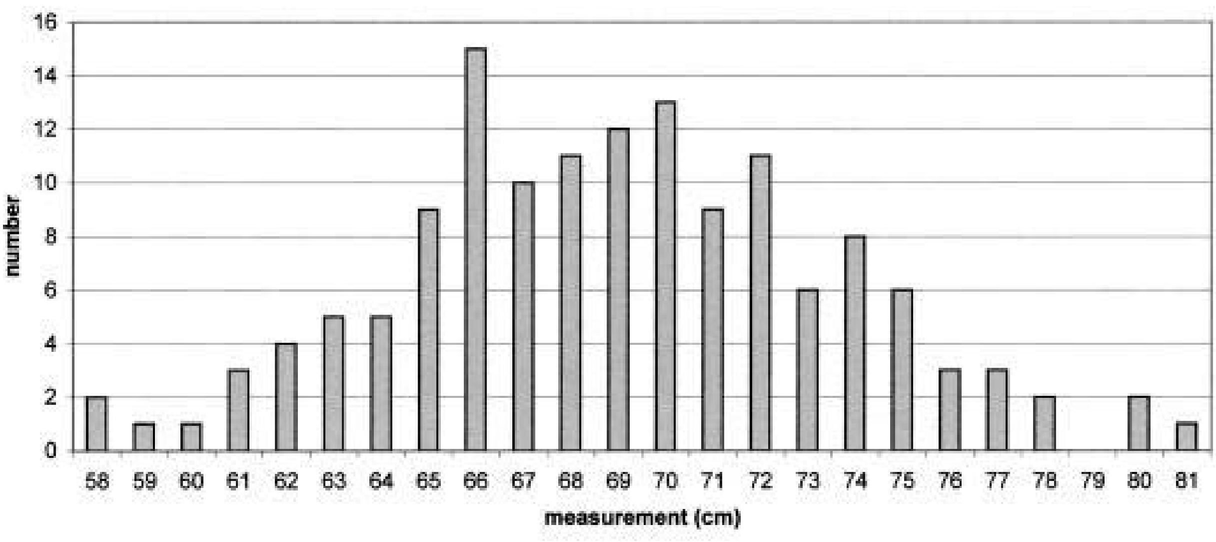
Complete drying - Event 2 (September 1994 – June 1995)

During the first complete drying event, Lambie et al. (1994) sampled the fish fauna remaining in the deeper sections of the lake (approximately 20cm depth) (Lambie *et al.* 1994). Of the nine sites sampled, fish were collected from seven, with all fish captured being carp.

Figure 7.7 indicates carp abundance in each size category, with a total of 142 fish being captured during one day's sampling. Abundance was normally distributed around 70cm length, with the smallest fish measured being 58cm and the largest 81cm, indicating that the fish population sampled totally comprised of large, sexually mature fish.

The average weight of carp caught was found to be 3.5kg, with 62% of fish checked (135 fish) being gravid (containing eggs). This is also an interesting observation, as carp are thought to have one major breeding event during spring with smaller events extending over summer (Hume *et al.*1983). As this sample of the population was predominantly gravid, it indicates that either the fish have retained their eggs in readiness for a later breeding event, or that conditions within the wetland were not conducive to breeding (likely due to the additional stress placed on fish as the water levels were being drawn down).

Figure 7.7 Carp size class data from sample during Complete drying - Event Two (21-12-94)



It is likely that other fish were also present at the time of the survey, however, these are likely to have been smaller species. It is also likely that as a result of the shallow water, many fish eating birds would have accumulated on the lake and removed many of the smaller size classes from the population.

The sampling method employed during this survey may have also biased the catch. In this survey, a 2m x 2m x 40cm high PVC frame covered with 12mm stretched mesh was thrown into the deeper sections of the lake and allowed to sink to the bottom before sampling began. Although the PVC frame had holes drilled into it to facilitate sinking, it would have taken a little time before the frame hit the bottom. This time lag may have allowed smaller size classes to escape from the frame and not be recorded. As there were no follow-up samples, these theories cannot be confirmed or denied.

In order to control carp intrusion into the lake, during the first complete drying event, fish screens were installed on the permanent inlet to Lake Merreti, with 'fish fences' also constructed on the temporary flow paths to prevent movement of large fish into the wetland at pool and during high river flows. On the upstream side of the main inlet structure a cage (514 x 153cm) surrounds both inlet pipes. Two solid walls are present either side of the cage, with the top covered in aluminium 'security' type mesh (100mm x 35mm holes). The front of the cage comprises 6 rotating aluminium mesh screen gates. Each of these gates is 145cm high and 78cm wide, and can be set open or closed and turned for cleaning of debris from the mesh.

Refilling - Event 3 (June 1995 – July 1997)

During Refilling Event 3, Stapleton (1996) sampled the fish fauna in both Ral Ral Creek and Lake Merreti (Stapleton 1996). Her study sampled the two environments using gill nets for larger fish and shrimp traps for smaller fish. Sampling was undertaken in autumn, winter and spring, although spring sampling in Ral Ral Creek was not possible due to high flows interfering with nets (Stapleton 1996).

Although this study did sample in different seasons, different gill net mesh sizes were used in different locations, therefore disallowing any habitat - species - time correlations to be made. A comparison of fish fauna between creek and wetland habitats was only possible for autumn and winter samples (strong currents in Ral Ral Creek stopped nets from being set in there in spring).

The fish species occurring in the greatest abundance in both Ral Ral Creek and Lake Merreti during this survey were bony bream, gambusia and carp (Figure 7.8, 7.9), with all other species occurring at less than 15 individuals (Stapleton 1996). Only slight variations occurred in the fish fauna between the two sites—callop were not captured in the lake; Lake's carp gudgeon and flathead gudgeon were not captured in Ral Ral Creek. Neither Murray cod nor hardyheads were captured during the survey, despite being captured by a professional fisher in spring in Ral Ral Creek (Murray cod) (Cooper 1996), and during previous studies in Lake Merreti (hardyhead (Suter *et al.* 1993)).

Figure 7.8 Stapleton (1996) catch figures Ral Ral Creek.

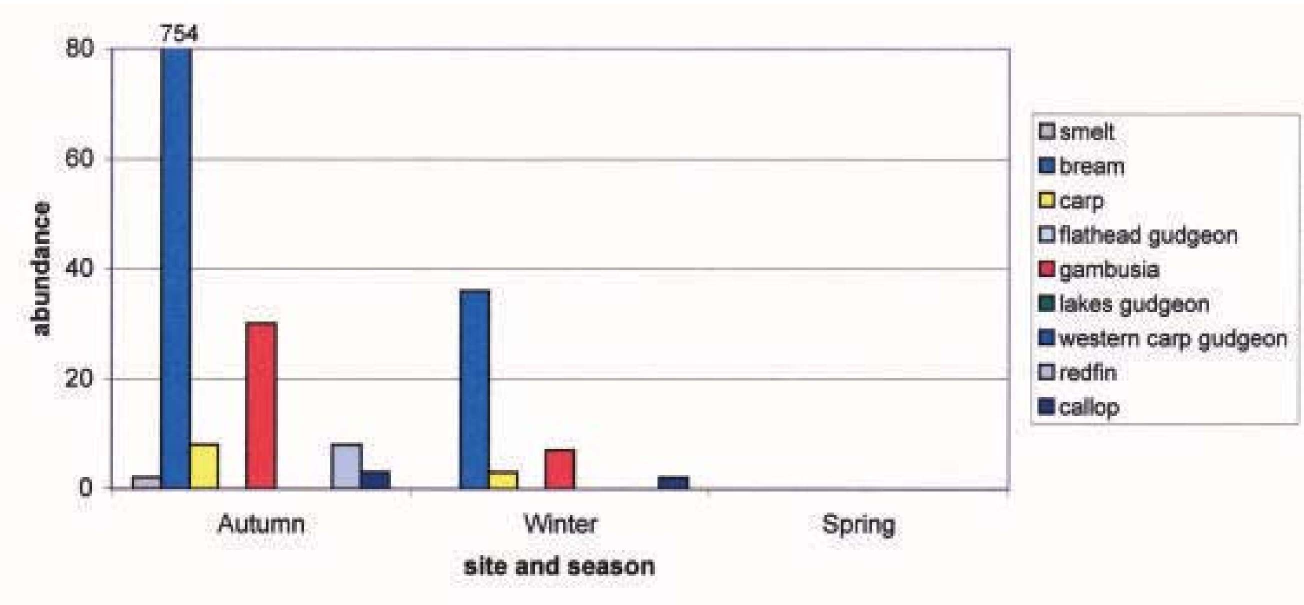
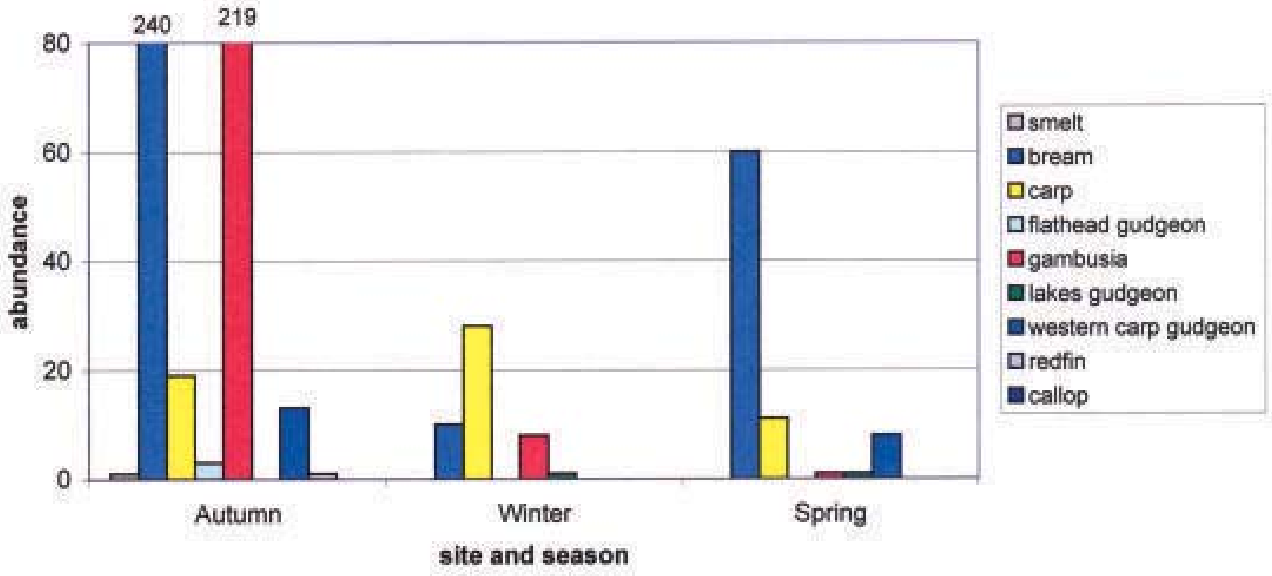
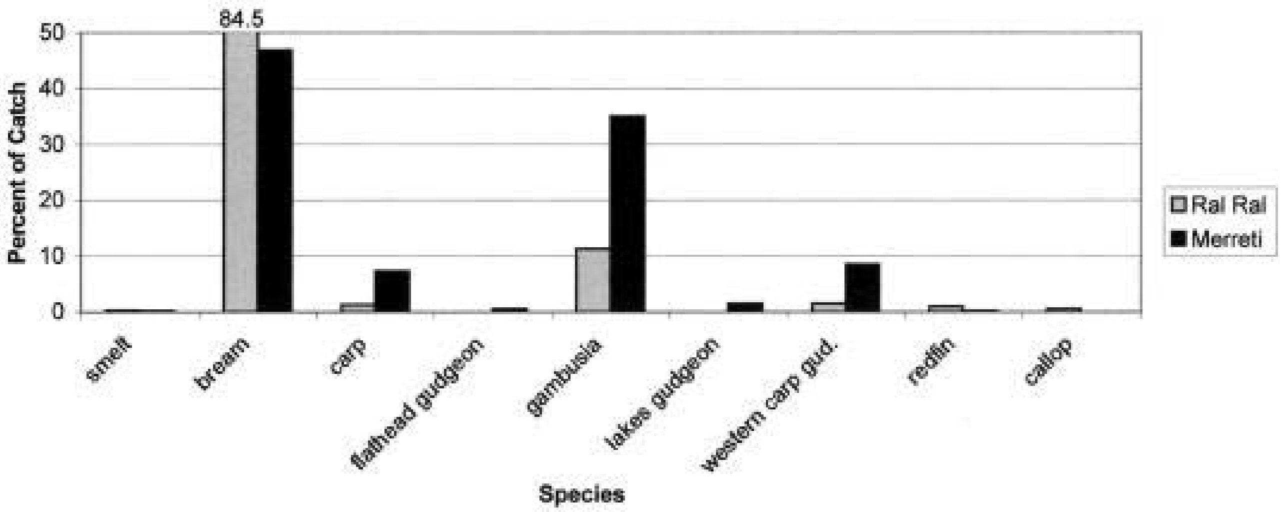


Figure 7.9 Stapleton (1996) catch figures Lake Merreti.



Catch effort also differed slightly throughout the survey (three samples in autumn, two in winter for Ral Ral Creek; two samples in autumn, one in winter, one in spring for Lake Merreti) (Stapleton 1996). Given these differences, when comparisons of percentage catch are made between the sites (Figure 7.10), it can be noted that bony bream comprise most of the catch for both Lake Merreti and Ral Ral Creek samples (more abundant in Ral Ral Creek samples), with gambusia being the next most abundant fish (for both sites also, although being far more abundant in Lake Merreti). Western carp gudgeons (*Hypseleotris klunzingeri*), carp, Lake's carp gudgeons (*Hypseleotris* sp. 5) and flathead gudgeons were also more abundant in Lake Merreti than in Ral Ral Creek, whereas redfin, callop and Australian smelt were more abundant in Ral Ral Creek than the lake environment.

Figure 7.10 Percent catch (regardless of season) for Lake Merreti and Ral Ral Creek (Stapleton 1996)



Size class data collected indicate that the maximum and minimum lengths of fish captured were limited by the size of the gear used—minimum sizes of bony bream and carp were 8cm total length, callop and redfin were 27 and 29cm respectively in Ral Ral Creek, 26cm (redfin) in Lake Merreti. Upper size limits captured were between 35cm (callop) and 43cm (bony bream and redfin) in Ral Ral Creek, 42cm (bony bream in Lake Merreti). The largest carp captured were 41cm in Ral Ral Creek and 92cm in Lake Merreti (Stapleton 1996).

The low abundances of small native fish indicate that the methods used in this survey could have been improved through means such as increasing the number of traps used, using different attractants within the traps, or the use of different traps (e.g. fyke nets).

In addition, it is recommended that gill nets are not used in future studies due to their destructive and non-specific nature of sampling. Again, fyke nets are noted as a better gear type as they catch large and small species and fish have a much better survival rate.

Refilling - Event 5 (August 1998 – December 1999)

The second longest survey of the small fish fauna of Lake Merreti was conducted by Tucker (2003) from 1998 to 2000, mostly during Refilling Event 5, although one sample was taken during Refilling Event 7 (September 2000 – March 2001) (Tucker 2003).

For this study, shrimp traps and a 10m seine net were used to capture fish within the wetland. A total of 434 fish were captured over the sample period, with the catch being dominated by gambusia (350), carp (35), and Australian smelt (32). Low catches overall indicate either a depauperate fish fauna at this time or ineffective sampling gear. Despite the greater effort (use of seine net and four shrimp traps at each of five sites) and longer time frame of this project, only slightly more fish were captured compared to the three surveys by Stapleton (1996) who used only a single shrimp trap at each site to capture small fish (a total of 302 small fish were captured) (Stapleton 1996).

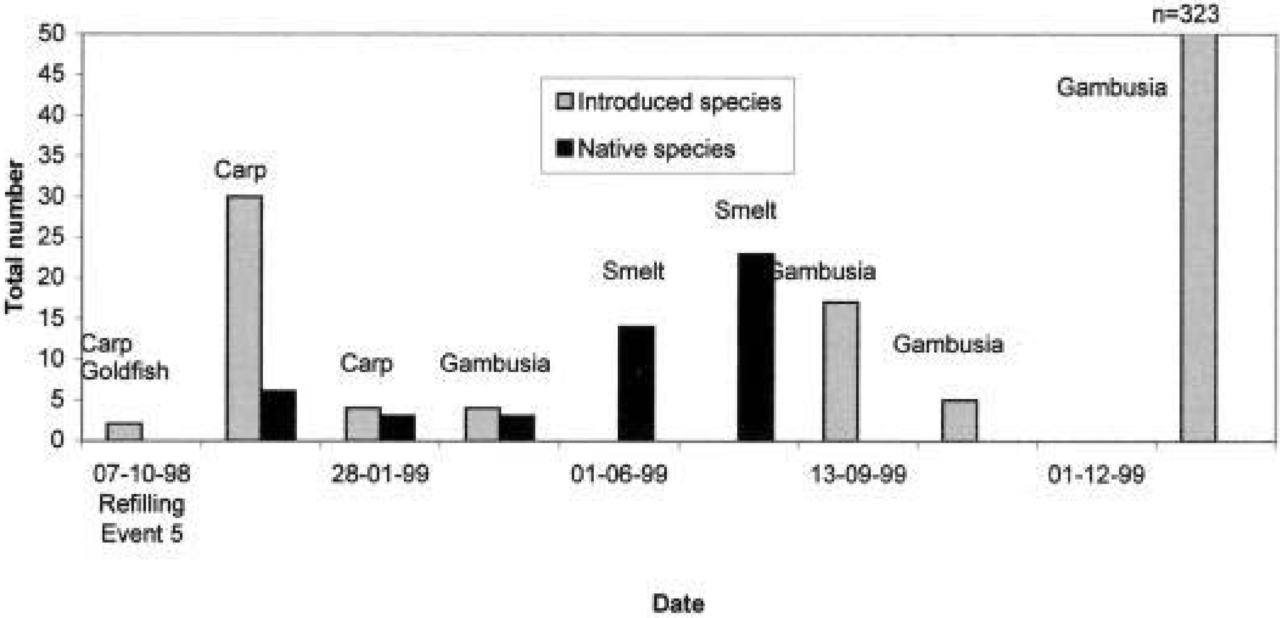
A summary of the fish captures during this survey is presented in Table 7.3. The seine net proved to be most efficient at capturing a greater number of fish species in larger numbers, although the shrimp traps captured two species – rainbowfish and dwarf flathead gudgeon that were not captured by the seine net.

