Murray Wetlands Management and Water Recovery Initiatives: Rapid assessment of fisheries values of wetlands prioritised for water recovery

Dean Gilligan, Alison McLean and Allan Lugg

NSW Department of Primary Industries
Aquatic Ecosystems Research
Batemans Bay Fisheries Office
PO Box 17, Batemans Bay, NSW 2526
Australia

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NON-TECHNICAL SUMMARY

Murray Wetlands Management and Water Recovery Initiatives: Rapid assessment of fisheries values of wetlands prioritised for water recovery

PRINCIPAL INVESTIGATORS: Dean Gilligan [1]
Alison McLean [2]
Allan Lugg [3]

ADDRESS: 1 – NSW Department of Primary Industries, Batemans Bay Fisheries Office, PO Box 17, Batemans Bay NSW, 2536.
Telephone: 02 4478 9111 Fax: 02 4472 7542.
2 – NSW Department of Primary Industries, Monaro Fisheries Office, Kosciusko Road, Jindabyne NSW 2627.
3 – NSW Department of Primary Industries, Huskisson Fisheries Office, PO Box 97, Huskisson NSW 2540.

NON TECHNICAL SUMMARY:

The current prolonged drought has led to declining inflows to the Murray River since October 1996, with the period since September 2001 being the 2nd driest seven year period on record. At a summit on the Murray-Darling Basin on 7 November 2006, the Prime Minister and the Premiers of New South Wales, Victoria and South Australia asked officials to examine contingency planning to secure urban water supplies during 2007-08. Concurrently, the NSW Department of Environment and Climate Change (DECC) were identifying opportunities for water savings to provide environmental flows under the Murray-Darling Basin Authority's *The Living Murray* program. A critical factor for water savings is the need to minimise the evaporative losses from permanently inundated wetlands. The aim of this project was to survey the fish assemblages existing within 20 permanently inundated wetlands identified by these initiatives as potentially suitable for temporary or permanent water savings, to ensure that proposed wetland disconnections did not impact on any species listed as threatened or of conservation significance and to recommend a monitoring strategy for those wetlands where ongoing managed wetting-drying cycles will be implemented.

Three of the wetlands had already commenced to dry after being disconnected from the Murray River by low river levels within the channel. The remaining 17 wetlands provided habitat for nine species of native fish and four alien fish species. Native Carp-gudgeons were by far the most abundant species, being over six times more abundant then the next most abundant fish. Other relatively common native fishes were Flat-headed gudgeon, Un-specked hardyhead and Australian smelt. The second most abundant fish was the alien Eastern mosquitofish. Alien Redfin perch and Common carp were also common. Despite being only the 7th most abundant species, carp, made up 87% of the total biomass and the four alien species combined made up 93% of the fish biomass within the wetlands. Therefore, although native fish dominate the fish assemblages within the wetlands numerically, and several native fish species where present, alien fish vastly dominate the wetlands in terms of their biomass. The four common native species and three of the alien species (Common carp, Goldfish and Eastern mosquitofish) were found in a majority of wetlands sampled. In contrast, alien Redfin perch were most abundant in and largely restricted to wetlands of the Murray River in the Albury to Mulwala reach, whereas the remaining native fishes were absent from these wetlands and were only found in wetlands of the Edward River or the Euston Lakes.

The only threatened species, or species of conservation concern detected within the wetlands were a single silver perch collected in Tumudgery Creek and seven Murray cod collected from Mutton Gut Lagoon (four individuals), Mooloomoon Lagoon (2 individuals) and North Dale Lagoon (1

individual). Although we did not collect any during our sampling, concurrent sampling by the Murray Darling Freshwater Research Centre had detected an important population of Freshwater catfish in Washpen Creek – one of the wetlands prioritised for drought water recovery. The remaining seven species of native fish detected within wetlands range from being common to abundant throughout the river channels and/or wetland systems of the Murray and Edward Rivers. Although, all are elements of the Endangered Lower Murray Aquatic Ecological Community, the fact that they are common and widespread in adjacent river systems suggest that the temporary loss of 20 individual wetland habitats will have negligible impacts on the status of their populations.

Based on our data and that reported by McCarthy *et al.* (2007) we conclude that with the exception of Washpen Creek in the Euston Lakes system, there is no evidence that temporary isolation of the 19 other prioritised wetland systems from the river channels would have any long-term environmental impacts. Apart from Washpen Creek, none of the wetlands sampled provided critical drought refugia for native fish and there is no justification for eliminating the prioritised wetlands surveyed from further consideration of water recovery actions. In fact, the poor ecological state of most wetland fish communities, with 93% of the biomass comprising alien pest fish, suggests that the isolation and drying of these wetlands may have nett positive ecological outcomes.

Not only will isolation of the wetlands prevent substantial populations of pest fish from returning to the river, but the resultant drying of the wetland sediments is also likely to have positive effects on many aspects of the wetlands ecological processes. However, to ensure the post-dry re-colonisation of native fishes, the regulators installed and the manner in which flows are delivered to the wetland should provide acceptable fish passage conditions for native fish. Consideration should be given to the installation of carp screens on regulators to exclude carp and perhaps large redfin perch.

The mapping data collected during this project has indicated that the vast majority of structural complexity and cover for aquatic organisms exists around the perimeter of the wetlands. This suggests that the habitat quality of wetlands is greatest when they are full. Therefore, the habitat values of the wetland should be expected to decline relatively quickly after a wetland has been isolated from the river channel. Remnant fish communities within drying wetlands would then experience increased exposure to bird predation and the wetland would have a reduced capacity to sustain fish populations. Therefore, our final recommendation is that when wetlands are re-filled, they should be filled to capacity and maintained at that level for a sufficient period of time for the fish community to reach a mature successional stage. Management actions should then be taken to give fish communities in the wetland an opportunity to move into the river channel (perhaps facilitated by attractant flows etc.) before the regulator gates are closed at the commencement of the next drying phase. However, embarking on an ongoing regime on managed wetting-drying cycles in the prioritised wetlands is far from a simple exercise and a substantial adaptive management process would be required in order to sustain any planned ongoing water savings.

The recommended adaptive management framework requires that any wetland management actions taken should be associated with at least some basic level of data collection. As a bare minimum, wetland fish communities should be re-surveyed prior to each disconnection to ensure that no populations of threatened fishes have colonised the wetland and established significant populations. However, access to a number of replicate regulated wetlands, that can each be managed independently, provides significant opportunities for improving 'fish friendly' wetland management practices. To maximise the knowledge gained, we advise that management actions taken represent a spectrum of alternatives rather that a uniform management protocol applied across all wetlands. These 'adaptive management exercises' would require more intensive monitoring, including the minimum pre-disconnection survey, in addition to sampling shortly after re-connection and at six monthly intervals (during spring and summer) each year that the wetland remains full.

KEYWORDS: Wetland, billabong, freshwater fish, water recovery, drought, drought management

1. INTRODUCTION

The current prolonged drought has led to declining inflows to the Murray River since October 1996, with the period since September 2001 being the 2nd driest seven year period on record (MDBC 2008). The 2006/07 financial year had the lowest inflows to the Murray system on record (Figure 1), with inflows to the Murray River being only 60% of the previously recorded minimum.

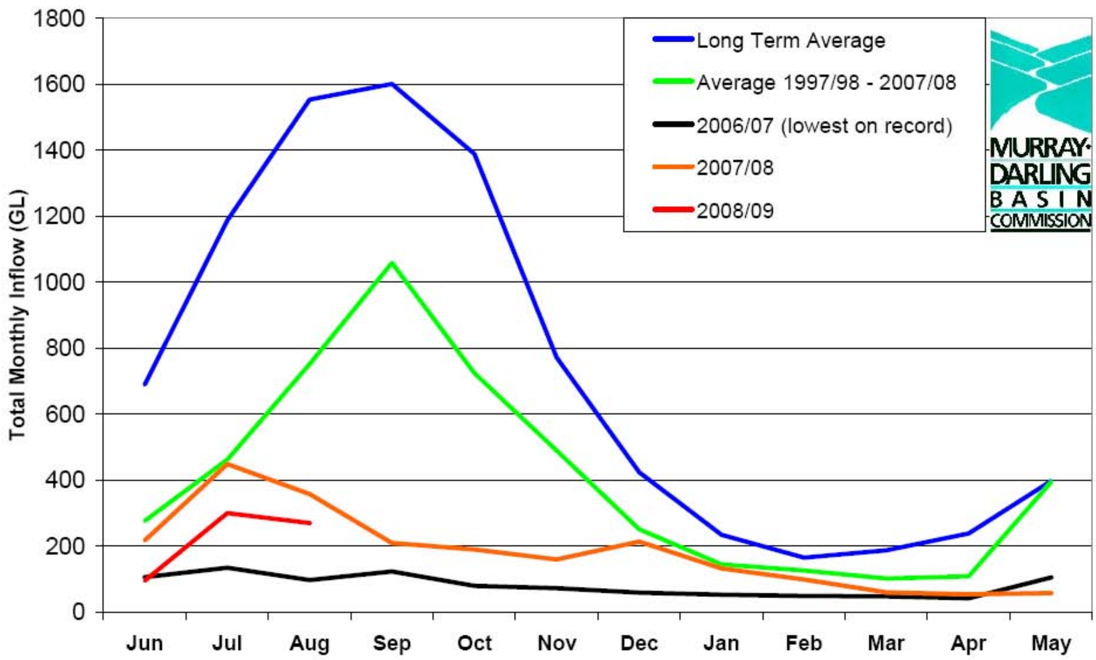

Figure 1. Murray system monthly inflows excluding Darling inflows and Snowy diversions (Source: MDBC 2008 – http:///www.mdbc.org.au).