Table 7.3 Fish species and abundance captured using seine net and shrimp trap as part of Tucker (2003) study.

Species	Seine Net (10m)	Shrimp Trap	TOTAL
Australian smelt	32	0	32
Bony bream	3	0	3
Carp gudgeon spp.	7	0	7
Flathead gudgeon	1	0	1
Flathead gudgeon (dwarf)	0	1	1
Fly-specked hardyhead	2	0	2
Rainbowfish (crimson spotted)	0	2	2
Common carp	30	5	35
Gambusia	283	67	350
Goldfish	1	0	1
TOTAL SPECIES	**8**	**4**	**12**
TOTAL ABUNDANCE	**359**	**75**	**434**

Sampling for this study began two months after Refilling Event 5 began in August 1998. During this first sample only two fish were captured—one carp and one goldfish. Introduced fish dominated the catch for the next three samples in December 1998, January 1999 and March 1999 (Figure 7.11). A large number of carp were captured in December 1998 (30 fish), with the majority being less than 10cm long (26 fish). Carp numbers dropped in the following sample (three fish only), and were not captured again until the final survey in Refilling Event 7 (one fish). The large numbers of small carp in the December 1998 sample probably reflects progeny from an annual breeding event that is focused between September and December (Hume *et al.* 1983), and the coincidence of this with a high river flow that also occurred at that time. It is unknown why this species was not captured during the latter part of Complete drying Event 6.

Figure 7.11 Introduced and native species abundance in Lake Merreti October 1998 to January 2000 (species indicated dominate the sample).



Near the beginning of Refilling Event 5, Tucker (2003) collected a large variety of native fish from the wetland (Tucker 2003). Rainbowfish, bony bream, fly-specked hardyhead, flathead gudgeon, dwarf flathead gudgeon, and carp gudgeon spp. were collected from the December to July samples, although always at a lesser abundance than the introduced species (carp in December and January, gambusia in March 1999). This trend changed for the June and July samples (11 and 12 months after refilling began), when Australian smelt and carp gudgeon spp. were the only species captured (Australian smelt dominating the catch), and again changed for the final two samples of Refilling Event 5 (September and November 1999), when the catch was comprised solely of gambusia. Australian smelt is a schooling fish (McDowall 1996a) that probably benefits from deeper, open water environments, therefore, it is possible that its comparatively high abundance in June and July is a reflection of the deeper water habitat available to it at that time. In November 1999, aquatic vegetation species including ribbon weed (*Vallisneria americana*), red water-milfoil (*Myriophyllum verrucosum*) and waterwort (*Elatine gratioloides*) were recorded in Lake Merreti. It is possible that these plants provided shelter from predators and supported high macroinvertebrate abundance, thereby providing favourable conditions for gambusia to thrive (however, these conditions would also suit the small native species).

At around the time of the September 1999 survey, an accumulation of fish was noted in the permanent inlet to Lake Merreti, possibly indicating poor water quality (dissolved oxygen in particular) in the lake at this time. The fish accumulating in the permanent inlet to Lake Merreti were most likely attracted to the water moving into the wetland (and its higher dissolved oxygen levels). An opportunity, therefore, presented itself to sample this subset of the population (LeBloas and Ebert 1999). Fish captured ranged in size from 23cm to 34cm, and the entire sample of 128 fish consisted of carp (LeBloas and Ebert 1999). The presence of this size class of fish in large numbers, and the fact that they were not collected in the normal sample period four days later also indicates that the survey methods for this project were inadequate to sample the fish fauna present.

This notion is supported by the finding that no fish at all were caught in the lake during the normal sampling period at the very end of Refilling Event 5 in December 1999. At this time, water in the wetland would have been reasonably high due to the inlet structure being open for the preceding year and aquatic vegetation had been recorded, therefore, potentially supporting a healthy fish population (although this is not reflected in the fish sample).

The possibility of employing a freshwater inflow or 'attractant flow' may be worth considering in the future where it is desirable to attract fish to the inlet structure for removal (e.g. prior to a drying event).

Chapter 7 ~ Fish

Complete drying - Event 6 (December 1999 - September 2000)

The only sample taken in Complete drying Event 6 (one month following the end of Refilling Event 5) saw the catch again nearly solely comprising gambusia at numbers far greater than collected previously (322 gambusia and one carp, compared to a previous maximum of 17 gambusia in September 1999 – Figure 7.11). Extensive growth of aquatic vegetation in the lake by the end of Refilling Event 5 may have provided a source of food and shelter for gambusia (and other species) when inundated. Due to the prolific breeding capacity of gambusia (they are live-bearers) and their aggressive nature (McDowall 1996b), (Myers 1965), this species may have been able to out-compete other native species at this time, thereby dominating the catch.

Refilling - Event 7 (September 2000 – March 2001)

In contrast to the very low fish abundance captured by previous studies, Nichols (2003) observed fish abundances in the hundreds when sampling throughout Refilling Event 7, Partial drying Event 8, and Refilling Event 9 (Nichols in prep.). This study differed from other studies in the gear used, with fyke nets employed to catch fish fauna of all size classes. This method of capture was able to sample a greater area than other methods (e.g. shrimp traps) through the use of a 5m long 'leader' to obstruct fish's movements and guide them into the net.

Nichols (2003) sampled Ral Ral Creek, Lake Merreti, and the inlet channel either side of the structure over a 2 ? year period (Nichols in prep.). The fish fauna collected in his study was the same in the wetland, creek, and the wetland inlet either side of the structure with three exceptions. Neither redfin nor callop were captured in Lake Merreti itself, although they were captured in the inlet channel on the wetland side of the structure, on the creek side of the structure and in Ral Ral Creek. This differs from Stapleton (1996) who caught redfin in the wetland near the inlet channel mouth (Stapleton 1996). Conversely, Nichols (2003) did not capture gambusia in the inlet channel (either side of the structure) or Ral Ral Creek, but only from Lake Merreti wetland itself (Nichols in prep.).

Results discussed here are for catches on the wetland side of the main inlet structure, with nets from the inlet and wetland proper combined. No further discussion of the fish fauna captured in Ral Ral Creek will be made.

Figure 7.12 shows the proportion each species contributed to the catch on any given date. Figures 7.13 and 7.14 indicate the catch per effort of fish in Lake Merreti for more common species (Figure 7.13) and less common species (Figure 7.14) throughout the survey period.

Figure 7.12 Proportion each species contributed to catch in Lake Merreti, 2000-2002.

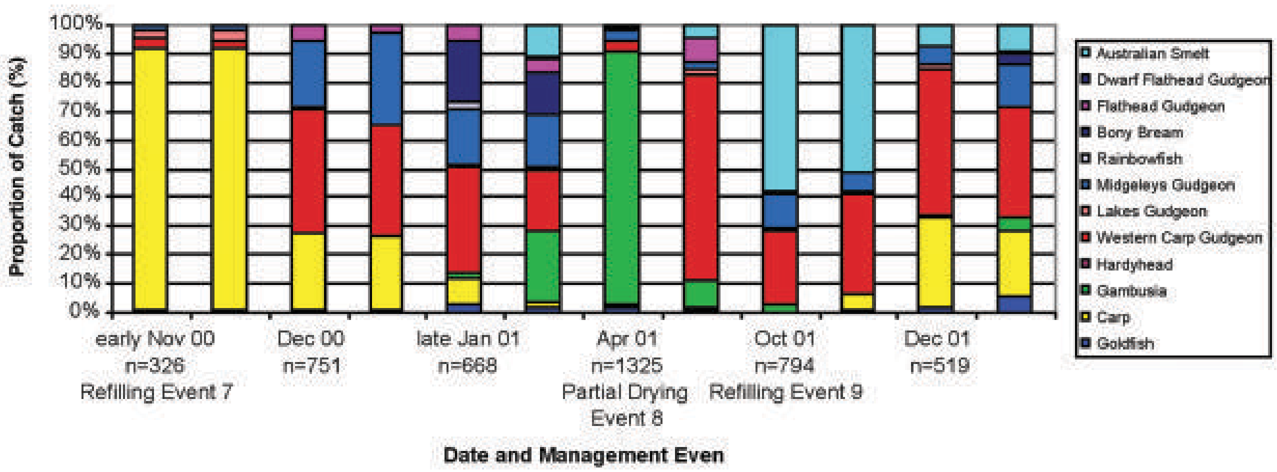


Figure 7.13 Common fish fauna captured in Lake Merreti, 2000-2002.

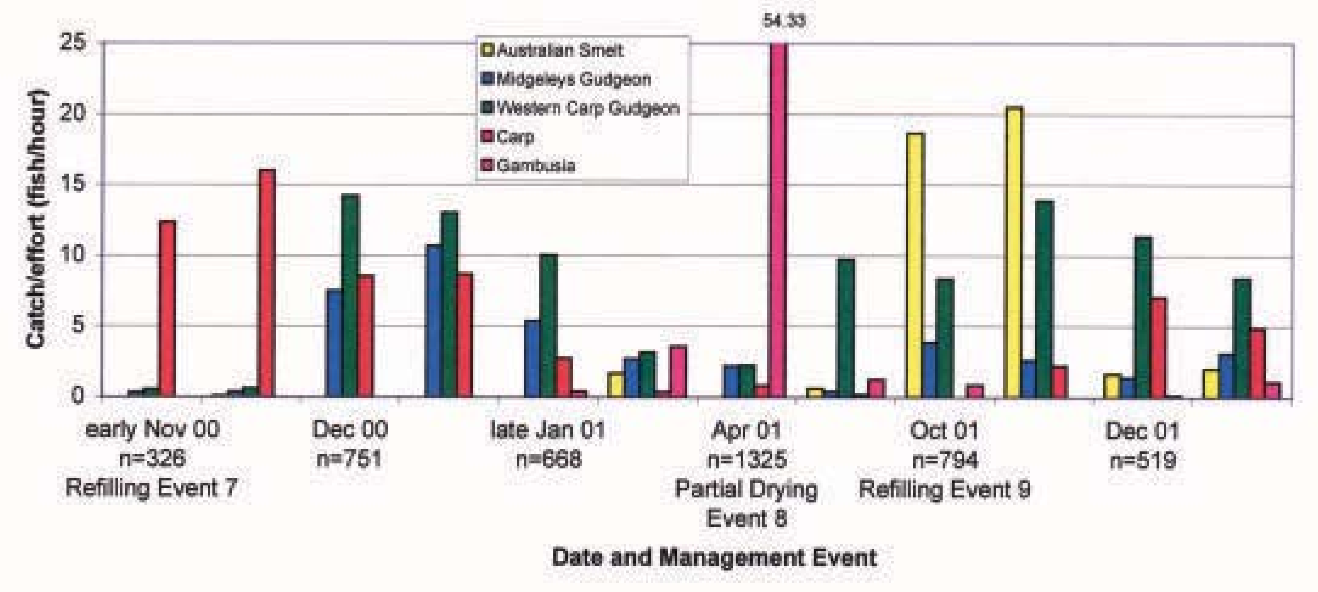
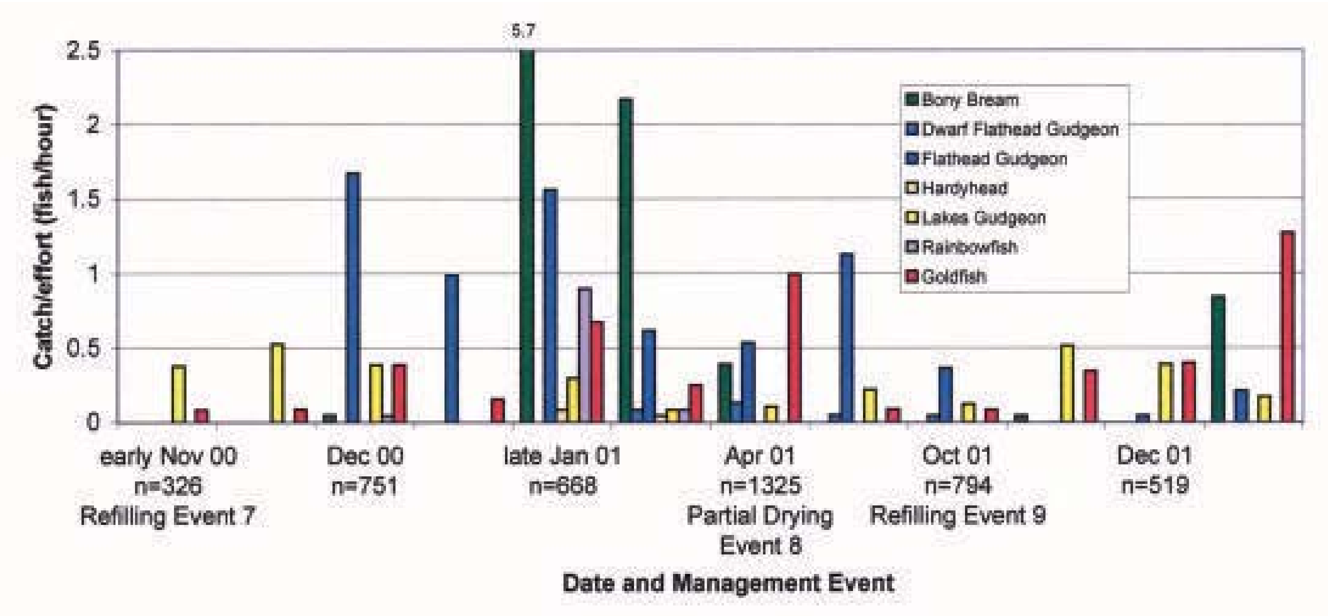


Figure 7.14 Less common fish fauna captured in Lake Merreti, 2000-2002.



As shown in Figure 7.12, carp dominated the catch during the first two samples (approximately 90% of the catch), two months after the lake began refilling in September 2000. Minor contributions from the suite of gudgeon species (western carp gudgeon, Lake's carp gudgeon and Midgely's carp gudgeon (*Hypseleotris* sp.4)) and goldfish comprised the remainder of the catch during these samples.

The dominance of carp declined dramatically during the proceeding samples, contributing less than 30% of the catch in December 2000 to less than 3% by the final sample in Refilling Event 7 (March 2001 – seven months after refilling began). Western carp gudgeon, Midgely's carp gudgeon, and flathead gudgeon made up the remainder of the catch four and five months after being refilled, with minor contributions at this time from Lake's carp gudgeons and goldfish.

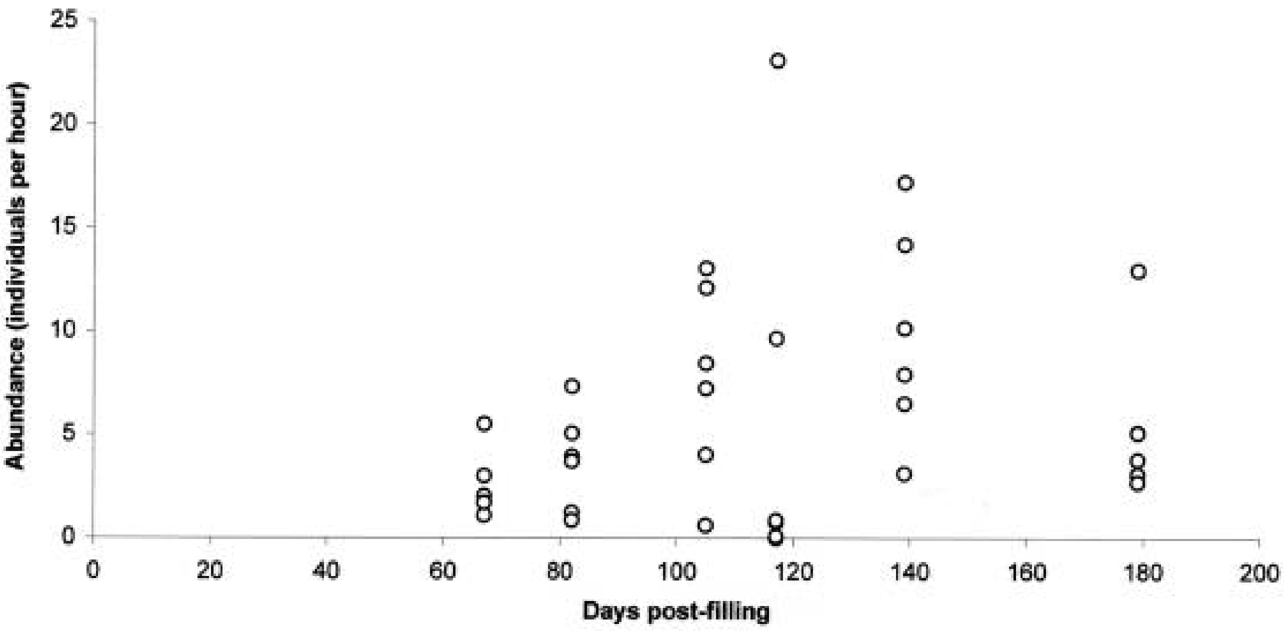
Towards the later part of Refilling Event 7, bony bream, rainbowfish and gambusia contributed approximately 26% of the catch (late January 2001), where they had not been present before and, with another newcomer (Australian smelt), contributed approximately 50% by the end of Refilling Event 7 (25% of the catch being gambusia).

Figures 7.13 and 7.14 reflect these changes during Refilling Event 7 with carp being captured at a rate of 12 (early November) and 15 (late November) fish per hour, decreasing to approximately 8.5 fish per hour in December and January, and further decreasing to 2.7 and 0.3 fish per hour at the end of Refilling Event 7. It is difficult to explain why these changes in the number of carp occurred.

Midgely's and western carp gudgeons comprised most of the catch in December and January, with capture rates of 7 and 14, 10 and 13, and 5 and 10 fish per hour respectively over three sample periods. Flathead gudgeon was the next most common species captured (at a rate of 1.6 and 0.9 fish per hour) for December and early January, although bony bream was captured at a greater rate in late January (5.7 fish per hour). The final sample in Refilling Event 7 (March 2001) showed low capture rates for all fish, with most species captured at a rate of between one and four fish per hour, with the dominant fish, gambusia, being captured at a rate of only 3.5 fish per hour.

Total abundances increased with time after refilling, particularly in the first half of Refilling Event 7, but began to drop towards the end of this event. Not surprisingly, therefore, when abundance data (number of fish captured per hour) were regressed against days post filling, the result was not significant i.e. abundances did not significantly increase with increasing time after the beginning of Refilling Event 7 (Figure 7.15, p=0.16).

Figure 7.15 Regression of fish abundance with days after refilling began (Refilling - Event 7).



In contrast, when species richness (number of fish species per net) and Shannon's diversity index (number of fish species with all nets pooled) were regressed against increasing time since the beginning of Refilling Event 7, both were found to be significant (Figure 7.16 - species diversity: a = 1.97, b = 0.04, $p < 0.0001$, $r^2=0.37$; Figure 7.17 - Shannon's diversity index: a = -0.10, b = 0.009, p = 0.012, $r^2 = 0.82$). This indicates that, within Refilling Event 7, both species richness and Shannon's diversity index increased with time since refilling.

These results can be visually confirmed in Figures 7.12 – 7.14, where a greater number of species can be seen to contribute to the overall catch toward the end of Refilling Event 7 compared to the beginning (Figures 7.12, 7.13), mainly due to the dominance of carp in the first two samples, and the more even rate of capture for the less common species in the last two samples (Figures 7.13, 7.14).

These results possibly indicate that carp are an early coloniser species, tolerant of a wide range of environmental conditions and were able to rapidly move into Lake Merreti to dominate the fish fauna.

Figure 7.16 Regression of species diversity with days after refilling began (Refilling - Event 7).

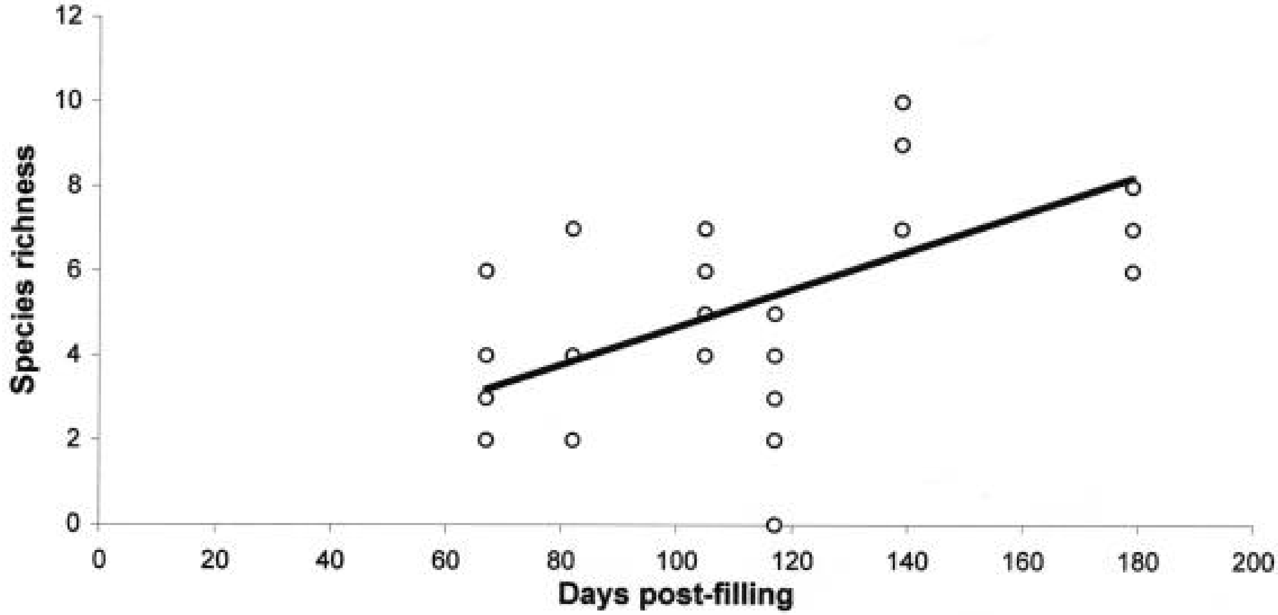
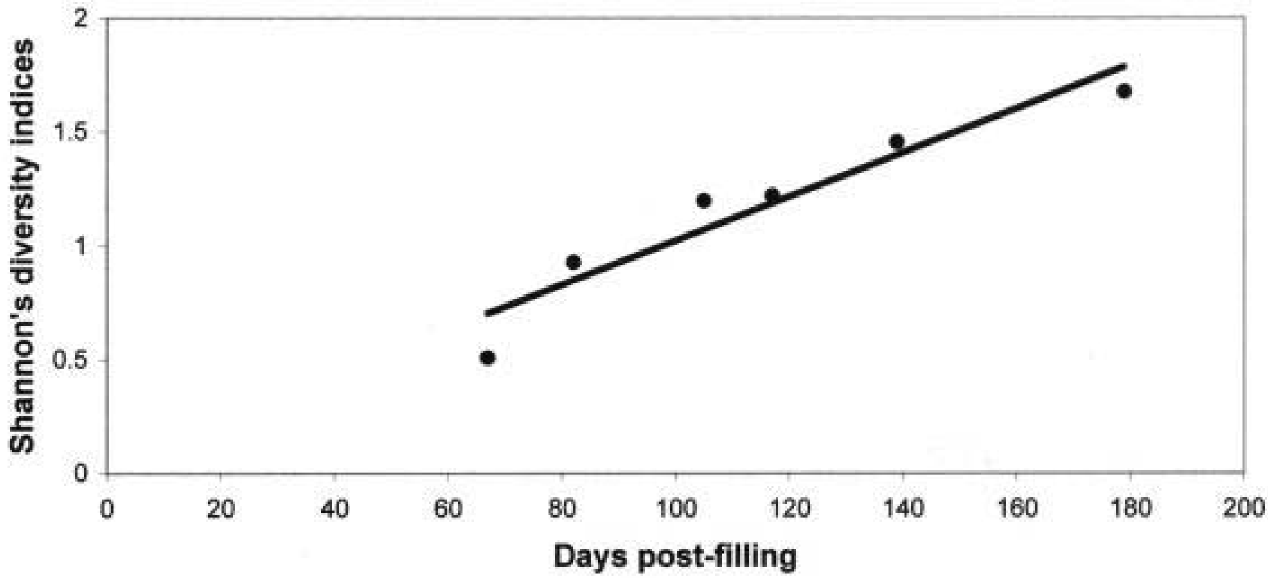


Figure 7.17 Regression of Shannon's diversity index with days after refilling began (Refilling - Event 7).

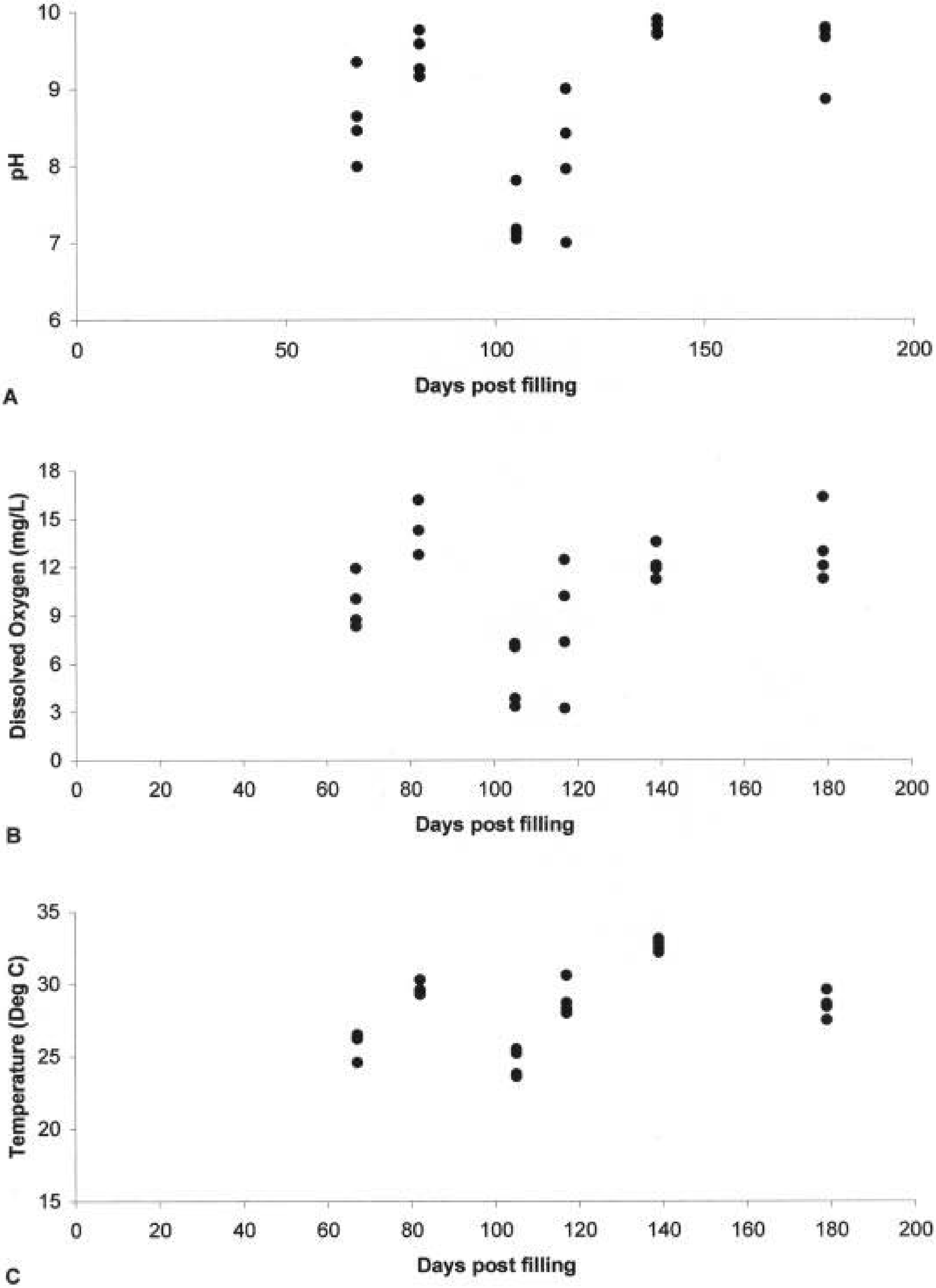


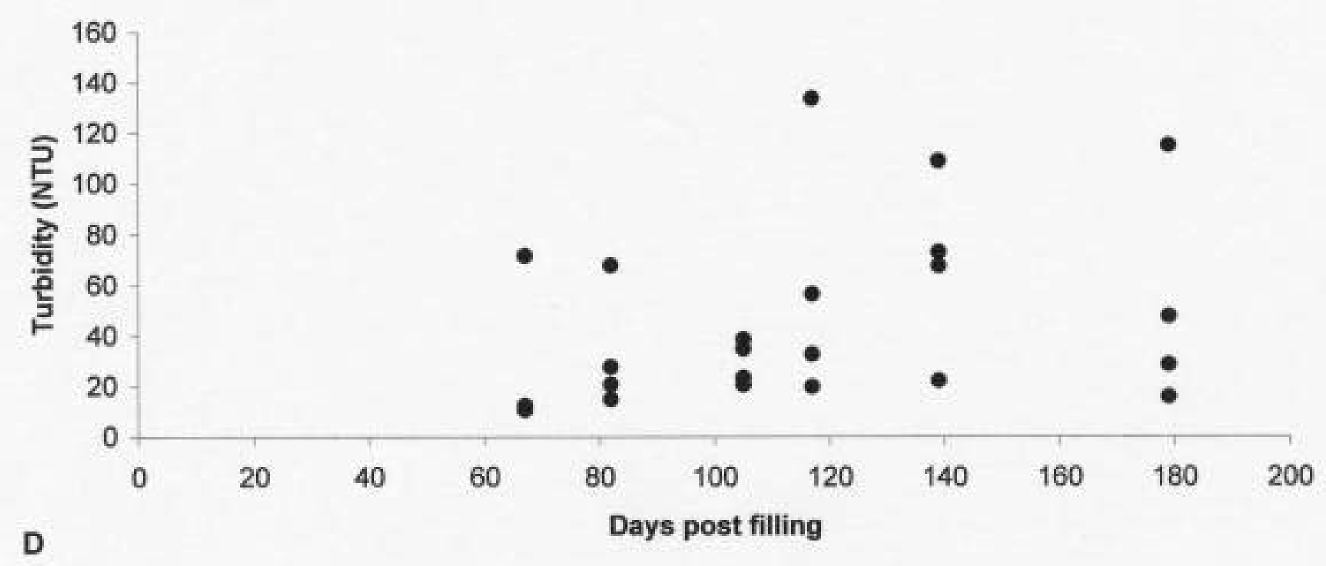
As conditions become more suitable, other native species are able to colonise the wetland and have a greater contribution to the fish population through competition, thereby removing the dominance of carp from the fish samples.

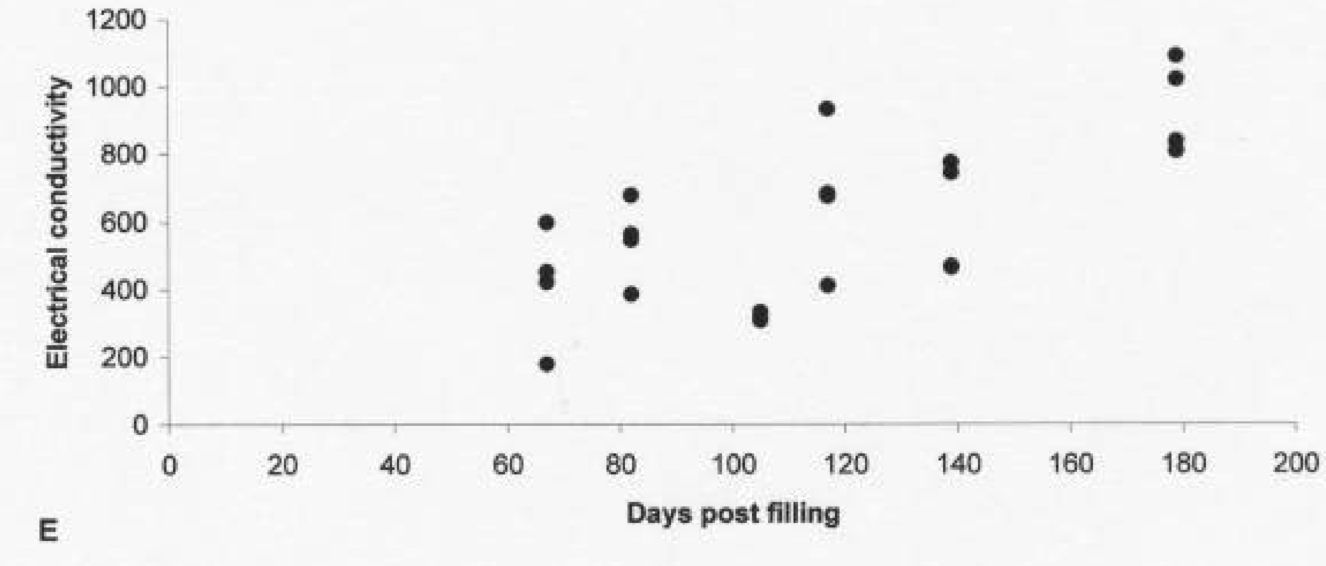
The theory that carp colonised the wetland first due to poor water quality at the time of refilling is unlikely, however, due to all the water quality variables measured (pH, dissolved oxygen, temperature, turbidity and salinity) being within 'normal' wetland limits i.e. tolerable to all fish species (Figure 7.18).

It should be noted, however, that despite the water quality variables being within 'normal' limits for most of the study, toward the end of Refilling Event 7 (March 2001) on separate occasions goldfish, some carp, and bony bream were observed gulping air in the inlet channel to Lake Merreti, indicating that dissolved oxygen conditions at this time were causing difficulties for these species.