At a summit on the Murray-Darling Basin on 7 November 2006, the Prime Minister and the Premiers of New South Wales, Victoria and South Australia asked officials to examine contingency planning to secure urban water supplies during 2007-08. If drought conditions continued throughout 2007, or if inflows were in the lowest 1% per cent of years on record, special measures were needed to ensure the supply the critical water needs of many towns, in particular Adelaide, which are reliant on water from the Murray River system. Although the possibility of there being sufficient water for urban supplies was higher than the possibility that there would not be, contingency plans against the risk of facing another very dry year needed to be put in place. With adequate preparation and actions, the critical demands of urban areas, towns and isolated households relying on the water supply systems of the southern Murray-Darling Basin could be met, even if the drought persisted throughout 2007.

Concurrently, the NSW Department of Environment and Climate Change (DECC) was investigating options to reduce evaporative losses from permanently inundated wetlands in order to secure environmental water for the Murray-Darling Basin Authority's *The Living Murray* (TLM) program.

A critical issue to maximise the water supply available for towns and to secure water for the TLM program is the need to minimise the losses from the river known as transmission losses. A significant component of transmission loss is the evaporative loss. Evaporative loss can be managed by minimising the surface area of water. Wetlands that are permanently inundated by elevated flows or raised weir pools in regulated reaches substantially increase the surface area of the system and consequently increase the rates of evaporative loss. Disconnecting these wetlands from the main river channel would reduce transmission losses. Disconnection of sites would involve closing regulators or gates where they are present, or the construction of permanent or temporary block-banks or regulators (or equivalent) at the connection with the main river channel or anabranch/creek. Water savings would be from reduced evaporation and where approved, pumping or draining of residual water back into the river channel.

The proposal under the drought water recovery plan for the Euston lakes, Back Creek and Tumudgery Creek was for the temporary disconnection of the wetlands until such time that sufficient water resources are available to ensure an ongoing supply. In contrast, the TLM program proposes to install permanent regulatory structures at the wetlands inlets which will ensure ongoing minimisation of evaporative losses, but also offers potential to manage the wetlands on an ongoing basis by reinstating managed wetting-drying cycles. A process that if undertaken appropriately, offers potential for improving the ecological health of the wetlands.

While further environmental and feasibility assessments were undertaken, including identification of alternative options for water supply, a number of sites were identified that had potential for significant evaporation savings through disconnection.

Proposed disconnections are subject to State and Federal legislation and should address the following principles:

1. Where there is no baseline data on environmental values, including whether the site is now a drought refuge, a rapid appraisal is required before any decision is made;
2. No approval be given to disconnect a wetland where evidence suggests long term environmental and water supply damage (e.g., from salinity intrusion);
3. Critical drought refuges should be maintained;
4. A consumptive user impact appraisal is required, including the potential for long-term water quality and human health impacts of wetland salinisation and development of acid sulfate soils;
5. Monitoring before, during and after disconnection is mandatory, with a focus on detecting saline intrusions, development of acid sulfate soils and loss of key species;
6. Where possible, works should be designed to facilitate long term water level management of the site.

The fish faunas occurring within wetland systems in the Murray-Darling Basin are poorly understood, as most broad-scale survey effort has focussed on river channels (Harris and Gehrke 1997; Davies *et al.* 2008). In most cases, no data on fish community composition within individual wetlands exists. Given its importance in the decision making process regarding wetland management, fish community data was urgently required.

The aim of this project was to rapidly identify and quantify the fishery values of those wetlands prioritised for disconnection from the Murray River channel. This was achieved by:

1. Sampling fish communities within prioritised wetlands.
2. Generating a list of fish species detected, including identification of any species listed as threatened or of conservation significance
3. Providing advice as to whether the site should be eliminated from further consideration due to the importance of the site for threatened fish species and/or whether additional sampling should be undertaken in adjacent river reaches to determine if the specie(s) in question exists outside the wetland.

And for those wetlands where installation of permanent regulator structures was proposed:

4. Propose a general monitoring strategy for ongoing assessment of the status of key species.

Three individual assessments were tendered by the NSW Department of Environment and Climate Change for three separate regions of the Murray catchment:

- Murray River wetlands from Albury to Lake Mulwala (*The Living Murray* program).
- Edward River wetlands (*The Living Murray* program).
- Back Creek and Tumudgery Creek (Drought water recovery plan).

A fourth assessment was tendered by the NSW Department of Water and Energy for an addition ‘region’.

- Euston Lakes and tributaries (Drought water recovery plan).

The results of these fish community surveys where provided to the relevant tenderer within 24 hours of their collection. This document presents the results of these four tenders as a single combined final report.

2. METHODS

2.1. Sites

The sites surveyed where those identified by the NSW Government as priorities for potential water savings. They represent those permanently inundated wetlands where modelled evaporative losses from each were considered to be significant.

Table 1. UTM coordinates (Zone 55) of the wetlands identified as potentially suitable for proposed works.

Wetland Name	MWWG Identifier*	Easting	Northing
Murray River Wetlands (Albury to Lake Mulwala)			
Cooks Lagoon	8212	484960	6008218
Quatt Quatta	7413	462049	6018626
Big Barren Lagoon	7410	460250	6018802
Chick Logie East	7369	458420	6020035
Chick Logie Lagoon	7339	458297	6020360
Snake Island Lagoon	7312	456593	6020528
Croppers Lagoon	7804	439484	6013224
Edward River Wetlands			
Moona Lagoon	5432	286750	6082500
Mutton Gut Lagoon	5335	276720	6090110
Yadabal Lagoon	5254	267260	6094490
Woorooma Lagoon	5047	238490	6108660
Smith’s Lagoon	5025	233880	6110850
Mooloomoon Lagoon	2740	218950	6114840
North Dale Lagoon	2624	208440	6120910
Back Creek and Tumudgery Creek			
Back Creek	5638	297697	6073586
Tumudgery Creek	5465	286802	6080517
Euston Lakes and tributaries			
Lake Benanee	1437	673473	6175144
Dry Lake	1426	667882	6178410
Washpen Creek	1455	667919	6173850
Taila Creek	1445	666321	6175310

**Murray Wetland Working Group Number.*

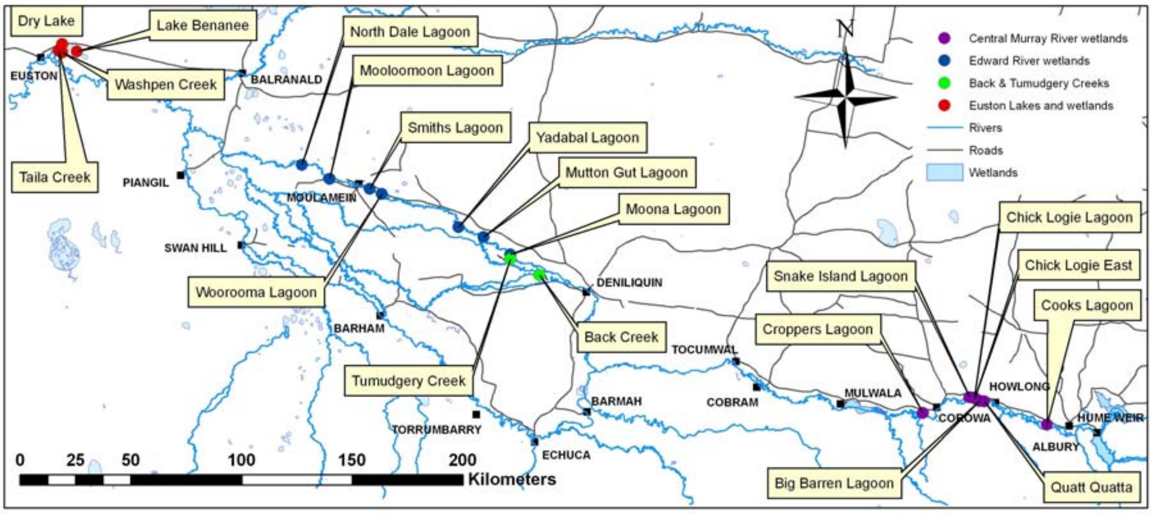

Figure 2. The location of wetlands surveyed as part of this project.

2.2. Fish sampling

Fish sampling was undertaken between 27 February and 5 September 2007.

The sampling procedure used was based on both the standardised sampling procedure developed for the SRA program (MDBC 2006) as well as a wetland sampling procedure similar to that used by Ho *et al.* (2004) and recommended by Baldwin *et al.* (2005). The SRA procedure is based on electrofishing (either boat, back-pack, bank mounted, or a combination of each depending on local conditions) with additional use of 10 un-baited shrimp traps and provides a consistent quantitative assessment of fish communities. However, the SRA protocol cannot be applied under conditions were both launchability and wadeability are compromised, as can occur in wetland systems. In an effort to ensure as much comparable data as possible between all wetlands sampled, additional gear-types were also utilised as per Ho *et al.* (2004) and Baldwin *et al.* (2005). These included a series of seine net hauls and the use of a panel net (in wetlands of sufficient depth) and fyke nets. Each individual electrofishing shot, seine haul and net or trap set is referred to as an ‘operation’.

A boat electrofishing system (7.5 kW Smith-Root model GPP 7.5 H/L or 2.5 kW Smith-Root model GPP 2.5 H/L depending on launch conditions) was used at all sites where a boat could be launched. Boat operations consisted of 90 seconds of electrofishing (power on). Each operation was undertaken using intermittent electrofishing, with a two minute break between consecutive operations. This protocol minimises the ‘herding’ of fish. As a further prevention of herding, operations were undertaken by first manoeuvring the boat diagonally away from the bank and then for the subsequent shot manoeuvring the boat diagonally back towards the bank. Each operation took an average of four minutes to complete. Twelve electrofishing operations were undertaken within each wetland. During each operation, dip-netters removed all electrofished individuals and placed them in an aerated live-well (boat fishing). All individuals that could not be dip-netted but could be positively identified were recorded as ‘observed’. All electrofishing was undertaken during daylight hours.

Backpack electrofishing was undertaken where a boat could not be launched, but where wading was possible. Backpack operations consisted of 150 seconds of electrofishing (power on). Each operation was undertaken using intermittent electrofishing, with the backpack used to fish all areas accessible to the stationary operators (1.5 – 2 metre radius). Following electrofishing of that area, the operators moved ~3 m and repeated the process. Each operation took an average of seven minutes to complete.

Ten commercially available bait traps were set (un-baited) in an attempt to sample small benthic fish species typically under-represented in electrofishing samples. Traps were set for a minimum period of two hours whilst electrofishing was being undertaken. Bait traps were set in water less than 1 m deep.

Four single-wing 25 mm mesh fyke nets, each with a 0.6 m high semi-circular entrance hoop and three internal funnel traps were set overnight. Fyke nets were preferentially set in water around 0.6 m deep, perpendicular to the bank with the wing towards the shore.

For wetlands greater than 1 metre deep, a single multi-panel gill net was set in the deepest part of the wetland for a minimum period of two hours whilst electrofishing was being undertaken. The panel net consisted of three 5 x 1.8 m panels of 30 mm, 70 mm and 100 mm mesh.

Five replicate hauls of a 5 m pocket-seine (1.5 m drop and 3 mm mesh) were undertaken within the shallows margins of each wetland.

At the completion of each operation, captured individuals were identified, counted, measured and observed for health conditions such as externally visible parasites, wounds, diseases etc. before being released. All taxa were recorded to species level except for the carp-gudgeon species complex, which were recorded as *Hypseleotris* spp. In the case of difficult identifications, specimens were preserved in 70% ethanol for laboratory identification. Length measurements to the nearest millimetre were taken as fork length for species with forked tails and total length for other species. Where large catches of a species occurred, only a sub-sample of individuals were measured and examined for each gear type. The sub-sampling procedure consisted of measuring all individuals in each operation until a total of at least 50 individuals had been measured. Only 20 individuals of that species from subsequent operations of that gear type were measured. All additional individuals were only counted. Sub-sampling for health status involved careful observation of one side (usually the left) of every fish that was measured.

2.3. Water quality

Water quality parameters; temperature (^{o}C), dissolved oxygen (mg/L), pH, and conductivity (µS/cm) were measured using either a Horiba U10 or YSI 556 MPS water quality meter. Turbidity was measured using either the Horiba U10 water quality meter or Lovibond PCcheckit turbidity meter and was also recorded using a secchi disk. Two measurements of each parameter were made at the surface (< 20 cm) in addition to a single ‘depth profile’, where parameters were assessed at 1 m intervals between the surface and substrate (only possible for turbidity using the Horiba instrument).

2.4. Habitat mapping

Aquatic and riparian habitat features were mapped at all but the four Euston Lakes sites. Mapping was undertaken using hand-held PDA units (Dell axim X51U and MIO digi walker pocket PC) with ESRI Arcpad 6.0.3 data acquisition software. Each PDA was linked to a Garmin 72 GPS unit via a bluetooth device (i.Trek Bluetooth Battery Adapter) to record positional data. Each PDA had an uploaded shapefile of the 1: 50, 000 topographical map (GDA 94_MGA Zone 55) for that region. Two technicians were each equipped with a mapping kit and working in pairs mapped all the habitat features within the wetland. Shallow and narrow reaches were mapped on foot. Deeper reaches were mapped from a canoe or small punt. The data capture system used allowed for the recording of positional data in either of two formats, position dependant or position independent, depending on the habitat feature being recorded.

Substratum was mapped as the position of a transition from one substrate type to another, as a position-dependant feature. Substrate transitions were mapped at the point considered to be the bank full water-line on the wetland. Substrate categories used were based on the classification of stream substrate materials of Platts *et al*. presented in Hamilton and Bergersen (1990). Meso-habitat transitions were also mapped as position dependant features as for substratum, but at the current waterline. Meso-habitat categories were: pool (still or very slowly flowing water), run (flowing water with little or no surface turbulence), riffle (flowing water with a turbulent surface), rapid (very turbulent with the presence of one or more abrupt drops in surface water level) or dry (no surface water). The wetland boundary was manually digitised within a desktop GIS using Spot 5 imagery as a template, at a resolution of 1:3,000. The resulting polygon was then manually split along its centreline. In order to overlay and quantify substrate and meso-habitat areas, these half-wetland polygons where then cut (from bank to centre-line) at each transition point and the resulting polygons coded by substratum and meso-habitat type.

The position of woody habitat (snags) and macrophyte beds were mapped as position-independent features. Woody habitats were further characterised as large or small, and simple or complex. Small and large woody habitats were distinguished by having a maximum length of 1 – 2 m or > 2 m respectively, and those with a single simple branch or trunk were recorded as 'simple' and those with multiple branches, trunks with branches, trunks with hollows or root masses were classified as 'complex'. The location of each woody habitat was recorded as the position of the middle of the snag. Any individual item of simple woody habitat with a maximum dimension of < 1 metre was not recorded.

The size, shape, and area of macrophyte beds were mapped as position independent features by drawing the outline of the macrophyte bed as a polygon onto the screen of the PDA in the field. The identity of macrophytes was recorded to genus level using Sainty and Jacobs (2003).

The position of each willow (*Salix* spp.) trunk was marked as a position-independent feature during field mapping.

All data was uploaded into a GIS (Geographic Information System) running ArcMap 9.1 (ESRI).

3. RESULTS

Raw data from each of the sub-projects are presented in Appendices 1 – 4.

3.1. Fish data

At the time of being surveyed, all 7 Murray River wetlands had already commenced to recede and/or dry due to reduced river height in the Murray River, with three wetlands already disconnected from the river and reduced to very shallow residual pools: Croppers Lagoon (72% dry), Chick Logie Lagoon (82%) and Chick Logie East (94%). The remaining four Murray River wetlands were 28 ± 3 % dry at the time of sampling. In contrast, most of the Edward River wetlands (including Back Creek and Tumudgery Creek) remained full or near full. The four Euston Lakes sites were not mapped, so no comparable 'fullness' data are available, although all but Dry Lake appeared to be 'full' while Dry Lake had receded to some extent.

Fish sampling using the minimum compliment of sampling gears and operations to constitute a sample could only be undertaken at 17 of the 20 wetlands. Insufficient water remained in Croppers Lagoon, Chick Logie Lagoon and Chick Logie East to use anything other that the seine net. However, this was further complicated by the very soft sediments that made wading difficult and impractical. Despite the small amount of very shallow water remaining, one and two carp were observed to persist in the residual pools at Croppers Lagoon and Chick Logie East respectively and no fish sampling was undertaken. Two seine hauls were achieved at Chick Logie Lagoon. Despite the high phytoplankton concentration (see site photo in Appendix 1), which would create a substantial oxygen deficit during the night, the residual pool sustained a single native fish species (99 Carp-gudgeons) and two alien fishes (3 Common carp and 25 Eastern mosquitofish). However, because these data were not collected using the minimum complement of sampling gears, these data cannot be compared with the total catches reported from other wetland sites.

Combined, the remaining 17 wetlands provided habitat for nine species of native fish and four alien fish species (Table 2). Native Carp-gudgeons were by far the most abundant species, being over six times more abundant than the next most abundant fish. Other relatively common native fishes were Flat-headed gudgeon, Un-specked hardyhead and Australian smelt. The second most abundant fish was the alien Eastern mosquitofish. Alien Redfin perch and Common carp were also common.

Despite being only the 7th most abundant species, Common carp, made up 87% of the total biomass and the four alien species combined made up 93% of the fish biomass within the wetlands. Therefore, although native fish dominate the fish assemblages within the wetlands numerically, and that several native fish species where present, alien fish vastly dominate the wetlands in terms of their biomass.

The four common native species and three of the alien species (Common carp, Goldfish and Eastern mosquitofish) were found in a majority of wetlands sampled. In contrast, alien Redfin perch were most abundant in and largely restricted to wetlands of the Murray River in the Albury to Mulwala reach, whereas the remaining native fishes were absent from these wetlands and were only found in wetlands of the Edward River or the Euston Lakes.

Based on the presence of young-of-year (YOY) individuals of large species and juveniles of smaller species, we detected evidence of recruitment within the wetlands for all but Murray cod, Golden perch and Silver perch. The presence and relative abundance of juveniles of most of the other ten species collected is suggestive that wetlands may be important recruitment areas. But without comparable data collected from adjacent river channels adjacent to the wetlands, this data is not conclusive.

The only threatened species, or species of conservation concern detected within the wetlands were a single silver perch collected in Tumudgery Creek and seven Murray cod collected from Mutton Gut Lagoon (four individuals), Mooloomoon Lagoon (2 individuals) and North Dale Lagoon (1 individual).

Table 2. Total catch from the 17 wetlands sampled using at least the minimum component of gear types and operations. Total abundance is the number of individuals caught or observed. Total biomass is the weight of individuals caught. The proportion of wetlands is the proportion of those 17 wetlands sampled where each species was present. The proportion of wetlands with recruits is the proportion of those 17 wetlands sampled where juveniles or individuals < one year of age of each species were present. Species are represented in order of most abundant to least abundant.

Common name	Species Name	Total abundance	Total biomass (kg)	Proportion of wetlands	Proportion of wetlands with recruits
Carp-gudgeon species complex	*Hypseleotris* spp.	3,629	1.42	0.94	0.88
Eastern mosquitofish	*Gambusia holbrooki*	567	0.08	0.71	0.35
Flat-headed gudgeon	*Philypnodon grandiceps*	422	0.38	0.88	0.65
Redfin perch	*Perca fluviatilis*	408	4.26	0.35	0.29
Un-specked hardyhead	*Craterocephalus stercusmuscarum*	334	0.05	0.65	0.59
Australian smelt	*Retropinna semoni*	291	0.19	0.94	0.65
Common carp	*Cyprinus carpio*	168	203.34	0.88	0.24
Goldfish	*Carassius auratus*	81	10.16	0.71	0.41
Bony herring	*Nematalosa erebi*	47	3.69	0.35	0.18
Murray-Darling rainbowfish	*Melanotaenia fluviatilis*	34	0.06	0.41	0.29
Murray cod	*Maccullochella peelii*	7	7.06	0.18	0
Golden perch	*Macquaria ambigua*	5	3.18	0.18	0
Silver perch	*Bidyanus bidyanus*	1	0.44	0.06	0

3.2. Habitat data

All aquatic habitat features where mapped within 16 of the 20 wetlands. The four sites excluded were those at the Euston Lakes, where mapping was not requested.