Figure 7.18 Water quality readings (A-E: pH, dissolved oxygen, temperature, turbidity and salinity) and days post filling for Refilling - Event 7.







It is more likely, therefore, that the native species take a longer time to colonise the wetland. The dominance of carp in the early samples is most likely a result of these samples occurring a short time after the annual spring breeding event for this species (large numbers of small individuals) (Hume *et al.* 1983), with young individuals growing up as Refilling Event 7 progressed. This is confirmed by size class data indicating that during the first samples, the carp caught in Lake Merreti had an average size of 4.2cm (n = 114), gradually increasing to 8.3cm (n = 76) by early January, and reaching a maximum of 2.3cm (n = 9) in the final sample in March 2001 (six months after refilling began).

The size class data also reflects the use of the fish screens on the main inlet to Lake Merreti, limiting the size of fish entering the lake to those that can fit through the 'security' mesh grill. However, it is interesting to note that, although the average sizes are discussed above, during the November sample, one fish captured was 27.5cm, several fish were between 10-15cm in the December sample, nine fish were between 20 and 36cm in early January, and the maximum size of a fish captured (March 2001) was 43cm. This indicates that several fish larger than could fit through the fish screen were present in the wetland, possibly as a result of accidental transfer of fish during setting and removal of nets.

Partial drying - Event 8 (March 2001 – September 2001)

Only two samples of the fish fauna were undertaken in Partial drying Event 8—the first 11 days after the inlet was closed, the second at 116 days.

Following the increase in the number of individuals of gambusia during the final two samples of Refilling Event 7 (late January and early March 2001), gambusia dominated the catch during the first sample in April 2001 (92% of the catch: Figure 7.12). However, by 116 days into the partial drying, this proportion fell dramatically to 9% of the total catch, with a suite of gudgeon species (western carp gudgeon, flathead gudgeon, Midgely's carp gudgeon and Lake's carp gudgeon) and Australian smelt making up the majority of the catch (92%).

Again, the catch proportions are confirmed in the catch rates for each species (Figures 7.13, 7.14), where gambusia were captured at a rate of 54.33 fish per hour in April, dropping to a rate of 1.2 fish per hour in July. Other more common fish species were captured at a rate of 0.8 (carp) to 2.26 (western carp gudgeon) fish per hour, with less common species ranging from 0.1 (Lake's carp gudgeon) to 0.9 fish per hour (goldfish).

As either a result of season, or of the management event, total abundances also dropped dramatically between the two samples (1325 fish in April (autumn) - 11 days after the inlet was closed, to 314 fish in July (winter) - 116 days after closure).

When analysed using ANOVA, the decline in abundance (catch per unit effort) and species richness were found to be significant (abundance: $F_{1,22} = 11.52$, $p = 0.003$; species richness: $F_{1,22} = 13.06$, $p = 0.002$), indicating that both the number of fish caught per hour, and the number of fish species per net declined with increasing time since the inlet was closed (Figure 7.19). Similarly, when data from all nets were pooled, Shannon's diversity index also declined with time since inlet closure.

Declines in species richness, abundance and Shannon's diversity index are to be expected as water is removed from Lake Merreti during a drying event. As water levels become lower, bird predation would have a greater impact on fish abundance and possibly be biased toward easier prey, such as those species that feed on the water surface (e.g. gambusia). Similarly, certain species would become less tolerant of the changed water conditions (e.g. increased salinity) as the drying event continued.

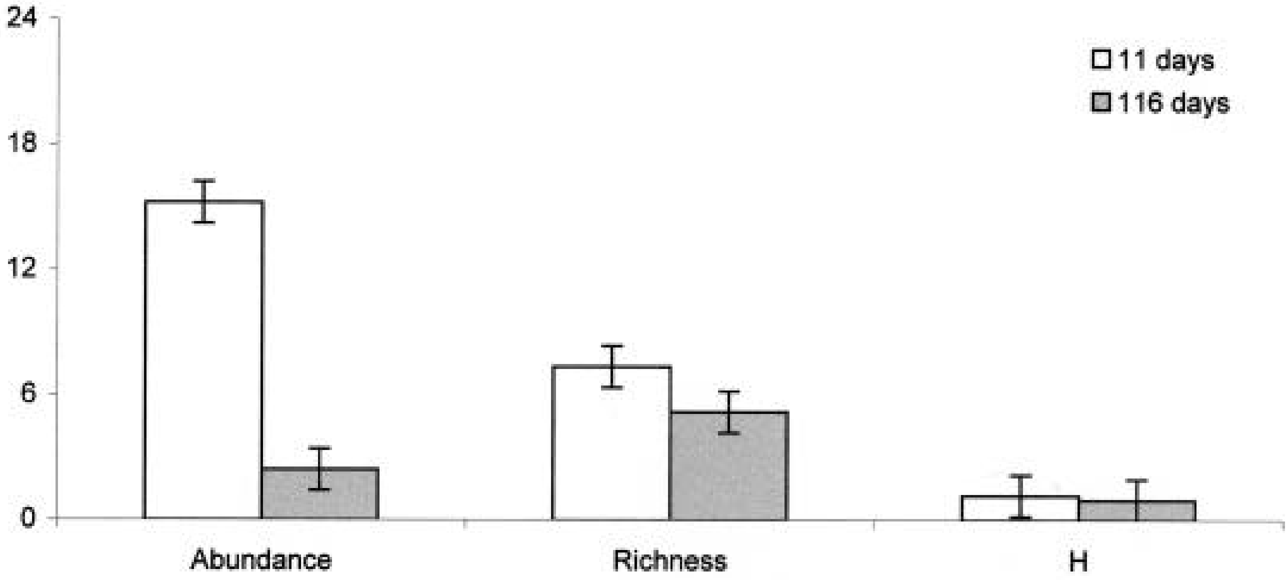
As occurred during September 1999 (Refilling – Event 5), in March 2001 another accumulation of fish occurred in the inlet channel to Lake Merreti (Nichols 2001a). Thousands of fish were noted gulping air at the surface on the wetland side of the inlet channel. At this time, the structure was closed, although a slight leak of freshwater was observed coming from the structure (Nichols 2001a). It was, therefore, decided to provide a small additional flow to the wetland and place a structure net on the inlet structure to capture any fish that may be trying to move out of the wetland. After only six hours of net set, approximately 4000 bony bream, 12 carp and 14 goldfish were captured, indicating that the attractant flow had worked.
From this preliminary result, it appears that the use of attractant flows to capture fish at the inlet structure for removal (either disposal for introduced species, or release for native species) may be beneficial.

Refilling - Event 9 (September 2001 – February 2002)

Unlike Refilling Event 7, where carp dominated the fish fauna in the early stages of refilling, the early stages of Refilling Event 9 (October and November samples, two and three months after the inlet was reopened) were dominated by the native species Australian smelt (60% and 53%), western carp gudgeon (27% and 31%) and Midgely's carp gudgeon (12% and 7%: Figure 7.12).

In this refilling event, carp began to contribute to the overall catch during November (5%), increasing to 32% at four months after refilling began, and dropping slightly to 23% of the total catch during the final survey in January (five months after the inlet was reopened).

Figure 7.19 Abundance, species richness and Shannon's diversity index for Partial drying - Event 8 (at 11 days and 116 days after the wetland inlet structure was closed).



In the later two samples in Refilling Event 9, western carp gudgeon and Midgely's carp gudgeon comprised the majority of the catch (59% in December and 55% in January). These two samples also saw a decline in the abundance of Australian smelt after dominating the catch in the first two samples (dropping to 7% in December and slightly rising to 9% in January).

Goldfish gradually increased in catch proportion with time since refilling began, although the proportion remained very low throughout the survey period, never reaching above 6% of the catch.

As with the sequence of events within Refilling Event 7, during Refilling Event 9, bony bream only began to contribute to the catch five months after refilling began although, like goldfish, their contribution to the total catch remained low (4%).

These trends correlate with the catch per effort data presented in Figures 7.13 and 7.14, that indicate a dominance of Australian smelt during the first two samples of Refilling Event 9 (18.6 fish per hour in October and 20.4 fish per hour captured in November), dropping to below 3 fish per hour in the last two samples.

Western carp gudgeon catch rate peaked in November 2001 (13.8 fish per hour), three months after Refilling Event 9 began, and gradually declined to its initial levels of 8.3 fish per hour by January 2002 (five months after refilling began).

Carp capture rates peaked in December 2001 (7 fish per hour), after rising from an initial rate of 2.2 fish per hour in November, and prior to declining to a rate of 4.8 fish per hour.

Capture rates for all other fish remained below 3 fish per hour, with less common species never being more than 1.2 fish per hour for goldfish during the final sample.

Overall abundances peaked in November (961 fish) after rising slightly from October (794 fish) and gradually declining to a minimum of 518 fish in January 2002.

As the wetland was not completely dried prior to refilling, no statistical analyses could be undertaken to determine the rate of colonisation of different fish species (as some species remained throughout Partial drying Event 8).

The only trend that could be explained is the increase in abundance of carp during the sample period. This, again, is likely to be a result of the October annual breeding event, although did not reach such high abundances as those observed during Refilling Event 7 as no high river coincided with carp breeding (flows remained below a peak of 13,112ML/day on 12/11/01).

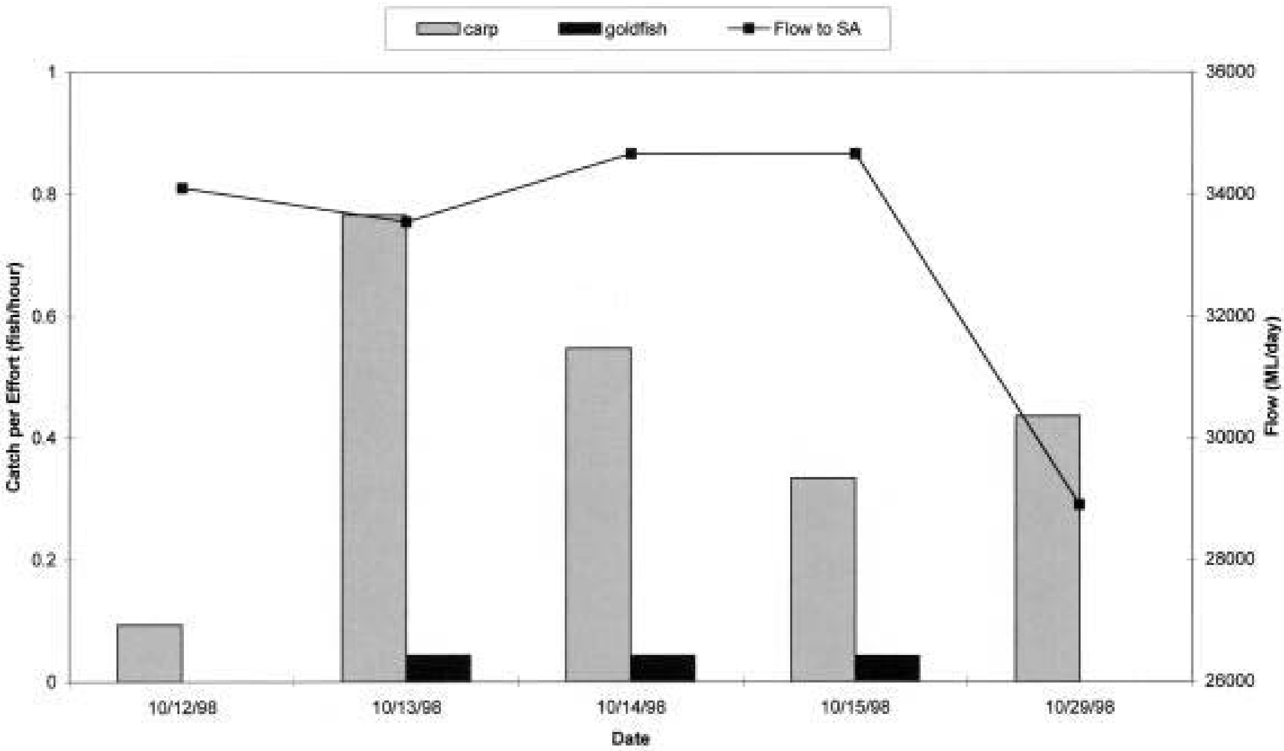
It is difficult to explain the large proportion of catch contributed by Australian smelt and the other native species in the early stages of Refilling Event 9. One possible explanation is that these species remained in Lake Merreti over the partial drying event and were, therefore, already present in high numbers when the wetland was refilled. This may have slowed colonisation of the wetland by carp, which were not able to build in numbers until sometime after the wetland had begun refilling.

Effect of small flood events on fish movement at Lake Merreti temporary flowpath

Refilling - Event 5 (August 1998 – December 1999)

During the high river flows in October 1998 (peaking at 34,666ML/day 15/10/98), fish were collected from the most upstream temporary inlet to Lake Merreti as part of the Tucker (2003) study (Tucker 2003). Samples of fish moving into the inlet were taken each day for four days at the height of the high river, with one sample taken 14 days after the flow had receded (Figure 7.20). Nearly all fish captured during these samples were carp, although 3 goldfish were captured on three of the four consecutive days. The majority of the carp were between 10-20cm (predominantly 14-17cm); goldfish were 18.5, 21.5, and 16cm respectively for the 13, 14, and 15/10/98. The dominance of carp in the catch was not surprising given the timing of flows (October), and known habitats of carp (moving into warm shallow water areas to spawn (Hume *et al.* 1983)).

Figure 7.20 Fish movement into Lake Merreti temporary inlet during high river flow October 1998.



Overall catch per effort in this sample was low – never becoming greater than 0.8 fish per hour. Despite the low capture rate, catch per effort increased dramatically from 12/10/1998 (0.09 fish/hour) to 13/10/1998 (0.7 fish/hour), before gradually declining to 0.33 fish/hour on the 15/10/1998, and again raising slightly to 0.43 fish/hour 14 days later on the 29/10/1998 as the high river flow receded.

As the flow peak continued, and as the flows subsided, the size class of carp also changed. Initially, most of the catch on 13/10/1998 and 14/10/1998 were between 10cm and 32cm, however, the size class increased so that most fish were between 20-30cm on the 15/10/1998, until the final sample on the 29/10/1998 when all fish captured were greater than 30cm. It is unknown why larger fish would want to enter the temporary inlet after smaller individuals, especially on a declining flow—if larger carp were using the warm shallow waters for breeding, then it would be expected that they would enter the temporary inlet on commencement to flow, rather than on its recession.

Refilling - Event 7 (September 2000 – March 2001)

As with Refilling Event 5, during Refilling Event 7 a high river flow occurred, presenting Nichols (2003) with the opportunity to again monitor fish movement into the most upstream temporary inlet to Lake Merreti (Nichols in prep.).

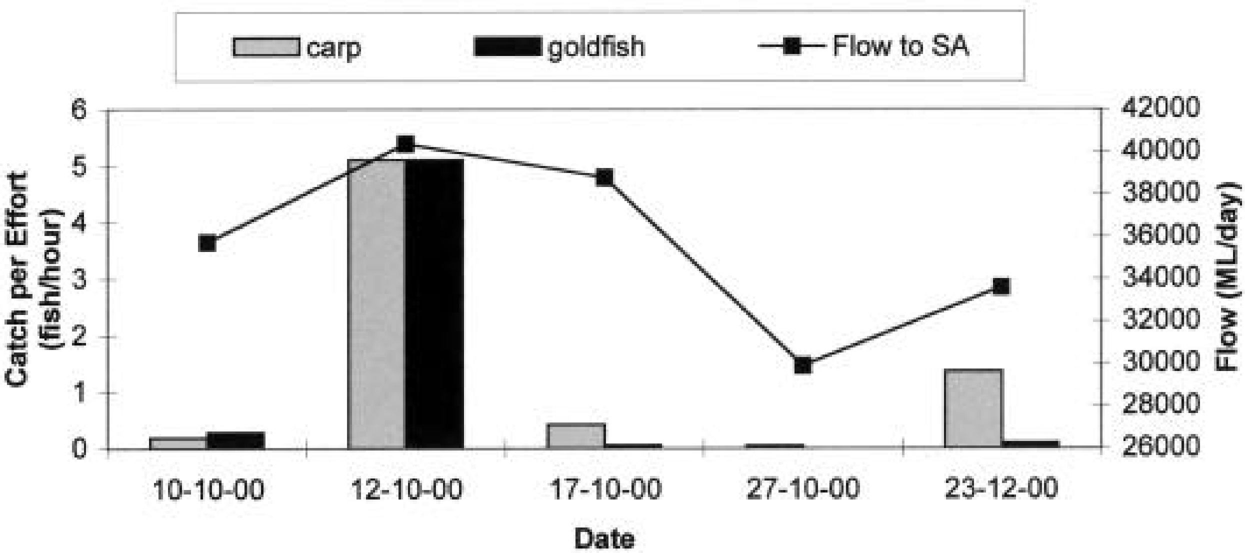
Four samples were taken at this inlet in the latter half of October, with one sample also in December. This enabled fish movement to be monitored prior to, at the peak in flow of 42,050ML/day occurring on the 13/10/2000, at four days after and 14 days after the peak had passed. Fish movement was also surveyed once in December on the recession of another flow peak of 63,427ML/day that occurred on 18/12/2000. Due to time constraints, samples were not taken leading up to the second (main) peak.

It is recommended that when flows of this caliber occur again, sampling at the temporary upstream inlet to Lake Merreti be undertaken, ensuring that samples are taken on the lead up to the flow peak, at the peak of flow, and on its recession.

Of the samples taken in October and December, three species were recorded—carp, goldfish and bony bream. The majority of the catch again consisted of carp and goldfish, with only three bony bream captured on two separate occasions: one fish on the 17/10/2000 (just after the first peak), and two fish on the 23/12/2000 (following the second flow peak).

Capture rates of carp and goldfish varied at all dates, being higher than those observed in 1998 at the first peak in flow (5.11 fish per hour for both carp and goldfish), and on the final sample (after the second peak: 1.3 fish per hour for carp: Figure 7.21). Capture rates generally mirrored changes in the hydrograph, although all other samples remained below 0.4 fish per hour.

Figure 7.21 Fish movement into Lake Merreti temporary inlet during high river flows October to December 2000.



The greater number of fish captured at the first flow peak (October 2000) may indicate that a higher flow is more beneficial to carp, with the higher capture rates observed in the December sample possibly being a 'drop' from even higher rates of movement into the temporary flow path during the second peak in flow.

Size information reveals that all goldfish captured were between 13.2cm and 17.5cm – with the largest fish being captured in the December sample, and the smallest in the first sample, prior to the first peak in flow.

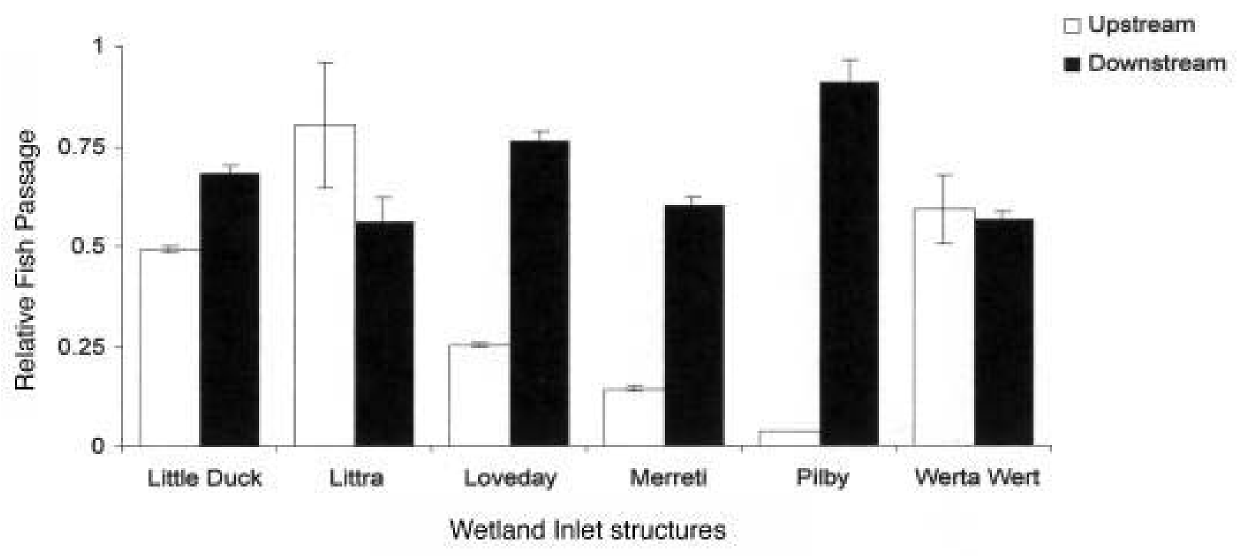
During the first peak in flow, carp ranged in size from 15cm (on the rise to this peak) to 33cm (at the recession of this flow peak); at the peak in flow the average size of carp captured was 20.5cm. These sizes are comparable to those fish captured during Refilling Event 5. In contrast to the first peak in flow, carp captured in December were 8.8cm on average, indicating that a breeding event had occurred (possibly in October) with the young from this event moving into the temporary flow path following the second peak. Observations of approximately ten pairs of carp spawning at the main and upstream inlets during the first flow peak support this claim.

Fish passage through Lake Merreti permanent inlet structure

Of the structures surveyed during his project (Lake Littra, Werta Wert Lagoons, Pilby Lagoon, Lake Merreti, Little Duck Lagoon and Loveday Wetlands), none inhibited movement of fish into the wetland for the fish community as a whole (i.e. none were significantly different from wetlands without flow controls structures on their inlets).

In contrast, for the fish community as a whole, fish passage out of wetlands was significantly different to unmanaged wetlands at three managed sites (Figure 7.22). Those structures that did inhibit fish movement from wetlands to the river or anabranch were Pilby Lagoon, Lake Merreti, and Loveday Wetlands. The structure at Lake Merreti was the second worst for fish passage (after Pilby Lagoon), with fish passage out of the wetland being only 28% that of free fish passage. This result highlights the need to improve the flow control structure at Lake Merreti (and other wetlands) in order to improve fish passage out of the wetlands.

Figure 7.22 Relative fish passage at each wetland inlet structure assessed for fish moving into (downstream) and out of (upstream) wetlands.



When the relative fish passage index for individual species are determined, upstream fish passage is inhibited for all species except carp and fly-specked hardyheads (Table 7.4). In addition, although fish passage for the fish community as a whole was found to be unobstructed (similar to a wetland without a flow control structure present), when individual species were investigated, the structure significantly inhibited callop, rainbowfish, flathead gudgeon and dwarf flathead gudgeon.

Table 7.4 The relative fish passage efficiency (RFP) of individual species migrating into and out of Lake Merreti (Gilligan 2002).

(Boxes highlighted in grey indicate species for which fish passage through the Merreti inlet structure significantly inhibits fish passage).

Species	Into wetland (RPF ± SE)	Out of wetland (RPF ± SE)
Australian smelt	0.47 ± 0.02	0.35 ± 0.01
Bony bream	0.64 ± 0.06	0.06 ± 0.00
Callop	0.09 ± 0.01	
Carp gudgeon (Lake's)	1.00 ± 0.06	0.21 ± 0.04
Carp gudgeon (Midgely's)	0.77 ± 0.10	
Carp gudgeon (western)	0.67 ± 0.02	0.09 ± 0.00
Flathead gudgeon	0.44 ± 0.01	0.15 ± 0.00
Flathead gudgeon (dwarf)	0.33 ± 0.01	0.23 ± 0.01
Fly-specked hardyhead	0.39 ± 0.06	0.70 ± 0.04
Rainbowfish (crimson spotted)	0.20 ± 0.01	
Common carp	0.54 ± 0.04	0.65 ± 0.16
Gambusia	0.99 ± 0.16	0.01 ± 0.00
Goldfish	0.67 ± 0.15	0.15 ± 0.05

These results for Lake Merreti inlet structure are not surprising. The inlet structure, consisting of two 90cm diameter pipes that are 17.8m long, forms a difficult, if not impossible, barrier to most species. Due to its length, when there is a slight head difference between Ral Ral Creek and the wetland side of the structure, high water velocities are produced in the pipe that fish must swim against in order to escape.

In order to negotiate upstream movement through a flow control structure, a fish must employ 'burst speed': the fastest means that a fish can swim. Burst speed is employed to escape from predators or swim against strong currents, and is such that it relies on the rapid production of energy in the muscle tissue that, in turn, leads to the rapid production of energy byproducts. When these byproducts build up in the muscle tissue, the muscle function is limited, stopping burst speed from being maintained over large distances.

In a structure such as that at the main inlet to Lake Merreti, fish find it difficult to fight against the long linear velocities for the entire length of the pipe. This impacts on their ability to move from the wetland to the creek, and is reflected in the poor fish passage indices displayed in Figure 7.22.

Ideally, a structure is thought to be of minimal impact to fish movement when it is short in length, has a wide cross sectional area (equal to the cross sectional area of the inlet channel), and the culvert is set at the inlet creek bed level. Therefore, ideally, in order to improve fish passage through the Lake Merreti structure, the structure would need to be shortened and the cross-sectional area increased dramatically. The installation of large box culverts instead of the existing pipe culverts would be ideal. However, due to cost constraints, installation of additional pipe culverts would also aid fish passage, potentially lowering water velocities within the pipes by spreading the volume of water moving through the structure over a greater area.

Chapter 7 ~ Fish

SUMMARY

- Several studies of the fish fauna have been conducted at Lake Merreti, using different methods and different time frames, thereby making comparison of fish fauna changes over time difficult.

- The gear type employed is important and can severely limit catches, or destructively sample the populations, thereby causing changes to the population itself. Seine nets and shrimp traps appear ineffective methods of capture while gill nets are destructive.

- Use of fyke nets is recommended as a passive method of capture—this gear catches large and small species and minimises capture deaths.

- Carp were first noticed in the area between 1970 and 1974.

- Although Murray cod and catfish were caught in the Ral Ral Creek anabranch, they are not common and have not been captured from the wetland proper.

- During the first complete drying event, monospecific samples of large numbers of large carp were collected from the remaining 'deeper' sections of the wetland.

- During the most recent study, the fish fauna either side of the permanent inlet flow control structure has been the same, although callop and redfin were not captured from the wetland itself (only the inlet channel), while gambusia was only captured from the wetland side of the inlet channel and the wetland itself, but not from Ral Ral Creek (Nichols in prep.).

- The use of attractant flows should be investigated further for use as a management tool for removal of fish from the wetland prior to drying.

- During Refilling Event 7, no significant relationship was observed between time since refilling and catch rate (fish per hour).

- During Refilling Event 7, a significant relationship was observed for species richness and Shannon's diversity with time since refilling began.

- The Lake Merreti upstream temporary inlet was monitored during two separate high river events and showed carp and goldfish between 10-30cm size range attempting to move into the inlet.

- The temporary inlets to Lake Merreti should be monitored again once a high river (greater than 35,000 ML/day) occurs to determine fish usage of these inlets.

- Overbank flows should also be monitored using the same techniques as Nichols (2003) to determine fish usage of temporary inlets, floodplain, wetland and anabranch during these times.

- The Lake Merreti permanent inlet structure is poor for fish movement out of the wetland (back to the creek). The structure should, therefore, be improved to facilitate fish movement out of the wetland by increasing the cross-sectional area of the culvert to more approximately that of the inlet itself. It is recommended to install either box culvert or additional pipe culverts at the structure to minimise water velocities within the structure.

Chapter 8 ~ Waterbirds

Mike Harper, Australian Landscape Trust
Bob Goodfellow

INTRODUCTION

Ornithologists have long recognised Lake Merreti as a site of high waterbird diversity (Ashby 1929), (Mack 1961) (Smith 1935). This characteristic is due to the lake's relatively large size (348ha) for a lower Murray wetland, its shallow nature (maximum depth at Weir 5 pool level of less than one metre), and low levels of disturbance afforded by its pastoral tenure and distance from human population. Jensen (1983) indicated that surveys of waterbirds at Lake Merreti by Cornish, Mack and Reid (pers. comm.) between 1948 and 1970, recorded 56 species of which 17 species breed at the site. Of the breeding species, seven were colonial nesters—darter, little pied cormorant, little black cormorant, glossy ibis, white ibis, straw-necked ibis and yellow-billed spoonbill. Jensen (1983) also indicated that Foweraker (pers. comm.) recorded both ibis and cormorant breeding rookeries as far back as 1937 (Jensen 1983). Foweraker (pers. comm.) also indicated that white-breasted sea eagles continued to breed at Lake Merreti until about 1974.

Over the past century, the hydrology of Lake Merreti has varied greatly and has ranged from a temporary/semi-permanent, to permanent and back to a semi-permanent wetland (Jensen *et al.* 2002). Cornish, Mack & Foweraker (pers. comm. in Jensen 1983) indicate that waterbird habitat conditions significantly changed through the cycles of flooding and drying, resulting in different waterbird species and number usage of the lake over time.

METHODS

Monitoring techniques

During the period July 1985 and September 1994 numbers of waterbirds were counted between sunrise and 1630 hours at intervals of approximately two weeks by the author (2). The surveys were not continuous however the 64 counts covered all seasons of the year during the nine-year period. Surveys were conducted from a number of predetermined locations around the edge of the lake to achieve total coverage of the wetland. Two pairs of binoculars (12 x 24 & 7-21 x 50) and a 82mm spotting scope (50 magnification) mounted on a tripod were used for observation.

During the period November 2000 and June 2002, numbers of waterbirds were counted between 1200 and 1500 hours in the first week of each month by the author (1). Surveys were conducted from a number of predetermined locations around the edge of the lake to achieve total coverage of the wetland similar to that of the 1985 to 1994 counts. A pair of binoculars (10 X 50) and a 60mm spotting scope (20 magnification) mounted on a tripod were used for observation. Author (1) also visited Lake Merreti two to three times during spring and early summer to count the number of nests during colonial nesting waterbird breeding events between 1987 and 2002. Surveys did not occur for four years during this 15-year period.

During the years 1968 to 1970, author (2) spent much time studying the birdlife that inhabited the Lake Merreti complex, including Lake Merreti, Lake Woolpolool and Clover Lake. The area was a huge attraction for many species of waterfowl and waders. Author (2), with Don Cornish, David Mack and Perce Munchenberg, assisted in banding many birds at Lake Merreti, and all were very excited about the huge numbers and species of waterbirds on the lake. During this time, there were no common carp in Lake Merreti and the water was relatively clear. Author (2) was absent from the Riverland between December 1970 and September 1977 during which time common carp colonised the Riverland's wetlands, and multiplied to huge numbers. On recommencing the regular waterbird observations at Lake Merreti after an absence of seven years, author (2) found that both the number and species of waterbids had declined significantly. Although no scientific research was conducted, author (2) concluded through his detailed observations that the disappearance of the many waterbirds that frequented the lake in the late 1960s could have been contributed to by the impacts common carp had on the health of the wetland.

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Hydrology during survey period

In the summer of 1994, Lake Merreti was completely dried for the first time since the 1950s. Since this drying event, the management of the lake's hydrology has changed the lake from a permanently inundated wetland to a semi-permanently inundated wetland. Surveys were conducted prior to and after changes to the hydrological management of the lake.

Pre management, general waterbird surveys included a range of water levels from just below pool level, which is considered to be 16.32m AHD, to a number of high river flow events Table 8.1). However, due to the lack of high-river flows during the post management, general waterbird surveys were conducted during a period of low water level (Table 8.1). At a water level of 15.90 AHD, about one third of the lake's surface area is dry and the average water depth is 10 to 15 centimetres.

During the 15-year period that colonial waterbird breeding surveys were conducted, there were nine years when the river received significant high flows that resulted in the inundation of the riparian zone around Lake Merreti (Table 8.2).

Table 8.1 Minimum and maximum water levels (m AHD) during general waterbird survey periods of each year, Lake Merreti pre and post management

Year of Survey	Minimum water level during low flow period (AHD)	Maximum water level during high flow period (AHD)	Difference between minimum & maximum water levels (m)
Pre Management			
1985	16.29	16.70	0.41
1986	16.25	17.32	1.07
1987	16.29	16.70	0.41
1988	16.25	16.65	0.40
1989	16.32	18.64	2.32
Post Management			
2000	16.30	16.45	0.15
2001	16.04	16.36	0.32
2002	15.92	16.14	0.22

Table 8.2 Yearly maximum height above pool level (16.32 AHD) at Lake Merreti.

Year	Maximum water level above weir pool level (m)
1987	1.05
1988	1.35
1989	2.34
1990	2.67
1991	1.34
1992	1.90
1993	2.08
1994	0.00
1995	1.40
1996	1.69
1997	0.16
1998	0.00
1999	0.53
2000	0.13
2001	0.04

Data analysis

One-way ANOVA's for general waterbird data collected at Lake Merreti were performed to determine:
- differences between pre and post management in waterbird abundance
- differences between pre and post management in waterbird species diversity.

Linear regressions for the general waterbird data collected were used to determine the effects of season, water depth and water conductivity on waterbird abundance and diversity. This line of analysis was abandoned, as even though these parameters were significant, the predictive accuracy was very low. A possible reason for the low predictive accuracy is the presence of large gaps in the survey data between the years 1985 and 1989 (see Table 4).

Figures of the general waterbird data collected at Lake Merreti were produced to determine:
- comparison of mean abundance per waterbird species between pre and post management
- comparison of proportion of surveys during which each species was found pre and post management.

Linear regressions for the colonial waterbird breeding survey data collected at Lake Merreti were used to determine the effects of maximum water depth on the number of species breeding and the number of nests observed.

For the purpose of this study, five broad waterbird feeding groups similar to Ziembicki (1997) were recognised:

Piscivores*:* specialist diving and surface fish-eating birds
Small wading birds: small shoreline birds that feed mainly on invertebrates in shallow wading habitat
Egrets, herons and allies*:* large bodied birds that feed on small animals in wading habitat
Waterfowl: dabbling, filtering and grazing ducks and swan
Crakes, waterhens and coots: birds that feed on invertebrates and submerged plants along shorelines and in open water.

In this ecological assessment the two wetland-related raptors—white-bellied sea-eagle (*Haliaeetus leucogaster*) and swamp harrier (*Circus approximans*), and perching bird species—clamorous reed warbler (*Acrocephalus stentorrus*) and golden-headed cisticola (*Cisticola exilis*), were not included. Table 8.3 lists these groups and their respective species.