The substratum of most wetlands was entirely mud, but several wetlands had small areas of other substrate types. Notable are: Back Creek which had substantial areas of both clay and sand substrates in addition to mud, Cooks Lagoon and Snake Island Lagoon that both have areas of gravel substrate, Cropper's Lagoon which has an area of cobble substrate and Moona Lagoon which was clay dominated with substantial areas of bedrock.

Habitat providing cover and structural complexity for fish and other aquatic organisms was restricted to woody habitat and macrophyte beds. Few rocky habitats were available (other than areas of bedrock in Back Creek and Big Barren and Moona Lagoons). As expected, there were no undercut banks within the wetlands.

The average density of woody habitat within the wetlands was 82 ± 57 snags per hectare, ranging from a minimum of 10 per hectare in Cropper's Lagoon to 252 per hectare in Back Creek. The most abundant type were large simple snags (54% of snags) followed by large complex snags (21%), small simple snags (15%) and small complex snags (9%).

Few macrophyte beds were present in any of the Edward River wetlands, with only very small beds of emergent macrophytes (Common reed *Phragmites australis*) in Moona and Mutton Gut Lagoons. Back Creek had 1,053 m^2 of emergent macrophytes (Cumbungi *Typha* spp.) while Tumudgery Creek had 2,496 m^2 of emergent macrophytes (Common reed) as well as 152 m^2 of submerged macrophtyes (Watermilfoil *Myriophyllum* spp.). However, in all these cases, this equated to < 1% macrophyte cover. In contrast, those wetlands on the Murray River between Albury and Mulwala had between 3% and 32% cover of aquatic vegetation, ranging from a low of 108 m^2 of emergent macrophytes (Cumbungi) and 10,714 m^2 of submerged macrophtyes (Watermilfoil) at Croppers Lagoon to 40,670 m^2 of emergent macrophytes (a combination of Spike-rush *Eleocharis* spp. and Cumbungi) at Quatt Quatta Lagoon.

Introduced willows (*Salix* spp.) where only present in Back Creek (3 trees), Cook’s Lagoon (8 trees) and Cropper’s Lagoon (16 trees).

An interesting observation was that virtually all of the habitat complexity and cover available to fish within the wetlands was distributed around the perimeter of the wetland (Figure 3). Very little habitat was available in the centre of wetlands. This is has important implications for the way water levels within wetlands are managed and the manner and rate at which wetlands are drained/dried.

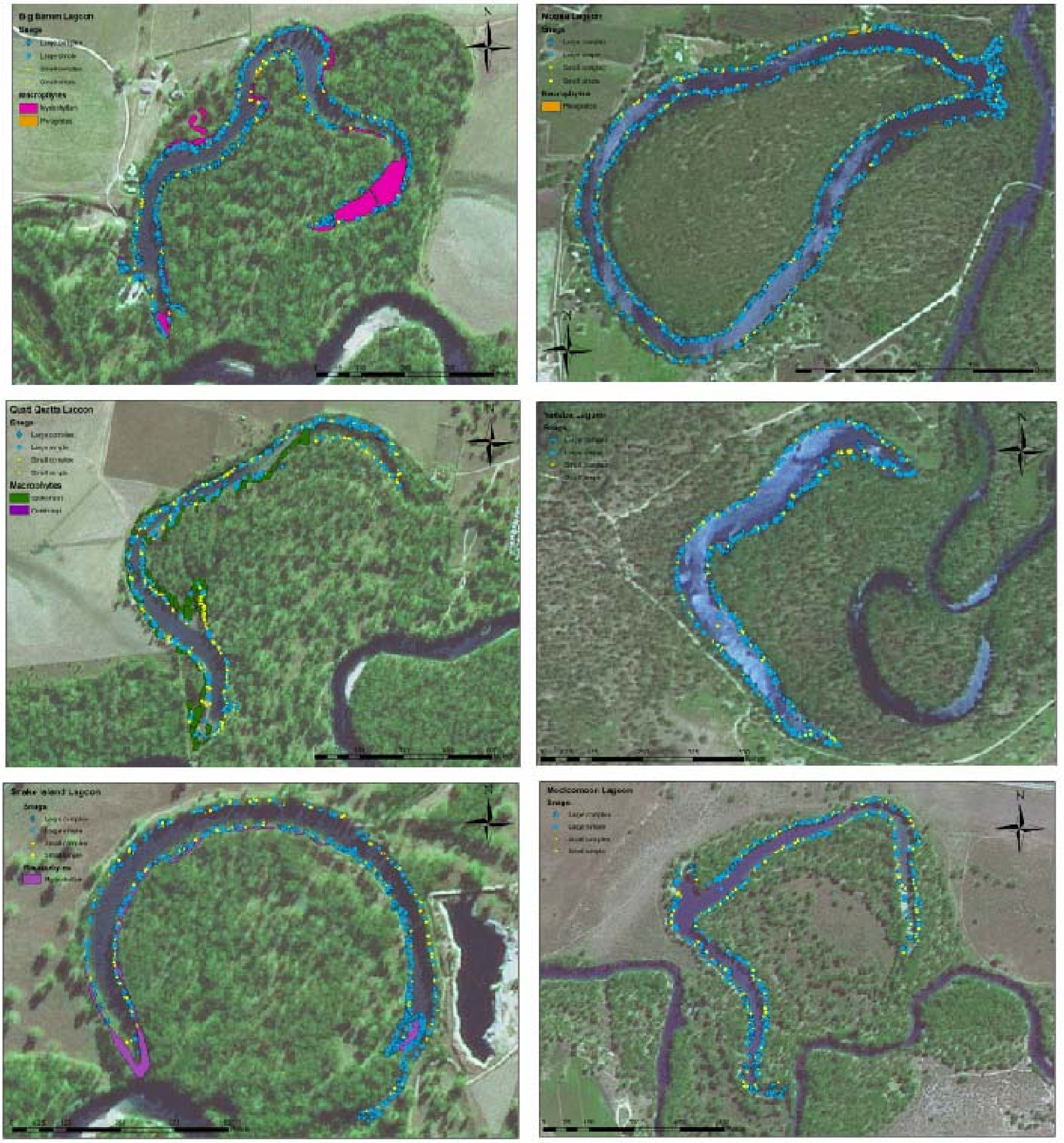

Figure 3. The distribution of habitats providing structural complexity and cover for fish and other aquatic fauna within a representative six of the 16 mapped wetlands. Top left – Big Barren Lagoon, middle left – Quatt Quatta Lagoon, bottom left – Snake Island Lagoon, top right – Moona Lagoon, middle right – Yadabal Lagoon, bottom right – Mooloomoon Lagoon.

4. DISCUSSION AND RECOMMENDATIONS

The only specimens collected during our fish surveys that are listed as threatened species were a single silver perch (listed as vulnerable under the NSW Fisheries Management Act 1994) collected in Tumudgery Creek and seven Murray cod (listed as vulnerable under the federal EPBC Act) collected from three of the Edward River Wetlands. None of these represent significant wetland 'populations' of these species. Both species are relatively common within the Edward River (NSW DPI Freshwater Fish Research Database), with the MDBC's Sustainable Rivers Audit reporting the fourth and third highest abundances of Murray cod and silver perch in the Murray-Darling Basin being in the Upper Central Murray zone (Davies *et al.* 2008). Further, there is little data suggesting that wetland habitats are critically important for any life-history stage of either of these species (Closs *et al.* 2006). Consequently, the temporary loss of wetland habitat, or the loss of any individuals resident within those wetlands isolated is unlikely to have any significant affect of the population status of either species.

The remaining seven species of native fish detected within wetlands range from being common to abundant throughout the river channels and/or wetland systems of the Murray and Edward Rivers (NSW DPI Freshwater Fish Research Database). Although, all are elements of the Endangered Lower Murray Aquatic Ecological Community, and despite the importance of wetland systems to some of these species (Closs *et al.* 2006), the fact that they are common and widespread in adjacent river systems suggest that the temporary loss of 20 individual wetland habitats will have negligible impacts on the status of their populations.

However, the sampling undertaken was a one-off snapshot, and does not necessarily reflect the 'normal' fish community condition. Nevertheless, the sampling was comprehensive in terms of the techniques used and with the exception of freshwater catfish (*Tandanus tandanus*) in Washpen Creek (see below), it is unlikely that significant populations of additional species occur in the wetlands sampled. However, fish communities in wetlands on the upper Murray floodplain exhibit considerable variation in composition (Closs *et al.* 2006), so these results cannot be used to infer that none of the wetlands within the regions surveyed are critical for native fish.

Native species not detected during sampling, but known to currently or have recently occurred within wetlands between the Euston Lakes and Hume Weir are Flat-headed galaxias (*Galaxias rostratus*), Southern pygmy perch (*Nannoperca australis*) and Freshwater catfish. Southern pygmy perch are listed as endangered under the Fisheries Management Act 1994 and nominations for both Flat-headed galaxias and freshwater catfish are under review for listing by the NSW Fisheries Scientific Committee. Flat-headed galaxias were most recently recorded in Norman's Lagoon, upstream of Albury in 2003 (NSW DPI Freshwater Fish Research Database). Southern pygmy perch were most recently recorded in the same lagoon in 2003 and in Toupna Creek and two associated lagoons (Pinchgut Lagoon and Fisherman's Bend Lagoon) in the Barmah-Millewa Forest in 2007 (Lee Baumgartner NSW DPI, pers. comm). Neither of these species has been reported in any of the wetlands prioritised for water recovery. In contrast, Freshwater catfish were most recently reported from a reach of Washpen Creek by McCarthy *et al.* (2007), who have sampled them consistently since Spring 2006 (Rohan Rehwinkel – Murray-Darling Freshwater Research Centre, pers. comm.). Although they were known to be present in the short reach in the terminal section of Washpen Creek at the time we sampled that system, we did not detect them at our sampling site which was 7.5 km downstream from where they have been detected by McCarthy *et al.* (2007). However, their presence within Washpen Creek dictates that whatever water recovery actions are undertaken at Lake Benanee or Dry Lake, concurrent actions are required to protect and conserve the habitat for this important population. Steps should be taken to ensure that this population is not only secure, but also that it has an opportunity to expand its distribution and re-colonise the Murray River and other wetland systems.