Table 8.3 Defined ecological "feeding groups" and their respective species

Piscivores	Small wading birds	Egrets, herons & allies	Waterfowl	Crakes, waterhens & coots
Australasian grebe	Black winged stilt	White-necked heron	Black swan	Australian spotted crake
Hoary headed grebe	Banded stilt	Great (large) egret	Freckled duck	Dusky moorhen
Great crested grebe	Red-necked avocet	Intermediate egret	Australian shelduck	Black-tailed native-hen
Australian pelican	Masked lapwing	White-faced heron	Pink-eared duck	Purple swamphen
Great cormorant	Banded lapwing	Little egret	Grey teal	Eurasian coot
Little black cormorant	Common greenshank	Cattle egret	Chestnut teal	
Pied cormorant	Red-capped plover	Nankeen night-heron	Pacific black duck	
Little pied cormorant	Black-fronted dotterel	White ibis	Australasian shoveler	
Australian darter	Red-kneed dotterel	Straw-necked ibis	Hardhead	
Silver gull	Marsh sandpiper	Glossy ibis	Australian wood duck	
Whiskered tern	Red-necked stint	Royal spoonbill	Musk duck	
Gull-billed tern	Sharp-tailed sandpiper	Yellow-billed spoonbill		
Caspian tern	Curlew sandpiper			

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MONITORING RESULTS

During the survey period from July 1985 to June 2002, 54 species of waterbirds and two wetland related raptors and perching bird species were recorded at Lake Merreti (see Appendix 1 for list of birds sighted). Table 8.4 presents the number of species and total bird numbers sighted during each survey. The periods when surveys were not conducted, or the wetland was dry, are also identified. During the pre management survey period the number of species sighted during a single survey was between 13 and 29, and the number of birds recorded was between 153 and 1,349. In comparison, during the post management survey period, the number of species sighted during a single survey was between 15 and 33, and the number of birds recorded was between 1,640 and 23,655.

The abundance of birds recorded at Lake Merreti was significantly greater post hydrological management (one-way ANOVA $F_{1,574}$; $P < 0.0001$) (Table 8.5). The diversity of birds recorded at Lake Merreti was significantly greater post hydrological management (one-way ANOVA $F_{1,80}$; $P < 0.0001$) (Table 8.5).

Table 8.4 Number of species and total bird numbers sighted each survey, Lake Merreti, 1985 - 2002

MONTH	1985	1986	1987	1988	1989	2000	2001	2002
JAN	NO SURVEY	19/269	NO SURVEY	21/296	27/379	WETLAND DRY	17/5,310	30/17,974
				19/693				
FEB		25/592		21/812	25/370		24/3,530	30/23,655
		22/577		21/1170	23/626			
MARCH		25/1005	15/764	23/1349	26/1260		25/8,930	33/19,497
			21/857	20/1233	26/601			
				24/932				
APRIL		29/957	18/710	19/873	19/308		27/14,320	28/16,837
		26/916	17/1032	17/926				
MAY		20/1050	18/601	13/339	18/299		32/18,550	25/9,105
		20/726	18/371		NO SURVEY			
		15/745	18/284					
JUNE		16/652	17/584	18/342			30/14,990	24/8,929
		18/717	19/381	NO SURVEY				
JULY	19/563	18/419	15/417		17/265		25/11,819	
	21/360	19/619	16/252					
AUG	19/335	21/286	NO SURVEY		18/421		NO SURVEY	
		NO SURVEY						
SEPT	21/528				18/747	NO SURVEY		
	26/504				21/659		33/11,326	
OCT	20/319				21/741	15/1,640		
	22/337				NO SURVEY		30/11,677	
NOV	25/243					23/4,630	28/14,561	
	15/153						30/8,217	
DEC	19/269		18/300					
	19/182							

Table 8.5 Mean number of bird species and mean abundance per species found per survey pre and post management, Lake Merreti, 1985 - 2002

Management stage	Diversity		Abundance	
	Mean no. species/survey	Std err (*n*)	Mean no. individuals/species/survey	Std err (*n*)
Pre	20	0.5 (64)	8	0.5 (4480)
Post	27	1.1 (18)	174	22.8 (1266)

The mean abundance per bird species occurring on Lake Merreti pre and post management is compared in Figure 8.1. Species not recorded during the pre management period but recorded during the post management period were Australasian grebe (*Tachybaptus novaehollandiae*), banded lapwing (*Vanellus miles*), marsh sandpiper (*Tringa stagnatilis*) and curlew sandpiper (*Calidris ruficollis*). Seven species were recorded during the post management period but not the pre management period. These species were great crested grebe (*Podiceps cristatus*), intermediate egret (*Ardea intermedia*), little egret (*Ardea garzetta*), cattle egret (*Ardea ibis*), glossy ibis (*Plegadis falcinellus*), freckled duck (*Stictonetta naevosa*) and purple swamphen (*Porphyrio porphyrio*).

Within the piscivores waterbird feeding group, five of the 13 species showed a significant increase in the mean abundance during the post management period (Figure 8.1). The species were hoary headed grebe (*Tachybaptus poliocephalus*), little pied cormorant (*Phalacrocorax melanoleucos*) and silver gull (*Larus novaehollandiae*). Only two of the 13 species of small waders feeding group showed a significant increase in the mean abundance during the post management period—black-winged stilt (*Himantopus himantopus*) and red-necked avocet (*Recurvirostra novaehollandiae*). Within the egrets, herons and allies group only the great egret (*Ardea alba*) showed a significant increase in the mean abundance during the post management period. Of the eleven species of waterfowl, six species showed a significant increase in the mean abundance during the post management period. The species were freckled duck, pink-eared duck (*Malacorhynchos membranaceus*), grey teal (*Anas gibberifrons*), Pacific black duck (*Anas superciliosa*), Australasian shoveler (*Anas rhynchoti*) and hardhead (*Aythya australis*). Within the crakes, waterhens and coots waterbird feeding group, two of the five species showed a significant increase in the mean abundance during the post management period—black-tailed native-hen (*Gallinura ventralis*) and Eurasian coot (*Fulica atra*). No species showed a significant increase in the mean abundance during the pre management period.

Figure 8.2 compares the proportion of surveys during which each species was found pre and post management. Grey teal was the only species sighted during each survey of the study period. Of the 58 species recorded eight were sighted for 80% or greater of the surveys, for both pre and post management periods. The species were Australian pelican (*Pelecanus conspicillatus*), yellow-billed spoonbill (*Platalea flavipes*), black swan (*Cygnus atratus*), Australian shelduck (*Tadorna tadornoides*), pink-eared duck, grey teal, Pacific black duck and masked lapwing (*Vanellus miles*). The species that were sighted 50% or more of the time during the post management than the pre management period were freckled duck, Australasian shoveler, hardhead, Eurasian coot and silver gull. No species were sighted for the reverse situation.

Table 8.6 presents the estimated number of nests for each colonial nesting waterbird species recorded breeding at Lake Merreti between 1987 and 1995. During 1996 and 1997 no surveys were undertaken, however, between 1998 and 2001 surveys were conducted but no colonial nesting waterbirds were found nesting. Of the nine colonial nesting waterbird species recorded, only the white ibis (*Threskiornis molucca*) and straw-necked ibis (*Threskiornis spinicollis*) were recorded breeding during all years when breeding events were recorded.

Linear regression analysis indicated that the number of colonial nesting species breeding at Lake Merreti is highly dependent upon the maximum water level ($p>0.0001$) with a high predictive accuracy ($r^2 =0.899295$). The regression analysis also indicated that the number of nests recorded is dependent upon the maximum water level reached during a flood event, ($p>0.0010$), with a significant predictive accuracy ($r^2 =0.106646$).

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Figure 8.1 Mean abundance of each bird species during pre and post management surveys, Lake Merreti, 1985 - 2002

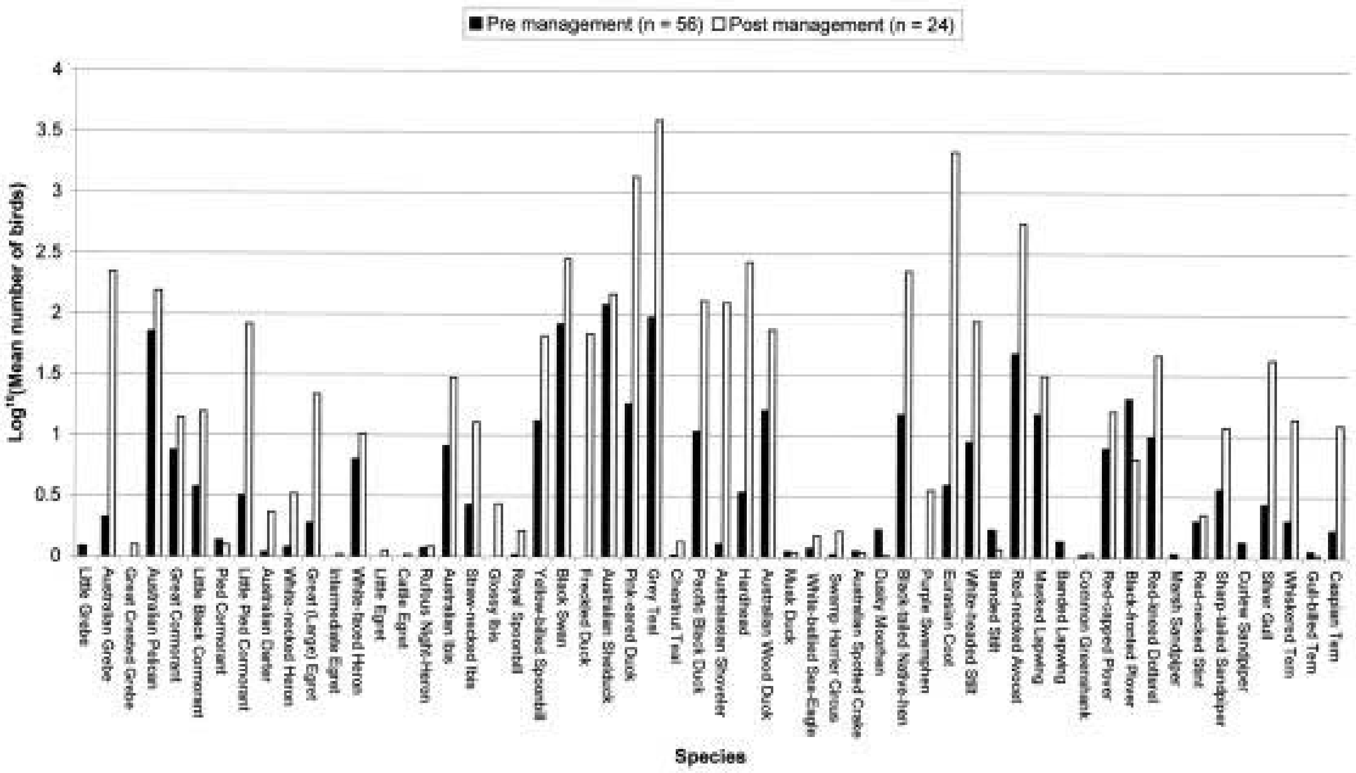

Figure 8.2 Proportion of surveys during which each waterbird species was found pre- and post management, Lake Merreti, 1985 - 2002

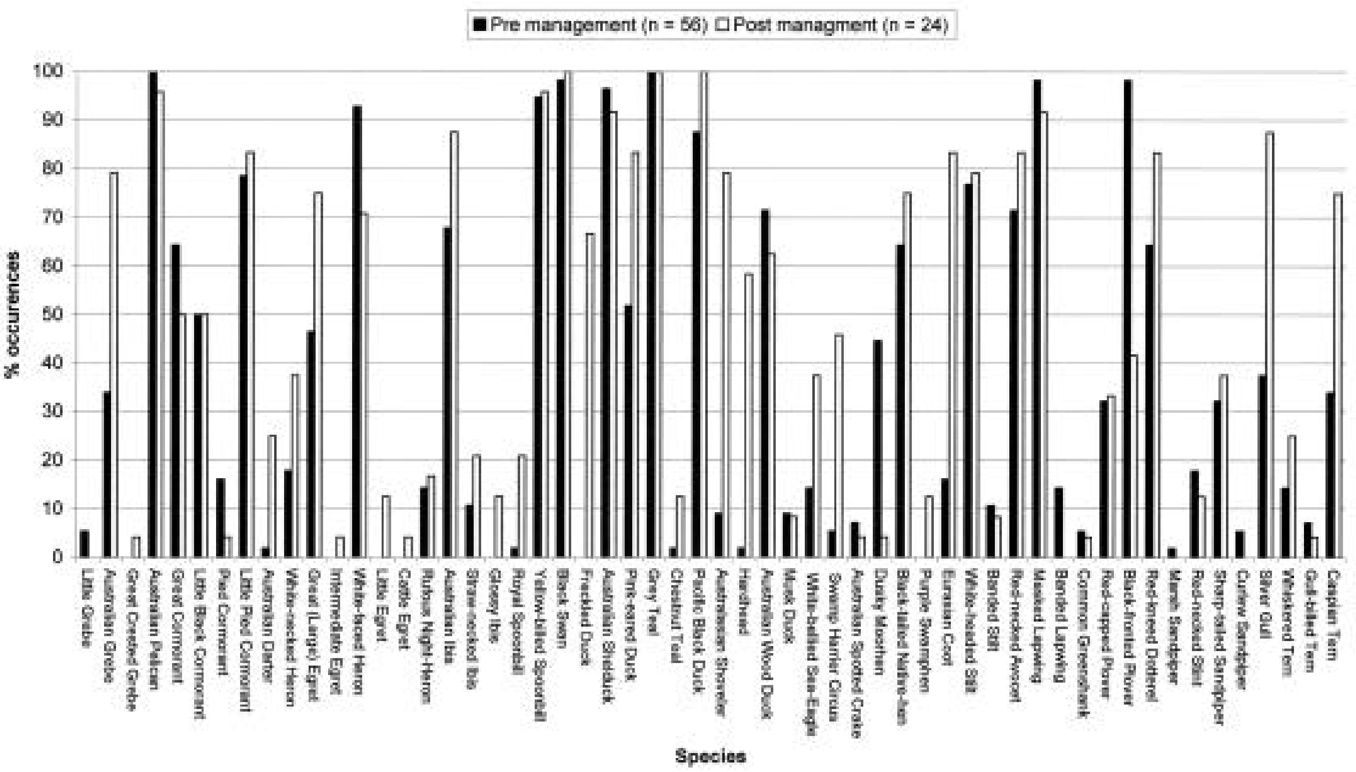

Table 8.6 Colonial nesting waterbird nests, Lake Merreti, 1987 - 1995
Recorded nesting but total number of nests not recorded

SPECIES	1987	1988	1989	1990	1991	1992	1993	1994	1995
Strawneck ibis	250	no survey	550	600	no survey	500	20	no nests	90
White ibis	250		245	304		80	20		50
Yellow-billed spoonbill			4	2					
Royal spoonbill			1						
Darter			2	3		14	18		#
Pied cormorant						3			
Little black cormorant			140	60		38	6		
Little pied cormorant			54			6			
Black swan									12

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DISCUSSION

A few species were recorded only during either the pre or post management surveys. Of the eleven species in this category only the freckled duck was regularly recorded in high numbers with the remaining species either single sightings or small numbers at irregular intervals. Regular sightings of freckled duck in the lower Murray-Darling Basin usually coincide with dry conditions in the species stronghold in the northern and central areas of south-eastern Australia (Frith 1977). During the post management survey period, the northern and central areas of south-eastern Australia experienced dry conditions. However, during 1985, dry conditions also coincided in the same area of Australia (Braithwaite *et al.* 1986) but freckled duck was not recorded at Lake Merreti during that period. The importance of Lake Merreti as a drought refuge for freckled duck, a threatened species, during the post hydrological management has greatly increased the wetland's conservation significance.

Fourteen, or 26% of species across the range of defined ecological "feeding groups" showed a significant increase in their mean abundance during the post management period. An explanation for this significant increase in numbers of birds is most likely related to the changes in the lake's waterbird habitat condition. The following water level and vegetation habitat parameters changed between the pre and post management survey periods:

- Lake Merreti water levels, as shown in Table 8.1, were significantly lower during the majority of the post management survey period, resulting in large areas of the lake having shallow water conditions (10 to 30 cm deep).
- As identified in Chapter 5 Vegetation, submerged water plants such as red water-milfoil (*Myriophyllum verrucosum)* and ribbon weed (*Vallisneria americana)* colonized the majority of the lake bed during the summer and autumn periods of the post management surveys. In contrast, during the pre management surveys submerged vegetation did not grow extensively throughout the lake.
- A significant increase in the area and width of cover, of both bulrush (*Typha* spp.) and spiny sedge (*Cyperus gymnocaulos)* along the lake shoreline occurred between the pre and post management survey periods (refer Chapter 5 Vegetation).

The lower water levels during the post management period would have increased the feeding area available to species within the small wader and egrets, herons and allies feeding groups of birds. Eurasian coot feed mainly on vegetation such as aquatic plants (Serventy 1985). During the post management survey period this species dramatically increased in mean abundance and the proportion of surveys sighted during this period. The ecological parameter that had the greatest influence on the increase in Eurasian coot numbers was the increase in submerged aquatic plants such red water-milfoil and ribbon weed.

Other ecological parameters within the lake changed significantly as a result of changes in water depth and vegetation cover between the pre and post management survey periods. One such example is the increased food availability for the smaller piscivores feeding group of waterbird, due to the increase in native fish diversity between the pre and post management survey periods (refer Chapter 7 Fish). Low water level during the post management period would have supplied a significant increase in loafing and roosting sites for species within the waterfowl and small wader feeding groups of waterbirds. The recovery of the lake's littoral zone vegetation between the two survey periods, as a result of destocking of the property, would also have favored these species.