Three other species, all listed as threatened; Olive perchlet (*Ambassis agassizii*), Murray hardyhead (*Craterocephalus fluviatilis*), and Southern purple spotted gudgeon (*Mogurnda adspersa*) are known or presumed to have historically occurred in wetlands between the Euston Lakes and Hume Weir, but none have been reported for several decades. Trout cod (*Maccullochella macquariensis*), Macquarie perch (*Macquaria australasica*) and river blackfish (*Gadopsis marmoratus*) are also currently or were historically present within these reaches, but are riverine fish unlikely to utilise wetland habitats even when they are present.

Based on our data and that reported by McCarthy *et al.* (2007) we conclude that with the exception of Washpen Creek in the Euston Lakes system, there is no evidence that temporary isolation of the 19 other prioritised wetland systems from the river channels would have any long-term environmental impacts. Apart from Washpen Creek, none of the wetlands sampled provided critical drought refugia for native fish and there is no justification for eliminating the prioritised wetlands surveyed from further consideration of water recovery actions.

In fact, the poor ecological state of most wetland fish communities, with 93% of the biomass comprising alien pest fish suggests that the isolation and drying of these wetlands may have nett positive ecological outcomes. The domination of wetlands by alien fishes is not specific to those wetlands surveyed, as previous wetland fish community surveys also report a dominance of alien fishes (see Closs *et al.* 2006). However, a surprising result was the absence of introduced oriental weatherloach (*Misgurnus anguillicaudatus*) from our samples of wetlands between Hume Weir and Mulwala. Koster *et al.* (2002) reported that this species was expanding within the Upper Murray region. We cannot explain why we did not detect even a single individual during our surveys, as the methods used were adequate to collect them if they were present. Perhaps the post-colonisation boom reported by Koster *et al.* (2002) has abated. Or alternatively, Oriental weatherloach may avoid or be incapable of persisting in permanently inundated billabong habitats, preferring some other wetland type.

Not only will isolation of the wetlands prevent substantial populations of pest fish from returning to the river, but the resultant drying of the wetland sediments is also likely to have positive ecological effects on many aspects of the wetlands ecological processes (Boulton and Lloyd 1992, Bunn *et al.* 1997, Boulton and Jenkins 1988). Once re-filled, the dried wetlands may return to a healthier state than that which exists after many years of artificial permanent inundation. However, to ensure the post-dry re-colonisation of native fishes, the regulators installed and the manner in which flows are delivered to the wetland should provide acceptable fish passage conditions for native fish (Nichols and Gilligan 2003, Meredith *et al.* 2006). Further, the dearth of information of all aspects of managing wetting–drying cycles for fish in wetlands (Closs *et al.* 2006, Meredith *et al.* 2006) means that the implementation of a managed wetting-drying cycle at the conclusion of the water-recovery period will require an adaptive management framework necessitating the trialling of a range of alternative strategies and the ongoing scientific assessment of the resultant outcomes. The range of factors that will require consideration include (but may not be limited to) aspects of; i) the duration of the dry phase, ii) the duration of the period of reconnection to the river channel, iii) the seasonality of reconnection, iv) the provision of migration cues to direct fish to enter of leave the wetland, v) the potential implications of de-coupling landscape-scale migration cues and indicators with the wetting and drying times and vi) whether the wetland should be dried completely or whether a refuge pool should be maintained.

The recommended adaptive management framework requires that any wetland management actions taken should be associated with at least some basic level of data collection. As a bare minimum, wetland fish communities should be re-surveyed prior to each disconnection to ensure that no populations of threatened fishes have colonised the wetland and established significant populations. However, access to a number of replicate regulated wetlands, that can each be managed independently, provides significant opportunities for improving 'fish friendly' wetland management practices. To maximise the knowledge gained, we advise that management actions taken represent a spectrum of alternatives rather that a uniform management protocol applied across all wetlands. For example, i) leave wetlands dry for a range of time periods before reconnection to asses the impact of the length of the dry period on wetland condition, ii) leave them filled for a range of time periods before disconnection to assess the impact of the length of the wet phase on wetland condition, iii) fill the wetlands at various times throughout the year to assess optimal timing for reconnection, iv) assess alternative options for triggering native fish to exit the wetland prior to disconnection (by either partially draining the wetland during periods of low river flow, or reconnecting the wetland briefly after it has been disconnected to create an attractant flow) or v) compare the response of fish communities to total wetland drying versus the maintenance of a small residual pool within the wetland. These 'adaptive management exercises' would require more intensive monitoring. This would include the minimum pre-disconnection survey, in addition to sampling shortly after re-connection and at six monthly intervals (during spring and summer) each year that water remains in the wetland. Concurrent sampling within the wetland and river channel whilst the wetland is re-connected would also provide a useful assessment of the importance of wetland systems for fish communities and species.

Consideration should also be given to installation of 'carp screens' within the existing wetland regulators or any installed to facilitate wetland disconnection (Recknagel *et al.* 1998, Nichols and Gilligan 2003, Meredith *et al.* 2006). Carp screens can exclude sexually mature carp from the wetland upon re-filling. If a suitable and ongoing wetting-drying cycle were then implemented, carp recruitment within the wetland could be prevented (Nichols and Gilligan 2003, Meredith *et al.* 2006). Further, appropriate operation of regulatory structures during filling periods could further limit the entry of larval and juvenile carp, and perhaps maintain it in a carp-free state (Nichols and Gilligan 2003, Meredith *et al.* 2006). The exclusion of carp from managed wetlands would provide numerous environmental benefits (Meredith *et al.* 2006, Wilson 2006). Similar options should be investigated to exclude re-colonisation of Redfin perch.

The mapping data collected during this project has indicated that the vast majority of structural complexity and cover for aquatic organisms exists around the perimeter of the wetlands (Figure 3). This suggests that the habitat quality of wetlands is greatest when they are full. Even a small reduction in water level within the wetlands as they dry will expose the snags and macrophyte beds in the littoral zone and result in an almost total absence of structural complexity and cover within the remnant pool in the bed of the wetland. Therefore, the habitat values of the wetland should be expected to decline relatively quickly after a wetland has been isolated from the river channel. As water levels decline, the reduced availability of cover would lead to remnant fish communities within drying wetlands experiencing increased exposure to bird predation and the wetland would have a reduced capacity to sustain a functional food-web and fish recruitment. Detailed bathymetric surveys of the wetlands that have been mapped would allow an accurate assessment of the minimum water level at which fish habitat was available within each wetland. Our final recommendation is that when wetlands are re-filled, they should be filled to capacity (or at least to a level at which fish habitat is available) and maintained at that level for a sufficient period of time for the fish community to reach a mature successional stage. Management actions should then be taken to give fish communities in the wetland an opportunity to move into the river channel, perhaps facilitated by attractant flows etc., before the regulator gates are closed at the commencement of the next drying phase.

4.1. Conclusions

Based on this rapid assessment of 20 prioritised wetlands, we conclude that all but one of the wetlands are available for further consideration of management actions that would minimise evaporative loses and contribute to the provision of critical water demands in the Murray system through the current drought period. An important population of Freshwater catfish in Washpen Creek (McCarthy *et al.* 2007) limits options for water recovery in the Euston Lakes system. However, in the remaining 19 wetlands, drying the wetlands is likely to result in nett positive ecological outcomes, by eliminating populations of pest fish and by allowing the drying of wetland sediments. However, embarking on an ongoing regime on managed wetting-drying cycles in the prioritised wetlands is far from a simple exercise and a substantial adaptive management process would be required in order to sustain any planned ongoing water savings. This would involve trailing a range of alternative management strategies in a scientific manner and the ongoing monitoring of the ecological response. As a bare minimum, wetland fish communities should be re-surveyed prior to each disconnection to ensure that no populations of threatened fishes have colonised the wetland and established significant populations.

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APPENDICES

APPENDIX 1: UPPER MURRAY WETLANDS

8212 – COOK'S LAGOON

27 February 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (^{o}C)	25.1	25.2
pH	9.1	9.1
Dissolved oxygen (mg/l)	3.40	2.98
Conductivity (µS/cm)	766	767
Turbidity (NTU)	61	62
Secchi depth (cm)	37	
Average depth	0.5 m	
Maximum depth	1 m	
Average velocity	No flow	

Sampling effort

10 bait traps (@ 2 hours), 8 backpack shots (@ 2.5 minutes), 4 fyke nets (@ 14.8 hours), 1 panel net (@ 2.1 hours) and 5 seine hauls.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Common carp	1 (14 obs.)		397	Pest	No
Carp-gudgeon	160	15 – 52	29 ± 5	Common	Yes
Eastern mosquitofish	91	18 – 39	26 ± 4	Pest	No
Flat-headed gudgeon	1		31	Common	Yes
Redfin perch	1		52	Pest	No
Freshwater Tortoise	22				

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		15.4
Substrate (ha)	Bedrock	0
	Cobble	0.9
	Gravel	7.3
	Sand	0.1
	Mud	7.1
	Clay	
Cover (item)	Large simple snags	221
	Large complex snags	37
	Small simple snags	38
	Small complex snags	12
Willows (trees)		8
Macrophytes (m^2)	*Myriophyllum*	1,282
	Eleocharis	303
	Phragmites	6,657
	Typha	0
Meso-habitat (ha)	Pool	11.3
	Dry	4.1

7413 – QUATT QUATTA LAGOON

1 March 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (°C)	29.0	13.6
pH	9.9	8.6
Dissolved oxygen (mg/l)	3.20	3.02
Conductivity (µS/cm)	63	51
Turbidity (NTU)	70	51
Secchi depth (cm)	NA	NA
Average velocity	No flow	
Average depth	0.6 m	
Maximum depth	1 m	