Eight of the 14 species that showed a significant increase in their mean abundance during the post management period are nomadic in their status. The species are hoary headed grebe, black-winged stilt, great egret, pink-eared duck, grey teal, hardhead, black-tailed native-hen and Eurasian coot (Frith 1977) (Serventy 1985) (Morcombe 2000). The management of Lake Merreti as a semi-permanent wetland has created an important drought refuge for nomadic waterbird species, especially during times when the central and northern areas of south-eastern Australia experience dry conditions.

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SUMMARY

- During the survey period from July 1985 to June 2002, 54 species of waterbirds and two wetland-related raptors and perching bird species were recorded at Lake Merreti. Of these only four species were sighted prior to but not after hydrological management, while seven species were recorded post but not pre hydrological management.

- The abundance and diversity of birds recorded at Lake Merreti were significantly greater post hydrological management.

- Fourteen (26%) species across the range of defined ecological "feeding groups" showed a significant increase in their mean abundance during the post management period. Increases were probably due to lower water levels, increased growth of submerged vegetation, and increased area and width of cover by littoral vegetation. No species had a significantly higher abundance pre management.

- There was a significant increase in the frequency of occurrence (>50%) of five species post management while no species were recorded significantly more frequently prior to management.

- The management of Lake Merreti as a semi-permanent wetland has created an important drought refuge for nomadic waterbird species, especially during times when the central and northern areas of south-eastern Australia experience dry conditions.

- Lake Merreti is one of only two wetlands along the River Murray in South Australia that continues to support significant breeding events of colonial nesting waterbirds. It is critical that the hydrological management of natural flood events at Lake Merreti continues to benefit colonial nesting species such as the ibis, spoonbill, darter and cormorant.

- Lake Merreti has long been recognised by environmentalists as a site of great importance to the conservation of waterbirds. This study identifies that, through active management of the hydrology of Lake Merreti, this wetland can become even more significant to the conservation of waterbird species, especially during times of drought in south-eastern Australia.

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APPENDIX 8.1 BIRDS RECORDED UTILIZING LAKE MERRETI DURING THE 1985 TO 2001 SURVEYS

Australasian grebe	*Tachybaptus ruficollis*	Hardhead	*Aythya australis*
Hoary headed grebe	*T. novaehollandiae*	Australian wood duck	*Chenonetta jubata*
Great crested grebe	*Podiceps cristatus*	Musk duck	*Biziura lobata*
Australian pelican	*Pelecanus conspicillatus*	White-bellied sea-eagle	*Haliaeetus leucogaster*
Great cormorant	*Phalacrocorax carbo*	Swamp harrier	*Circus approximans*
Little black cormorant	*P. sulcirostris*	Australian spotted crake	*P. fluminea*
Pied cormorant	*P. varius*	Dusky moorhen	*Gallinura tenebrosa*
Little pied cormorant	*P. melanoleucos*	Black-tailed native-hen	*G. ventralis*
Darter	*Anhinga novaehollandiae*	Purple swamphen	*Porphyrio porphyrio*
White-necked heron	*Ardea pacifica*	Eurasian coot	*Fulica atra*
Great (large) egret	*A. alba*	Black-winged stilt	*Himantopus himantopus*
Intermediate egret	*A. intermedia*	Banded stilt	*Cladorhynchus leucocephalus*
White-faced heron	*A. novaehollandiae*	Red-necked avocet	*Recurvirostra novaehollandiae*
Little egret	*A. garzetta*	Masked lapwing	*Vanellus miles*
Cattle egret	*A. ibis*	Banded lapwing	*V. tricolor*
Nankeen night-heron	*Nycticorax calendonicus*	Common greenshank	*Tringa nebularia*
White ibis	*Threskiornis molucca*	Red-capped plover	*Charadrius ruficapillus*
Straw-necked ibis	*Threskiornis spinicollis*	Black-fronted dotterel	*C. melanops*
Glossy ibis	*Plegadis falcinellus*	Red-kneed dotterel	*C. cinctus*
Royal spoonbill	*Platalea regia*	Marsh sandpiper	*T. stagnatilis*
Yellow-billed spoonbill	*P. flavipes*	Red-necked stint	*Calidris ruficollis*
Black swan	*Cygnus atratus*	Sharp-tailed sandpiper	*C. acuminata*
Freckled duck	*Stictonetta naevosa*	Curlew sandpiper	*C. ferruginea*
Australian shelduck	*Tadorna tadornoides*	Silver gull	*Larus novaehollandiae*
Pink-eared duck	*Malacorhynchos membranaceus*	Whiskered tern	*Childonias hybridus*
		Gull-billed tern	*Gelochelidon nilotica*
Grey teal	*Anas gibberifrons*	Caspian tern	*Hydroprogne caspia*
Chestnut teal	*A. castanea*	Clamorous reed warbler	*Acrocephalus stentorrus*
Pacific black duck	*A. superciliosa*	Golden-headed cisticola	*Cisticola exilis*
Australasian shoveler	*A. rhynchotis*		

Chapter 9 ~ Management objectives and guidelines

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Reviewed by Dr. Sean White

INTRODUCTION

The water regime of Lake Merreti has undergone significant change since the 1930s, when low-level regulating weirs were established in the lower River Murray. The frequency of small to medium flooding events has reduced and water levels in Lake Merreti have become more stable (refer Chapter 2 Lake Merreti: A checkered history). For example, flooding events that inundate the riparian zone of Lake Merreti and support a suite of species with varying water stress tolerances are less frequent, while drying events that consolidate the lake bed sediments and improve conditions for aquatic plant growth upon refilling no longer occur naturally. It is difficult to quantify the changes that have occurred within the vegetation communities of Lake Merreti, however, it is probable that species suited to fluctuating water levels have been replaced by others favoring stable water levels. The management objectives for Lake Merreti aim to compensate for the shift in species composition by supporting a wide range of vegetative habitats through time.

MANAGEMENT OBJECTIVE

The management objective for Lake Merreti is to establish and maintain a range of habitats through time, including:

- a riparian zone with a range of species, in particular the newly established river red gum fringe
- emergent vegetation
- dry wetland bed vegetation
- submerged vegetation.

The desired outcome is wetland habitats that will support a diversity of native invertebrate, fish and bird species, and provide a summer and drought refuge for waterbirds.

GUIDELINES FOR MANAGEMENT

The recommendations in these guidelines address the management objective for Lake Merreti. These guidelines are based on three years of research and monitoring within this and other wetlands in the lower Murray (Siebentritt in prep) (van der Wielen in prep) (Tucker 2003g) (Smith 1999) (Miles 2000). The guidelines are also supported by the findings of other researchers that have been summarised in *Your Wetland: Supporting Information* (Tucker 2003g). These guidelines are intended to point managers in the right direction, indicating the best options for hydrological management currently available to achieve the management objectives for Lake Merreti.

Research has found that plant growth, survival and reproduction will respond readily to hydrological change (Blom *et al.* 1990) (Blanch *et al.* 1998) (Siebentritt in prep). The duration, rate, timing and frequency of filling and drying, as well as the depth of water, will influence the types of habitats that are created and thus the types of macroinvertebrates, fish and birds inhabiting a wetland. Since water regime is so important for the germination and survival of plants in wetlands, hydrological management can lead to a wide range of outcomes.

As shown in the outcomes of Table 9.1, a range of submerged, emergent and dry wetland bed habitats can be created in Lake Merreti when all components of the water regime (duration, rate, depth, timing and frequency) are considered. To achieve this range of habitats the suggested water regime for Lake Merreti incorporates several management stages (Figure 9.1, Table 9.1).

Chapter 9 ~ Management objectives and guidelines

Management stages

The management stages for Lake Merreti include partial and complete drying as well as working with natural river flow to enhance the duration of spring flooding of the wetland. Each of these management stages is interdependent. The responses that are observed following a single management event also reflect actions that have taken place in the past and may even be a result of a number of management actions. For example, several dry stages may need to be implemented before a response is observed in the submerged species. The seed bank of the wetland will be one of the limiting factors for the germination of plants. The history of water regime management will affect the types and amount of seeds in the seed bank. If particular species were absent from the seed bank as a result of extended periods of flooding, they would need to re-establish via propagules.

Complete dry

The complete drying of Lake Merreti from mid summer to early spring will support the germination of a range of dry wetland bed plants that provide nutrients and shelter for aquatic fauna once the wetland refills in early spring. The periodic complete drying from mid summer to early spring only needs to occur once the submerged vegetation starts deteriorating (Figure 9.1). Complete drying for approximately six months will consolidate wetland sediments and allow dry wetland bed plants to complete their life cycles and contribute to the seed bank. On refilling, the release of nutrients, warm temperatures and low re-suspension rates achieved from drying will create conditions suitable for the germination of submerged plant species.

Full (during river flows less than 15 000ML/day)

On refilling, nutrients are released (Baldwin and Mitchell 2000) (van der Wielen in prep) supporting algae and biofilms. Biofilms are the slimy growths of algae, bacteria and fungi that are found on submerged wood, aquatic plants and other surfaces. Gradually filling Lake Merreti in early spring should provide nutrient rich, warm and clear water conditions suitable for the germination of submerged plants (Johnstone and Robinson 1987). These plants provide habitat and an abundance of resources for invertebrates and small fish that, in turn, provide food resources for animals higher up the food chain like waterbirds and larger species of fish. The consolidation of sediments during the dry period will ensure that initially the sediment is not readily resuspended on refilling (van der Wielen in prep).

Once refilled, water should remain in Lake Merreti for approximately two years, ensuring submerged plants complete their life cycle by flowering and contributing to the seed bank or until the time when plants begin to break down (Figure 9.1). This guideline is based on the flooding duration required for ribbon weed to germinate, mature and set seed (Roberts and Marston 2000). This information is currently unavailable for other submerged species. It is, therefore, critical that the life stage of submerged species is monitored to make key decisions about changing the hydrology of Lake Merreti. Techniques for monitoring the life stage and abundance of submerged vegetation are outlined in *Your Wetland: Monitoring Manual* (Tucker in prep).

Partial dry

During the full stage, the structural diversity in Lake Merreti can be enhanced further by partially drying the edges of the wetland. Lowering water levels will encourage emergent plant species to move down the elevation gradient, increasing structural complexity on refilling and supporting the establishment of a new littoral zone. This management regime will also promote the survival of the newly established river red gum fringe. River red gum survival will be enhanced by removing water from the root zone of the trees in late summer of every year (Table 9.1).

To remove water from the root zone of the river red gums, water levels in Lake Merreti must be drawn down to 16.10 m AHD. In order to reach this desired level by late summer, the lake must be at pool by the end of January. Closure of the gates on the main inlet structure will allow further drawdown through evaporation. The partial drying event should be of approximately four months duration, with low water levels maintained throughout by manipulating the inlet valves, before opening the gates to reflood in late winter/early spring.

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Enhancing natural flooding (during river flows greater than 15 000ML/day)

To continue to support the survival of vegetation in the riparian zone of Lake Merreti, natural flooding can be enhanced through structure management. (For the purposes of this report flows exceeding 15 000 ML/day are considered natural flood events.) Closing the wetland inlet at the peak of a small to medium spring flood, or after large floods have receded to 50 000 ML/day, will enable the duration of flooding in the riparian zone to be extended to mimic more natural flooding lengths (approximate total flooding length 4-7 months). Increasing flood duration will continue to support mature river red gums, lignum and river cooba in this area (Table 9.1). However, care should be taken when extending the flooding of the riparian zone area as experiences in the Barmah Forest have shown that shallow flooding over hot summer months can cause moisture stress and death of mature river red gums (Dexter *et al.* 1986). Once the spring flooding period is over, water levels should be lowered and Lake Merreti partially dried to continue the cycle of water regime management and ensure the survival of the newly established river red gums.

To achieve the partial drying in late summer, drawdown after an enhanced flood event must be timed so that Lake Merreti is at pool level (16.30 m AHD) or floating with Ral Ral Creek by the end of January. The rate of drawdown is determined by the number of inlet pipes open and the head difference between the lake and Ral Ral Creek. It is estimated that lake levels will drop by at least one metre over 30 days if both inlet pipes are open and there is a head difference of at least 50 cm (i.e. an average rate of approximately 3 cm/day). However, if lake salinity exceeds 700 EC the Cooltong Irrigators need to be consulted (via Central Irrigation Trust) regarding the rate of release. Water releases will be restricted to a single pipe when the salinity of the lake is significantly greater than that of Ral Ral Creek. Such a restriction will impact upon the drawdown timeframe and must be taken into account so that pool level will still be reached by late January. Hence, biweekly monitoring of lake salinity throughout the extended flood event is essential so that the timing of drawdown can be adjusted when necessary.

At present, small to medium flood events (15 000ML/day – 50 000ML/day) have little effect on lake water levels due to the low capacity of the main inlet structure and short duration of the high flow events. It is recommended that works to increase the hydrological capacity of this structure be undertaken as soon as possible to take full advantage of these flood events.

Reducing carp abundance

In large numbers carp are known to increase the turbidity of wetlands (which may influence the germination and survival of submerged plants) and uproot submerged vegetation (Robertson *et al.* 1997) (Roberts and Ebner 1998) (Roberts *et al.* 1995). However, carp are as much a symptom of a changed environment as they are a cause of the problems. Concentrating on habitat management rather than managing for a single species (e.g. carp) will have benefits for a wide range of wildlife in the wetland.

One of the advantages of a managed wetland water regime is the reduction in carp abundance when the wetland is dried. The subsequent use of fish screens that exclude large fish on wetland inlets can maintain low numbers of large breeding sized carp in the wetland for some time. Removable fish screens have been installed on the main and temporary inlets to Lake Merreti. The fish screens generally remain in place during non-flood conditions but should be removed to facilitate the passage of large native fish when high river flows (> 40 000ML/day) occur. The fish screens should not then be replaced until after a complete drying event. Of the large native fish species, only bony bream are likely to be disadvantaged by this management action, as they readily inhabit wetlands and backwaters at low flows. Species such as callop tend not to use wetlands until high river flows occur and, therefore, are unlikely to be disadvantaged.

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Figure 9.1 Decision framework for managing Lake Merreti

Note: This diagram should be used in conjunction with Table 9.1. Rectangles represent the management stages described in detail in Table 9.1, while the habitats supported by that stage are shown in ***bold italics***. Diamonds represent decisions to be made about whether to change management, based on river flow and monitoring outcomes (Table 9.1). The shaded and non-shaded sections show the approximate season in which the management stages begin and when decisions should be made. Some management stages finish after a given time, this is shown in **bold** and is also outlined in Table 9.1.

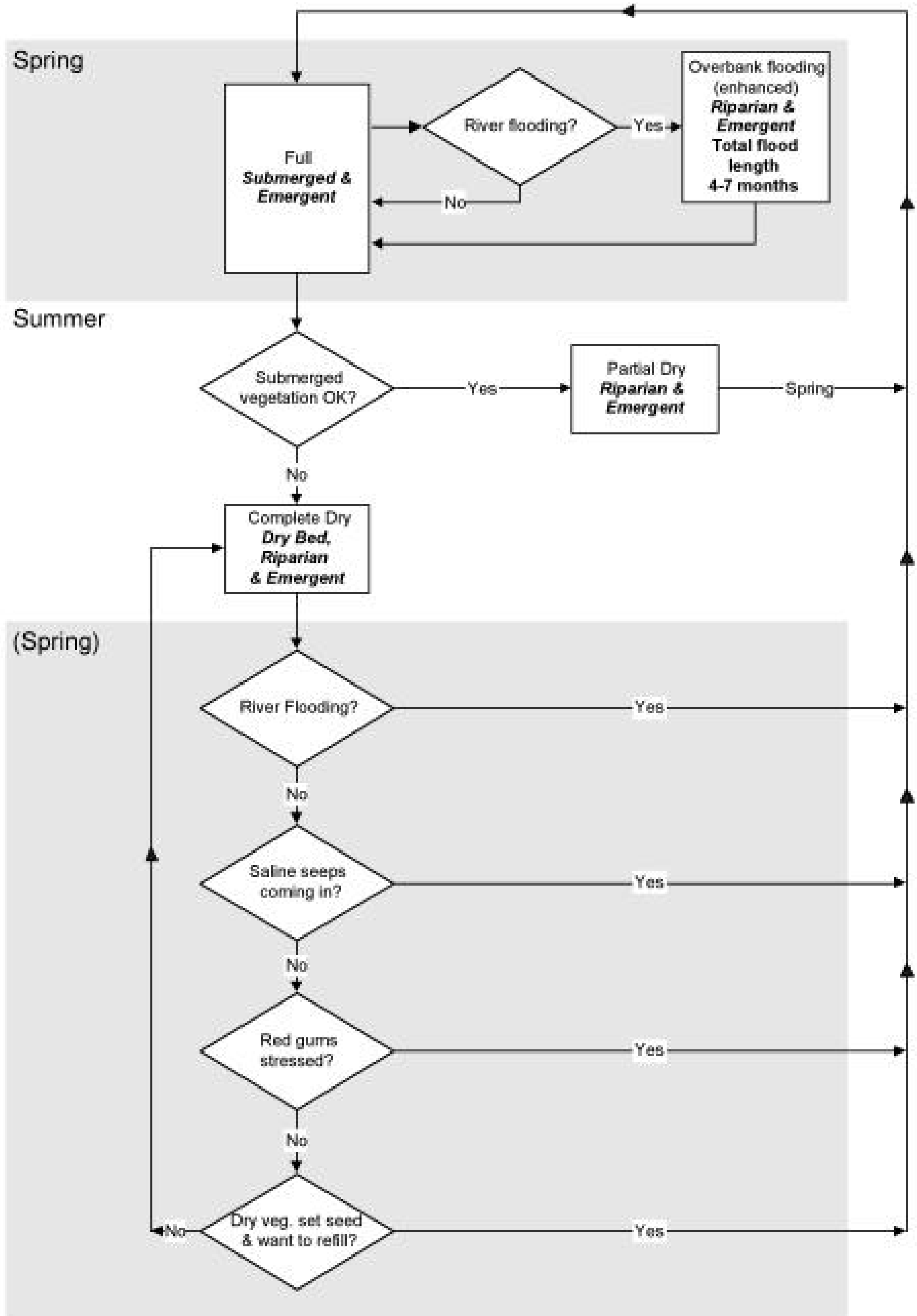

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Table 9.1 Management Guidelines for Lake Merreti