Sampling effort

10 bait traps (@ 2.75 hours), 12 boat shots (@ 1.5 minutes), 4 fyke nets (@ 19 hours) and 5 seine hauls. The panel net was not set at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	17	29 – 64	41 ± 11	Common	Yes
Common carp	29	122 – 584	434 ± 115	Pest	No
Carp-gudgeon	363	17 – 48	30 ± 5	Common	Yes
Eastern mosquitofish	235	15 – 43	27 ± 6	Pest	No
Flat-headed gudgeon	5	32 – 53	42 ± 10	Common	Yes
Fly-specked hardyhead	10	25 – 43	36 ± 7	Common	Yes
Goldfish	14	56 – 257	95 ± 50	Pest	No
Redfin perch	12	48 – 91	69 ± 14	Pest	No

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		12.6
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0
	Mud	12.6
	Clay	0
Cover (item)	Large simple snags	323
	Large complex snags	36
	Small simple snags	246
	Small complex snags	24
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	40,477
	Phragmites	0
	Typha	203
Meso-habitat (ha)	Pool	9.4
	Dry	3.2

7410 – BIG BARREN LAGOON

1 March 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (°C)	24.33	24.00
pH	8.4	8.5
Dissolved oxygen (mg/l)	3.27	3.54
Conductivity (µS/cm)	52	52
Turbidity (NTU)	52	53
Secchi depth (cm)		
Average velocity	No flow	
Average depth	0.5 m	
Maximum depth	1 m	

Sampling effort

10 bait traps (@ 2.5 hours), 12 boat shots (@1.5 minutes), 4 fyke nets (@ 20.5 hours), 1 panel net (@ 2 hours) and 5 seine hauls.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	2	36 – 44	40 ± 6	Common	Yes
Common carp	21	124 – 595	439 ± 143	Pest	No
Carp-gudgeon	636	17 – 88	31 ± 9	Common	Yes
Eastern mosquitofish	33	15 – 35	24 ± 4	Pest	No
Flat-headed gudgeon	74	25 – 54	39 ± 7	Common	Yes
Fly-specked hardyhead	1		51	Common	Yes
Goldfish	6	68 – 90	79 ± 10	Pest	No
Redfin perch	50	35 – 103	68 ± 8	Pest	No

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		10.8
Substrate (ha)	Bedrock	0.02
	Cobble	0
	Gravel	0.20
	Sand	0
	Mud	10.52
	Clay	0.04
Cover (item)	Large simple snags	453
	Large complex snags	340
	Small simple snags	87
	Small complex snags	132
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	25,455
	Eleocharis	0
	Phragmites	1,361
	Typha	0
Meso-habitat (ha)	Pool	7.2
	Dry	3.6

7369 – CHICK LOGIE EAST

1 March 2007

Water quality

Water quality parameter	Surface
Temperature (^{o}C)	27.7
pH	9.0
Dissolved oxygen (mg/l)	3.71
Conductivity (μS/cm)	784
Turbidity (NTU)	485
Secchi depth (cm)	
Average velocity	No flow
Average depth	0.1 m
Maximum depth	0.1 m

Sampling effort

Fish sampling not possible. Shallow depth prevented boat electrofishing and all forms of netting. Deep soft mud prevented backpack electrofishing and seine hauling.

Fish collected

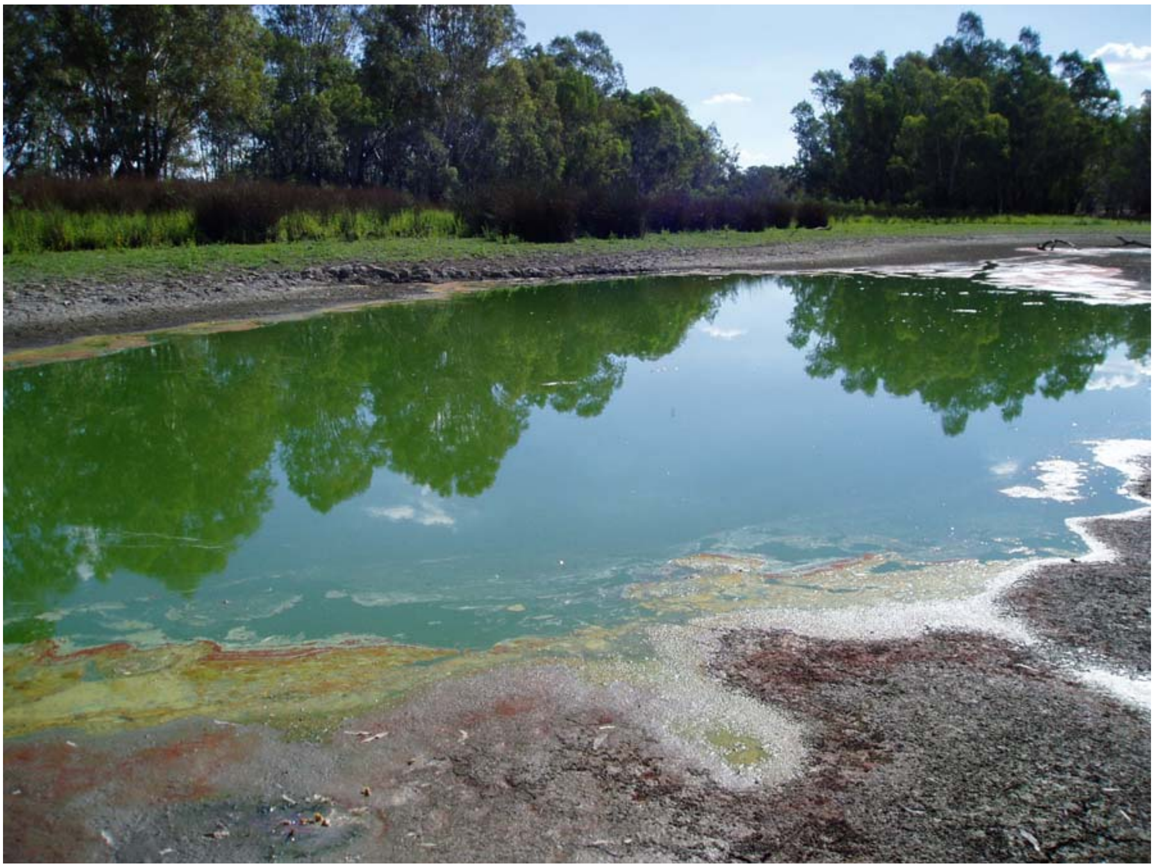
NA. But two carp observed.

Habitat

Habitat feature		
Wetland area (ha)		13.2
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0
	Mud	13.2
	Clay	0
Cover (item)	Large simple snags	327
	Large complex snags	150
	Small simple snags	38
	Small complex snags	68
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	37,035
	Eleocharis	0
	Phragmites	0
	Typha	0
Meso-habitat (ha)	Pool	0.8
	Dry	12.4

7339 – CHICK LOGIE LAGOON

1 March 2007



Water quality

Water quality parameter	Surface
Temperature (°C)	27.9
pH	9.9
Dissolved oxygen (mg/l)	8.7
Conductivity (µS/cm)	367
Turbidity (NTU)	501
Secchi depth (cm)	
Average velocity	No flow
Average depth	0.2 m
Maximum depth	0.2 m

Sampling effort

Two **s**eine net hauls only. Shallow depth prevented boat electrofishing and all forms of netting. Deep soft mud prevented backpack electrofishing.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Common carp	3 (obs)			Pest	No
Carp-gudgeon	99	14 – 58	28 ± 6	Common	Yes
Eastern mosquitofish	25	16 – 34	28 ± 4	Pest	No

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		6.6
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0.1
	Sand	0.8
	Mud	5.7
	Clay	0
Cover (item)	Large simple snags	45
	Large complex snags	204
	Small simple snags	71
	Small complex snags	48
Willows (trees)		
Macrophytes (m^2)	*Myriophyllum*	25,172
	Eleocharis	0
	Phragmites	0
	Typha	0
Meso-habitat (ha)	Pool	1.2
	Dry	5.4

7312 – SNAKE ISLAND LAGOON

28 February 2007

Water quality

Water quality parameter	Surface	1 m deep	2 m deep
Temperature (^oC)	24.5	24.3	24.1
pH	8.4		
Dissolved oxygen (mg/l)	6.12	5.69	2.89
Conductivity (µS/cm)	51	50	50
Turbidity (NTU)	41	45	-
Secchi depth (cm)	36		
Average velocity	No flow		
Average depth	0.6 m		
Maximum depth	2 m		

Sampling effort

10 bait traps (@2.7 hours), 12 boat shots (@1.5 minutes), 4 fyke nets (@ 14.7 hours), 1 Panel net (@ 2.25 hours) and 5 seine hauls.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	1		43	Common	Yes
Common carp	8	261 – 507	430 ± 96	Pest	No
Carp-gudgeon	869	14 – 54	28 ± 6	Common	Yes
Eastern mosquitofish	41	17 – 35	26 ± 5	Pest	No
Flat-headed gudgeon	31	27 – 63	40 ± 8	Common	Yes
Fly-specked hardyhead	3	18 – 54	35 ± 18	Common	Yes
Goldfish	2	62 – 255	130 ± 109	Pest	No
Redfin perch	341	31 – 122	57 ± 9	Pest	No

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		13.2
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	2.3
	Sand	0
	Mud	10.9
	Clay	0
Cover (item)	Large simple snags	506
	Large complex snags	218
	Small simple snags	113
	Small complex snags	105
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	11,293
	Eleocharis	0
	Phragmites	0
	Typha	0
Meso-habitat (ha)	Pool	9.4
	Dry	3.9

7804 – CROPPERS LAGOON

28 February 2007

Water quality

Water quality parameter	Surface
Temperature (^{o}C)	26.1
pH	8.8
Dissolved oxygen (mg/l)	3.22
Conductivity (μS/cm)	115
Turbidity (NTU)	467
Secchi depth (cm)	
Average velocity	No flow
Average depth	0.1 m
Maximum depth	0.2 m

Sampling effort

Fish sampling not possible. Shallow depth prevented boat electrofishing and all forms of netting. Deep soft mud prevented backpack electrofishing and seine hauling.

Fish collected

NA. One carp observed.

Habitat

Habitat feature		
Wetland area (ha)		34.7
Substrate (ha)	Bedrock	0
	Cobble	2.8
	Gravel	0.5
	Sand	0
	Mud	31.4
	Clay	0
Cover (item)	Large simple snags	202
	Large complex snags	93
	Small simple snags	55
	Small complex snags	11
Willows (trees)		16
Macrophytes (m^2)	*Myriophyllum*	10,714
	Eleocharis	0
	Phragmites	0
	Typha	108
Meso-habitat (ha)	Pool	9.9
	Dry	24.8

APPENDIX 2: MID MURRAY WETLANDS

5432 – MOONA LAGOON

3 April 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (^oC)	20.0	18.6
pH	8.0	7.6
Dissolved oxygen (mg/l)	7.29	6.39
Conductivity (μS/cm)	87	85
Turbidity (NTU)	100	133
Secchi depth (cm)	11	
Average velocity	No flow	
Average depth	0.7 m	
Maximum depth	1.3 m	

Sampling effort

10 bait traps (@ 2 hours), 12 boat electrofishing shots (@ 1.5 minutes), 4 fyke nets (@ 14 hours) and 5 seine hauls. The panel net was not set at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	14	25 – 56	43 ± 12	Common	Yes
Common carp	10	217 – 460	287 ± 92	Pest	No
Carp-gudgeon	402	16 – 46	31 ± 4	Common	Yes
Eastern mosquitofish	20	20 – 31	27 ± 3	Pest	No
Flat-headed gudgeon	87	27 – 63	46 ± 10	Common	Yes
Fly-specked hardyhead	12	34 – 45	40 ± 8	Common	Yes
Redfin perch	3	354 – 394	376 ± 20	Pest	No

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		14.1
Substrate (ha)	Bedrock	3.7
	Cobble	
	Gravel	
	Sand	
	Mud	2.8
	Clay	7.6
Cover (item)	Large simple snags	786
	Large complex snags	438
	Small simple snags	123
	Small complex snags	242
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	0
	Phragmites	644
	Typha	0
Meso-habitat (ha)	Pool	14.1
	Dry	0

5335 – MUTTON GUT LAGOON

4 April 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (^{o}C)	20.4	18.6
pH	7.9	7.4
Dissolved oxygen (mg/l)	9.11	8.33
Conductivity (µS/cm)	73	72
Turbidity (NTU)	68	60
Secchi depth (cm)	27	
Average velocity	No flow	
Average depth	0.7 m	
Maximum depth	0.8 m	

Sampling effort

10 bait traps (@ 2 hours), 12 boat electrofishing shots (@ 1.5 minutes), 4 fyke nets (@ 14.75 hours) and 5 seine hauls. The panel net was not set at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	5	40 – 47	42 ± 3	Common	Yes
Bony herring	1		174	Frequent	Yes
Common carp	20	209 – 617	442 ± 84	Pest	No
Carp-gudgeon	49	21 – 41	31 ± 4	Common	Yes
Eastern mosquitofish	3	28 – 39	32 ± 6	Pest	No
Golden perch	2		405	Common	Yes
Goldfish	2		280	Pest	No
Murray cod	4	463 – 535	503 ± 37	Nationally vulnerable under the EPBC Act.	Yes
Murray-Darling rainbowfish	1		42	Frequent	Yes

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		43.4
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0.7
	Mud	38.2
	Clay	0
Cover (item)	Large simple snags	1598
	Large complex snags	537
	Small simple snags	258
	Small complex snags	396
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	0
	Phragmites	0
	Typha	179
Meso-habitat (ha)	Pool	38.9
	Dry	0

5254 – YADABAL LAGOON

3 April 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (°C)	18.2	16.8
pH	7.6	7.3
Dissolved oxygen (mg/l)	7.50	5.64
Conductivity (µS/cm)	108	107
Turbidity (NTU)	76	107
Secchi depth (cm)	NA	
Average velocity	No flow	
Average depth	0.7 m	
Maximum depth	1.2 m	

Sampling effort

10 bait traps (@ 2.2 hours), 12 boat electrofishing shots (@1.5 minutes), 4 fyke nets (@ 19 hours) and 5 seine hauls. No panel net was set at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	3	48 – 58	54 ± 6	Common	Yes
Common carp	5	299 – 596	479 ± 140	Pest	No
Carp-gudgeon	79	18 – 42	30 ± 5	Common	Yes
Eastern mosquitofish	24	21 – 31	27 ± 3	Pest	No
Flat-headed gudgeon	72	28 – 58	38 ± 5	Common	Yes
Murray-Darling rainbowfish	5	46 – 56	50 ± 5	Frequent	Yes

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		8.2
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0
	Mud	8.2
	Clay	0
Cover (item)	Large simple snags	396
	Large complex snags	103
	Small simple snags	94
	Small complex snags	61
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	0
	Phragmites	0
	Typha	0
Meso-habitat (ha)	Pool	8.2
	Dry	0

5047 – WOOROOMA LAGOON

22 March 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (^{o}C)	22.0	22.1
pH	7.3	7.4
Dissolved oxygen (mg/l)	2.54	2.52
Conductivity (µS/cm)	710	690
Turbidity (NTU)	119	108
Secchi depth (cm)	31	
Average velocity	No flow	
Average depth	0.7 m	
Maximum depth	0.8 m	

Sampling effort

10 bait traps (@ 3.3 hours), 8 backpack electrofishing shots (@2.5 minutes), 4 fyke nets (@ 16.75 hours) and 5 seine hauls. No panel net was set at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	23	27 – 53	36 ± 9	Common	Yes
Carp-gudgeon	461	20 – 45	32 ± 4	Common	Yes
Eastern mosquitofish	18	21 – 38	28 ± 5	Pest	No
Flat-headed gudgeon	45	19 – 44	30 ± 6	Common	Yes
Fly-specked hardyhead	9	23 – 43	32 ± 7	Common	Yes
Goldfish	2	122 – 192	157 ± 49	Pest	No

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		7.2
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0
	Mud	7.2
	Clay	0
Cover (item)	Large simple snags	461
	Large complex snags	81
	Small simple snags	295
	Small complex snags	111
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	0
	Phragmites	0
	Typha	0
Meso-habitat (ha)	Pool	7.2
	Dry	0

5025 – SMITH’S LAGOON

10 April 2007

Water quality

Water quality parameter	Surface	1 m deep	2 m deep
Temperature (°C)	20.9	17.2	17.0
pH	8.6	7.3	7.1
Dissolved oxygen (mg/l)	10.87	4.44	3.86
Conductivity (µS/cm)	97	86	86
Turbidity (NTU)	201	266	409
Secchi depth (cm)	25		
Average velocity	No flow		
Average depth	1.1 m		
Maximum depth	2.6 m		

Sampling effort

10 bait traps (@ 2.6 hours), 12 boat electrofishing shots (@ 1.5 minutes), 4 fyke nets (@ 18.4 hours), 5 seine hauls and one panel (@ 2 hours).

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	31	24 – 46	39 ± 5	Common	Yes
Bony herring	26	101 – 145	118 ± 11	Frequent	Yes
Common carp	12	250 – 480	398 ± 86	Pest	No
Carp-gudgeon	81	15 – 43	27 ± 5	Common	Yes
Flat-headed gudgeon	2		66	Common	Yes
Fly-specked hardyhead	2	21 – 25	23 ± 3	Common	Yes
Goldfish	6	152 – 225	196 ± 36	Pest	No

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		18.7
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0
	Mud	18.7
	Clay	0
Cover (item)	Large simple snags	616
	Large complex snags	154
	Small simple snags	192
	Small complex snags	180
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	0
	Phragmites	0
	Typha	0
Meso-habitat (ha)	Pool	18.7
	Dry	0

2740 – MOOLOOMOON LAGOON

11 April 2007

Water quality

Water quality parameter	Surface
Temperature (°C)	21.1
pH	8.3
Dissolved oxygen (mg/l)	9.00
Conductivity (µS/cm)	80
Turbidity (NTU)	273
Secchi depth (cm)	18
Average velocity	No flow
Average depth	0.4 m
Maximum depth	0.4 m

Sampling effort

10 bait traps (@ 2.5 hours), 12 boat electrofishing shots (@1.5 minutes), 4 fyke nets (@ 18.2 hours) and 5 seine hauls. A panel net was not set at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	2	42 – 53	49 ± 6	Common	Yes
Bony herring	5	50 – 102	73 ± 26	Frequent	Yes
Common carp	10	511 – 622	559 ± 57	Pest	No
Carp-gudgeon	8	23 – 34	29 ± 3	Common	Yes
Fly-specked hardyhead	22	11 – 45	28 ± 7	Common	Yes
Goldfish	3	95 – 162	123 ± 35	Pest	No
Murray cod	2	390 – 471	431 ± 57	Nationally vulnerable under the EPBC Act.	Yes
Murray-Darling rainbowfish	5	32 – 42	37 ± 4	Frequent	Yes

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		11.4
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0
	Mud	11.4
	Clay	0
Cover (item)	Large simple snags	447
	Large complex snags	139
	Small simple snags	169
	Small complex snags	90
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	0
	Phragmites	0
	Typha	0
Meso-habitat (ha)	Pool	11.4
	Dry	0

2624 – NORTH DALE LAGOON

11 April 2007

Water quality

Water quality parameter	Surface
Temperature (°C)	19.3
pH	7.7
Dissolved oxygen (mg/l)	6.81
Conductivity (µS/cm)	210
Turbidity (NTU)	975
Secchi depth (cm)	12
Average velocity	No flow
Average depth	0.5 m
Maximum depth	0.6 m