Water Regime	Completely dry	Full (flow <15 000ML/day)	Partially dry	Enhanced natural flooding (flow >15 000ML/day)
Outcomes	• Establish dry wetland bed vegetation and support species that persist during the wet to provide habitat on refilling • Allow dry-bed plants to complete their life cycle and contribute to the seed bank • Kill carp • Consolidate the lake bed	• Create habitat for fish, invertebrates and birds by supporting an abundance of submerged and emergent vegetation • Allow submerged and emergent vegetation to reach sexual maturity, flower, and contribute to the seed bank	• Maintain the newly established river red gum fringe • Continue to support submerged vegetation and a range of emergent vegetation that may move down the elevation gradient	• Increase the duration of flooding in the riparian zone by enhancing flooding flows (>15,000 ML/day) • Reduce water stress of riparian species such as river red gums and river cooba
Actions	Dry wetland	Fill wetland	• Partially dry to below the newly established river red gum fringe • Maintain lake level at 16.10 m AHD by operating valves	• Close structures on all inlets once natural flood waters peak or recede to 50 000 ML/day • Remove carp screens when over-bank flows occur
Timing	Begin drying in mid-late spring to ensure lake is dry by the end of January	Fill in early spring	Partially dry in late summer	Spring – summer (depending on natural flows) Commence drawdown at end of December to achieve partial dry by late summer
Duration	Approximately 3-6 months to dry completely, then remain dry until early spring	Approximately 4 – 6 months	Approximately 4 – 6 months	Until December in each flood year
Frequency	Variable, dependent on monitoring findings	Every year, except years of complete drying	Annually	Variable, dependent on natural flooding conditions
Rate	Evaporative	Fill as slow as possible - less than 1cm per day to allow submerged species to germinate and emergent species to survive	Evaporative	Fill at the rate determined by the flood Drawdown at a rate that will prevent bank slumping and the rate determined by the head difference between Lake Merreti and Ral Ral Creek
Depth	Completely dry	Maximum	16.10 m AHD	Maximum
Monitoring for Adaptive Management	• Record changes to dry wetland bed vegetation and ensure plants contribute to the seedbank (Tucker in prep) • Monitor the salinity and thickness of the freshwater lens under the lake bed and riparian zone (Tucker in prep)	Record changes to submerged vegetation, and dry the wetland once submerged plants have set seed and started to deteriorate (Tucker in prep)	Monitor the health of river red gums at the edge of the wetland basin (Tucker in prep). Ensure trees are supported by the proposed water regime by wetting/drying when they exhibit signs of stress	• Monitor the health of indicator species (e.g. river red gums) (Tucker in prep) and dry the area when trees exhibit signs of stress • Monitor lake water salinity biweekly to determine rate and timing of water releases

Note: An approximate or minimum duration has been outlined in Table 9.1, but the actual duration and frequency will need to be based on the monitoring results (Monitoring for Adaptive Management).
Details on how to carry out Monitoring for Adaptive Management are outlined in the *Your Wetland: Monitoring Manual* (Tucker in prep).

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Table 9.1 Management Guidelines for Lake Merreti *cont.*

Water Regime	**Completely dry**	**Full (flow <15 000ML/day)**	**Partially dry**	**Enhanced natural flooding (flow >15 000ML/day)**
Risks	Increase in groundwater salinity through the loss of the freshwater lens due to drying the lake for too long or too frequently	Keeping water in the root zone of river red gums for 18 to 24 months is likely to stress / kill this species	Increase in abundance/dominance by bulrush, which will out-compete other plant species and limit habitat diversity	Stress / death of river red gums from: • keeping water in the root zone for 18 to 24 months • enhancing consecutive floods that are not interspersed with a partial dry • shallow flooding over hot summer months (Dexter *et al.* 1986) Increased flood frequency in the riparian zone (e.g. seasonally) will alter the understorey species composition (Roberts and Marston 2000) Fish screens can inhibit the movement of large native fish between the river and wetland habitats during and after over-bank flows

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MANAGEMENT RISKS

In wetland management it is just as important to consider the *limitations* and *risks*, as it is to understand the options for management. There are at least three golden rules that should always be followed regardless of what stage the management regime is at. These rules, and the associated risks should they be broken, are outlined in detail in Box 9.1.

Box 9.1

The GOLDEN RULES

...of managing wetlands

The following rules should prevail over all decisions you make about managing your wetland.

THEY SHOULD NEVER BE BROKEN!

Don't kill long lived vegetation

Understand the water stress tolerances of species such as lignum (*Muehlenbeckia florulenta*) and red gums (*Eucalyptus camaldulensis*) to ensure their survival is not compromised by your water regime management. Maintaining established red gums requires an average flood frequency of 1-3 years, not lasting for more than 18-24 months [Leitch, 1989 #1749] [Roberts, 2000 #1706]. Experiences in the Barmah Forest have shown shallow flooding over hot summer months caused moisture stress and death of mature red gums [Dexter, 1986 #1750]. Lignum require an average flood frequency of 1-8 years, not lasting for more than 3-5 months [Roberts, 2000 #1706]. Complete drying between flood cycles is required for both of these species [Roberts, 2000 #1706].

Don't salinise your wetland

Ensure that you understand the groundwater processes under your wetland before you embark on an extended drying. Ensure there is a freshwater lens (layer of freshwater under a dry wetland) and monitor its integrity through a number of dry stages.

Let big floods through. This will ensure the difference in water height between the wetland and floodplain is minimized reducing hydraulic pressure and lowering the risk of saline regional groundwater to rising to the surface in, and at the edges of, your wetland.

Don't destroy threatened communities or habitats of threatened species

Get to know your wetland before you change anything. Learn about its flora and fauna to ensure that changing the water regime will not compromise the habitats of threatened species and communities.

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In addition to the golden rules, there are also a number of management risks that should be avoided in order to achieve management objectives. These risks are summarised below.

Rapid filling (greater than 3cm/day)
In wetlands that are greater than 50 cm deep, rapid filling is likely to limit the germination and consequent survival of *submerged plant species*. Generally, as water depth increases the amount of light reaching the sediment surface will decrease. Low light conditions resulting from deeper water will limit the germination of this group of species. Filling should be slow so plants have a chance to grow and stay close to the surface. In Lake Merreti, this is mainly a consideration when there is a large head difference between Ral Ral Creek and the lake. Generally, the rate of filling will not reach greater then 3 cm/day.

Short dry (less than 3 months)
Few dry wetland bed plants will establish in the basin of the wetland during a short dry period (Tucker 2003e). Dry wetland bed plants that germinate e.g. knotweed (*Persicaria spp.*) will utilize some of the nutrients released when the wetland refills. If there is limited germination of these species during the dry stage, the nutrients that are released from the sediments on refilling will not readily be taken up by plants, and conditions suitable for the abundance of algae may be created.

In wetlands with clay sediments, an increase in the length of drying is likely to result in an increase in sediment consolidation. The greater the consolidation effect, the less likely it is that sediment can be readily re-suspended on refilling (van der Wielen in prep). If wetland sediments are not strongly consolidated, the re-suspension of sediments could reduce the amount of light reaching the sediment surface and the low light conditions will limit the germination and survival of submerged species (Roberts and Marston 2000).

Long wet (in the riparian zone)
Inundation of the riparian zone for an extended period is unlikely to be a major consideration for Lake Merreti unless there are two consecutive years of natural flooding. If the natural floods were enhanced in both years, plants in the riparian zone may be inundated for longer than they can tolerate. To avoid this, the specific water stress tolerances of plant species (e.g. river red gum and lignum) should be considered.

River red gums can only tolerate flooding in their root zone for up to 18 –24 months before exhibiting signs of stress. Lignum is less tolerant of extended periods of flooding, only coping with 3 - 5 months of water before dying (Roberts and Marston 2000) (Leitch 1989). Experiences in the Barmah Forest have shown that shallow flooding over hot summer months resulted in moisture stress and death of mature river red gums (Dexter *et al.* 1986).

Long dry (greater than 6 months during warm months)
Drying a wetland for a period greater than six months can alter groundwater dynamics and result in the seepage of saline groundwater into the wetland. If Lake Merreti is dried for an extended period, the thickness of the freshwater layer under the wetland (freshwater lens) could be affected. Extended dry periods may result in the evaporation of the freshwater layer and deposition of salts in the surface soil of the wetland through capillary action.

In some cases, the expansion of dry wetland bed vegetation during extended dry stages may create unfavorable conditions for aquatic fauna once the wetland refills. Low oxygen conditions could occur when the dry wetland bed vegetation breaks down after flooding. The expansion of species such as the native water couch can occur in wetlands where drying does not limit their expansion (e.g. groundwater remains high during the dry stage). Species such as water couch are of particular concern because they rapidly expand to cover the bed of the wetland during the dry stage and have a soft structure that breaks down readily on refilling, predisposing the wetland to low dissolved oxygen conditions.

MONITORING

Monitoring is essential to adaptive management of wetlands because it assists in deciding when to change the wetland water regime and allows the evaluation of the success of the wetland management project. Two types of monitoring are outlined below:

- Operational monitoring: basic monitoring required when managing the wetland and making decisions about when to change water regime management
- Monitoring objectives: more detailed monitoring required to understand responses to wetland management, document changes and evaluate management.

Details on techniques that can be used to implement the monitoring are outlined in *Your Wetland: Monitoring Manual* (Tucker in prep). The specific frequency for monitoring in Lake Merreti is outlined below.

Operational monitoring

Management records

Maintain a management log book to record management actions and key biological responses e.g. growth of submerged vegetation, colonisation by carp (Tucker in prep).

Surface water

Water levels

Maintain water level monitoring in Ral Ral Creek and in the deepest part of Lake Merreti using data loggers. Collect real time water level data to make informed decisions about management, record water levels off of gauge boards in Lake Merreti and Ral Ral Creek on a weekly basis.

Water quality

Monitor turbidity and surface water salinity to:

a) develop a better understanding of the water quality responses to consecutive drying
b) ensure that managing water levels after flooding will not significantly increase the salinities recorded in Ral Ral Creek.

Initially water quality should continue to be monitored at several sites along the north-south axis of the lake. Once it is established that no salinity gradient exists, a single accurately measured sample in the middle of Lake Merreti (site 3) will be adequate for assessing the water quality of the lake. Water quality monitoring sites in Ral Ral Creek located upstream and downstream of the wetland inlet are also required to assess any potential impacts of Lake Merreti on the water quality of the creek.

During non-flood conditions water quality data should be collected seasonally, and monthly during drying and refilling. When Lake Merreti water is being held above the level of Ral Ral Creek to enhance the duration of flooding, water quality data should be collected more frequently (twice weekly) to assess the salinity impacts of releasing water from Lake Merreti into Ral Ral Creek.

Groundwater

Broad scale floodplain

Maintain the water level data loggers in the piezometers adjacent to Lake Merreti to improve our knowledge of the ways in which managing water levels in the lake influence regional groundwater patterns.

Riparian

Monitor the salinity and water depth of piezometers in the riparian area at the end of summer each year, prior to drying the lake and every three months while drying.

Lake bed

Survey the salinity and groundwater depth in the lake bed piezometers (two sites) at the end of summer each year, prior to drying Lake Merreti, in the middle of the dry period, and just prior to refilling. This information will assist in determining if drying Lake Merreti is affecting the integrity of the freshwater lens. Sampling groundwater depth and salinity prior to drying will also provide an indication of the 'recharge' effect of the inundated period. The installation of data loggers on some of the lake bed piezometers will provide greater insight into the groundwater processes occurring under the lake because, at present, significant detail is being missed due to intermittent sampling.

Measure soil salinity to improve the understanding of how flood duration influences surface water – groundwater interactions. Soil samples should be collected when monitoring the lake bed groundwater at locations adjacent to the two nested piezometer sites. Samples should be collected and analysed for salinity and water content as per the methods outlined in *Your Wetland: Monitoring Manual* (Tucker in prep). The results will identify the 'wetting front' in the soil profile that will, in turn, determine the depth of influence of the flooding event.

Vegetation

Emergent, dry wetland bed and submerged species

In conjunction with the quantitative data collected when monitoring objectives (see below), previously established photopoints should be used to monitor changes to the vegetation communities. The photographs will document the germination, reproductive stage, survival and vigor of groups of species, and can be used to assess the need to alter the wetland water regime. Initially, photos should be taken in the middle of spring and at the end of summer each year, however, this may be reduced to summer only if seasonal changes are limited. Photos should also be taken at key times in relation to management i.e. prior to filling and during filling to record the germination of plants (Tucker in prep).

Riparian species

Monitor the condition of long-lived riparian vegetation including river red gums, river cooba and lignum to identify early signs of stress. During low flow conditions, assess the health of trees and take photographs of the lignum in spring. Select trees that will be influenced during enhanced flooding conditions (areas affected by a 50 000 ML/day flood) and trees that will not be affected by managing water levels (e.g. along Ral Ral Creek) to act as controls (Tucker in prep).

When water levels in Lake Merreti are being managed to enhance floods or the wetland is being dried, monitor the health of vegetation more frequently. Prior to commencing an extended dry period, assess health of vegetation, repeat monitoring mid drying and prior to refilling. When floods are being enhanced, monitor prior to enhancing flooding, mid enhanced flood and prior to drying. During enhanced flooding monitoring may need to occur more frequently if a response in the vegetation is observed.

Macroinvertebrates

Monitor the macroinvertebrate fauna to indicate how the management of the water regime and subsequent changes in resource availability (e.g. plant habitat and nutrients) influences this community. Surveys should be conducted annually in spring-summer at a minimum, but preferably seasonally. Sample methods are outlined in *Your Wetland: Monitoring Manual* (Tucker in prep) and collected macroinvertebrates should be identified to family level.

Fish

Survey the fish community to assess the status of the carp population and ensure native fish diversity is being supported by the wetland water regime. Monitoring should be carried out in late spring/early summer, as this is when fish activity is highest and when river floods occur. Ral Ral Creek should be sampled together with the wetland to gauge fish passage through the inlet structure. All sampling should be carried out using fyke nets, which allow large and small fish to be captured at a range of water depths.

Monitoring objectives

Vegetation

Emergent, dry wetland bed and submerged species

The data collected to monitor the habitat objectives for Lake Merreti can also be used to assess when to change the water regime. Use the techniques already established for monitoring vegetation at Lake Merreti to assess the cover, life stage and extent of vegetation in and around the wetland basin.

Concentrate on monitoring vegetation at these key times:

- during wet stage: survey vegetation mid refill to assess germination success (e.g. 2 months after filling during warm seasons)
- during partial drying: monitor once drawdown reaches the emergent fringe
- during dry stage: end of dry phase (just prior to refill)
- prior to drying the lake to determine if submerged plants have flowered and set seed. Additional surveys may need to be undertaken if results do not show a significant percentage of vegetation flowering.

CONCLUSION

Ecologically sound and adaptive wetland management requires a consistent and rigorous monitoring program. Such a program must involve not only collecting but also interpreting the data to assess the results of management against the management objectives and the golden rules of managing wetlands (Box 9.1). This information is critical for making decisions for future management, such as if or when to alter management actions or perhaps even the management objectives.

The hydrological management guidelines for Lake Merreti described in this report were formulated from over 20 years of research findings, monitoring and experience in wetland management. This is a step towards ensuring that the current management objective for Lake Merreti is achieved. The rest is in the hands of the future managers of this precious natural resource.

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Table 9.2. Suggested monitoring timetable for Lake Merreti

Parameter	Technique referred to in *Your Wetland: Monitoring Manual*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Operational Monitoring Management log book		a	a	a	a	a	a	a	a	a	a	a	a
Surface water													
Water levels	Reading gauge boards	a	a	a	a	a	a	a	a	a	a	a	a
	Dataloggers – download 3 monthly	a			a			a			a		
Water quality	9 (surface water sampling)*	a			a			a			a		
Groundwater													
Broad scale floodplain	Data loggers in existing floodplain piezometers – down load 3 monthly	a			b			a			b		
Riparian	7 (gradient monitoring)*	a											
Lake bed	8 (freshwater lens)*	a											
Vegetation													
Emergent, submerged & dry bed vegetation	3 (photopoint monitoring)*		b								a		
Riparian vegetation	5 (health assessment)*										b		
Wetland fauna													
Macro-invertebrates	15 (dip net survey)												a
Fish	13 (fyke net survey)*												a
Objective Monitoring / Operational Monitoring													
Vegetation													
Emergent, submerged & dry bed vegetation	Use quantitative survey techniques already established at Lake Merreti~												

* Parameter to be monitored more frequently when management changes e.g. during enhanced flooding, refilling or drying (see notes on previous page)

~ timing of quantitative vegetation surveys determined by management actions (see notes on previous page)

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