Sampling effort

10 bait traps (@ 2.1 hours), 12 boat electrofishing shots (@1.5 minutes), 4 fyke nets (@ 14.75 hours) and 5 seine hauls. A panel net was not set at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	4	31 ± 46	40 ± 5	Common	Yes
Common carp	12	122 ± 497	267 ± 108	Pest	No
Carp-gudgeon	28	20 ± 40	27 ± 5	Common	Yes
Flat-headed gudgeon	5	25 ± 42	32 ± 7	Common	Yes
Fly-specked hardyhead	5			Common	Yes
Golden perch	2	261 ± 355	308 ± 66	Common	Yes
Goldfish	17	83 ± 195	114 ± 33	Pest	No
Murray cod	1		266	Nationally vulnerable under the EPBC Act.	Yes

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		12.0
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0
	Mud	12.0
	Clay	0
Cover (item)	Large simple snags	458
	Large complex snags	1063
	Small simple snags	148
	Small complex snags	90
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	0
	Phragmites	0
	Typha	0
Meso-habitat (ha)	Pool	7.6
	Dry	4.4

APPENDIX 3: BACK CREEK AND TUMUDGERY CREEK

5638 – BACK CREEK

5 March 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (°C)	17.8	17.8
pH	8.0	7.9
Dissolved oxygen (mg/l)	3.64	3.50
Conductivity (µS/cm)	61	61
Turbidity (NTU)	58	
Secchi depth (cm)	42	
Average velocity	No flow	
Average depth	0.6 m	
Maximum depth	1.1 m	

Sampling effort

10 bait traps (@ 2.66 hours), 12 boat shots (@1.5 minutes), 4 fyke nets (@ 14.92 hours), 1 panel net (@ 2 hours) and 5 seine hauls.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	71	24 – 50	33 ± 5	Common	Yes
Common carp	4	113 – 412	301 ± 131	Pest	No
Carp-gudgeon	190	17 – 51	31 ± 6	Common	Yes
Eastern mosquitofish	28	11 – 26	21 ± 3	Pest	No
Flat-headed gudgeon	15	24 – 58	42 ± 13	Common	Yes
Fly-specked hardyhead	45	21 – 53	32 ± 7	Common	Yes
Goldfish	2	74 – 311	193 ± 168	Pest	No
Murray-Darling rainbowfish	2	39 – 64	52 ± 18	Frequent	Yes

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		24.21
Substrate (ha)	Bedrock	0.5
	Cobble	0
	Gravel	0
	Sand	4.7
	Mud	14.5
	Clay	4.5
Cover (item)	Large simple snags	3,734
	Large complex snags	1,161
	Small simple snags	741
	Small complex snags	466
Willows (trees)		3
Macrophytes (m^2)	*Myriophyllum*	0
	Eleocharis	0
	Phragmites	0
	Typha	1,053
Meso-habitat (ha)	Pool	16.5
	Dry	7.7

5465 – TUMUDGERY CREEK

5 March 2007

Water quality

Water quality parameter	Surface	1 m deep
Temperature (^{o}C)	20.7	20.6
pH	7.1	8.3
Dissolved oxygen (mg/l)	3.54	2.73
Conductivity (µS/cm)	72	70
Turbidity (NTU)	52	
Secchi depth (cm)	49	
Average velocity	No flow	
Average depth	0.9 m	
Maximum depth	1.1 m	

Sampling effort

10 bait traps (@ 2.6 hours), 12 boat shots (@ 1.5 minutes), 4 fyke nets (@ 20.58 hours), 1 panel net (@ 2.17 hours) and 5 seine hauls.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	13	19 – 44	35 ± 9	Common	Yes
Common carp	18	295 – 538	413 ± 63	Pest	No
Carp-gudgeon	176	18 – 60	29 ± 5	Common	Yes
Eastern mosquitofish	11	18 – 32	26 ± 4	Pest	No
Flat-headed gudgeon	45	26 – 48	33 ± 5	Common	Yes
Fly-specked hardyhead	6	24 – 36	30 ± 5	Common	Yes
Goldfish	10	154 – 265	187 ± 35	Pest	No
Murray-Darling rainbowfish	10	26 – 56	39 ± 8	Frequent	Yes
Silver perch	1		310	Vulnerable	Yes

**Lower Murray Endangered Ecological Community*

Habitat

Habitat feature		
Wetland area (ha)		27.1
Substrate (ha)	Bedrock	0
	Cobble	0
	Gravel	0
	Sand	0.5
	Mud	26.6
	Clay	0
Cover (item)	Large simple snags	901
	Large complex snags	234
	Small simple snags	290
	Small complex snags	216
Willows (trees)		0
Macrophytes (m^2)	*Myriophyllum*	152
	Eleocharis	0
	Phragmites	2,496
	Typha	0
Meso-habitat (ha)	Pool	25.4
	Dry	1.7

APPENDIX 4: EUSTON LAKES AND TRIBUTARIES

1455 – WASHPEN CREEK

3 September 2007

Water quality

Water quality parameter	Surface	1 m deep	2 m deep
Temperature (^{o}C)	14.7	14.2	13.4
pH	8.6	8.6	8.4
Dissolved oxygen (mg/l)	9.00	8.95	9.30
Conductivity (µS/cm)	241	240	241
Turbidity (NTU)	91	65	61
Secchi depth (cm)	48		
Average velocity	Slow		
Average depth	1.1 m		
Maximum depth	2 m		

Sampling effort

10 bait traps (@ 3.33 hours), 12 boat electrofishing shots (@ 1.5 minutes), 1 panel net (@ 2 hours) and 5 seine hauls.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	5	46 - 52	48 ± 3	Common	Yes
Bony herring	3	188 – 364	302 ± 99	Common	Yes
Common carp	10	298 – 463	395 ± 86	Pest	No
Carp-gudgeon	4	18 – 23	20 ± 3	Common	Yes
Flat-headed gudgeon	1		69	Common	Yes
Fly-specked hardyhead	2	32 – 34	33 ± 1	Common	Yes
Goldfish	8	124 – 184	145 ±34	Pest	No
Murray-Darling rainbowfish	1		71	Frequent	Yes

**Lower Murray Endangered Ecological Community*

1246 – DRY LAKE

4 September 2007

Water quality

Water quality parameter	Surface
Temperature (^{o}C)	15.7
pH	10.3
Dissolved oxygen (mg/l)	11.86
Conductivity (μS/cm)	187
Turbidity (NTU)	392
Secchi depth (cm)	NA
Average velocity	No flow
Average depth	0.4 m
Maximum depth	0.4 m

Sampling effort

10 bait traps (@ 2 hours), 8 backpack electrofishing shots (@ 2.5 minutes), 4 fyke nets (@ 16.17 hours) and 5 seine hauls. The panel net was not set at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	25	37 – 60	47 ± 6	Common	Yes
Bony herring	5	34 – 46	41 ± 5	Common	Yes
Carp-gudgeon	8	17 – 41	26 ± 9	Common	Yes
Eastern mosquitofish	1		36	Pest	No
Flat-headed gudgeon	4	57 – 65	62 ± 3	Common	Yes

**Lower Murray Endangered Ecological Community*

1437 – LAKE BENANEE

3 September 2007

Water quality

Water quality parameter	Surface	1 m deep	2 m deep
Temperature (°C)	12.6	12.6	12.6
pH	9.3	9.3	9.4
Dissolved oxygen (mg/l)	10.40	10.26	10.27
Conductivity (µS/cm)	1010	1080	931
Turbidity (NTU)	203	187	195
Secchi depth (cm)	24		
Average velocity	No flow		
Average depth	0.9 m		
Maximum depth	2.0 m		

Sampling effort

10 bait traps (@ 3 hours), 12 boat electrofishing shots (@ 1.5 minutes), and 1 panel net (@ 2 hours). No fyke net or seine net operations were undertaken at this site.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	21	27 – 65	50 ± 10	Common	Yes
Bony herring	7	67 – 305	235 ± 89	Common	Yes
Common carp	2	432 – 481	456 ± 35	Pest	No
Flat-headed gudgeon	5	31 – 64	53 ± 12	Common	Yes
Golden perch	1		408	Common	Yes
Redfin perch	1		227	Pest	No

**Lower Murray Endangered Ecological Community*

1445 – TAILA CREEK

5 September 2007

Water quality

Water quality parameter	Surface	1 m deep	2 m deep
Temperature (^{o}C)	14.8	14.6	14.2
pH	9.3	9.0	8.5
Dissolved oxygen (mg/l)	11.12	11.70	11.30
Conductivity (µS/cm)	91	91	92
Turbidity (NTU)	45	47	43
Secchi depth (cm)	57		
Average velocity	Slow		
Average depth	1.1 m		
Maximum depth	2.1 m		

Sampling effort

10 bait traps (@ 3 hours), 12 boat electrofishing shots (@ 1.5 minutes), 4 fyke nets (@ 15.5 hours), 1 panel net (@ 2.25 hours) and 5 seine hauls.

Fish collected

Species	Catch	Size range (mm)	Average size (mm ± SD)	Conservation status	Element of the LMEEC*?
Australian smelt	54	18 – 52	38 ± 7	Common	Yes
Common carp	3		627	Pest	No
Carp-gudgeon	16	16 – 32	27 ± 4	Common	Yes
Eastern mosquitofish	37	23 – 36	28 ± 3	Pest	No
Flat-headed gudgeon	10		62	Common	Yes
Fly-specked hardyhead	222	14 – 43	24 ± 5	Frequent	Yes
Goldfish	9	84 – 172	134 ± 24	Pest	No
Murray-Darling rainbowfish	10	30 – 72	46 ± 17	Frequent	Yes

**Lower Murray Endangered Ecological Community*

Other titles in this series:

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No. 1 Andrew, N.L., Graham, K.J., Hodgson, K.E. and Gordon, G.N.G., 1998. Changes after 20 years in relative abundance and size composition of commercial fishes caught during fishery independent surveys on SEF trawl grounds. Final Report to Fisheries Research and Development Corporation. Project No. 96/139.

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