Assessment of fish movement to and from Margooya Lagoon upon re-connection to the Murray River during elevated flows: Spring 2010

The Murray-Darling Freshwater Research Centre

Prepared by: Iain Ellis and Leigh Pyke

mallee catchment management authority

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Final Report prepared for the Mallee Catchment Management Authority by The Murray-Darling Freshwater Research Centre

Mallee Catchment Management Authority
PO Box 5017
Mildura Vic 3502
Ph: (03) 5051 4377; Fax: (03) 5051 4379

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Iain Ellis
The Murray-Darling Freshwater Research Centre
PO Box 3428
Mildura Vic 3502
Ph: (03) 5051 4050; Fax: (03) 5023 6248

Email: I.Ellis@latrobe.edu.au
Web: www.mdfrc.org.au
Enquiries: info@mdfrc.org.au

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Contents

Summary

The Mallee Catchment Management Authority (Mallee CMA) is currently managing hydrological regimes of Margooya Lagoon via the control of a regulator fitted with a Carp exclusion screen (mesh width of 35 mm) located on the connecting creek to the Murray River. Margooya Lagoon experienced a managed dry phase throughout most of 2009, before it was filled via pumping directly from the Murray River into the inlet creek in late 2009. A survey of Margooya by The Murray-Darling Freshwater Research Centre (MDFRC) in December 2009 identified the presence of early juvenile Golden perch and Silver perch which had entered the Lagoon through the pump.

Assessment of fish movement between the Murray River and Margooya Lagoon detected movement of Golden perch and Silver perch juveniles back towards the Murray River on a filling event (a pumped event in June 2010), but not on a minor drainage events (see Ellis 2010).

This report presents the results of subsequent assessments of fish movement conducted in the spring of 2010 at Margooya Lagoon. The first was conducted when the regulator was again opened to allow partial drainage of the wetland in October 2010 (with a more rapid drawdown rate than the earlier draining event in April 2010). The second assessment was conducted when the wetland was subsequently re-filled via elevated flows in the Murray River during November 2010. The results of these assessments allowed us to investigate the response of key species to different modes of wetland operation (i.e. filling via pumping; filling via natural flows; and drainage during high and low river flows).

As with the previous drainage event, no Golden perch or Silver perch were detected exiting the wetland as it drained in October 2010. Thousands of juvenile Carp were; however, recorded entering the wetland during the October drainage event. In keeping with the previous filling event in June 2010, Golden perch were again induced to exit the wetland when it was refilled (by rising river flows) in November 2010, although movement of larger individuals through the Carp exclusion screen on the regulator is likely to have been impeded.

Flooding in early 2011 over-topped the regulator allowing these larger individuals to return to the Murray River. No Silver perch were recorded in surveys after June 2010 and their survival in Margooya Lagoon is undetermined.

Throughout the Murray River flood of 2010/11, a protracted blackwater event resulted in low dissolved oxygen concentrations in the Murray River. Oxygen stressed and dead fish were recorded throughout the blackwater event along the Murray River. This blackwater, which persisted throughout most of the 2010/11 flood event, appears to have suppressed the spawning of native fish, particularly Golden perch and Silver perch, which are normally induced to spawn during flow pulses. Consequently, we expect few if any larvae from spawning events in the Murray River channel in 2010/11 will have colonised Margooya Lagoon.

Introduction

Margooya Lagoon is a floodplain wetland in the Lock 15 Weir Pool (Euston Weir) located in the Beggs Bend State Forest, 12 km south-east of Robinvale (Figure 1). The wetland is approximately 30 ha in size. In recent decades the hydrology of the wetland has been altered from historically ephemeral (alternating between dry and wet phases) to almost permanent inundation and connection to the Murray River above the lock and Weir 15 at Euston.

The Mallee Catchment Management Authority (MCMA) manages the hydrological regime of Margooya Lagoon via the control of a regulator located on the inlet/outlet creek near the Murray River which was constructed in 2009. The regulator is fitted with a Carp exclusion screen (35 mm mesh size), restricting fish passage through the regulator.

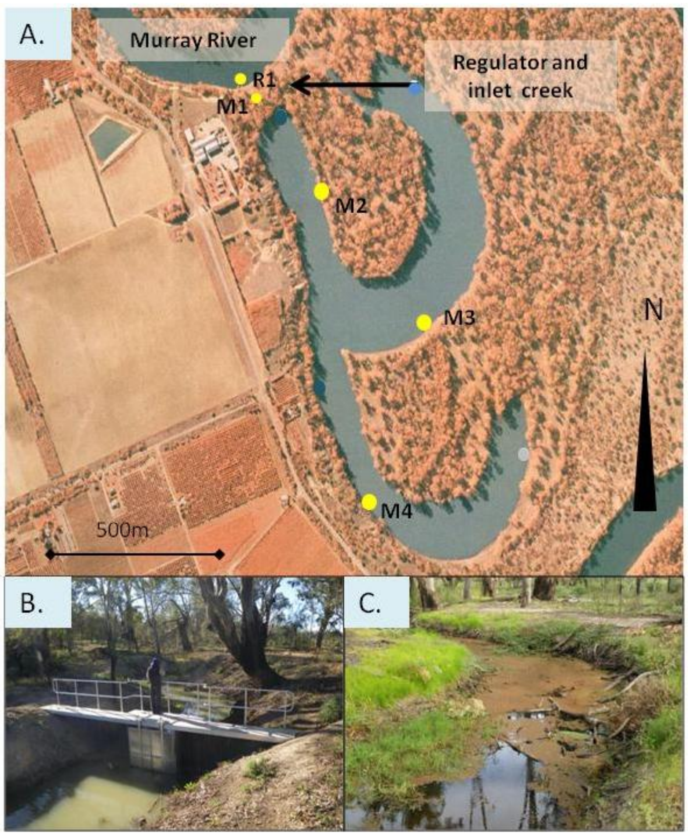


Figure 1. (A) Margooya Lagoon with sample sites indicated; (B) regulator on the inlet creek; (C) the defined channel of the inlet creek.

Off-channel habitats such as Margooya Lagoon are recognised as important for fish populations because of the increased habitat diversity offered by floodplains, with heightened survival, feeding and reproduction opportunities (Junk et al. 1989; Lyon et al. 2010). Closs et al. (2005) demonstrates that wetlands of the Murray-Darling system support a variety of native fish species, including species of conservation significance, highlighting the importance of these systems for conserving fish biodiversity.

Improving lateral connectivity between floodplain nursery habitats such as Margooya Lagoon and the Murray River is important for fish populations as floodplains provide feeding and nursery zones (Closs et al. 2005; Mallen-Cooper 2001). Fish community structure, functioning and subsequent fishery production can relate to river–floodplain connectivity (Junk et al. 1989).
Surveys of the fish community in Margooya Lagoon and its inlet creek indentified juvenile Golden perch (*Macquaria ambuigua*) and Silver perch (*Bidyanus bidyanus*) in the wetland which had been deposited in the Lagoon during a pumped filling event in 2009 (see Ellis 2010). The Murray River demonstrated elevated (but within bank) flows through the Euston Weir (Lock 15) during late November and early December 2009 (Figure 2) which appear to have stimulated these species to spawn in the river channel. Some of these eggs and larvae were subsequently transported into Margooya Lagoon during the environmental pumping event in 2009.

These juveniles demonstrated rapid growth in Margooya Lagoon. However, for the full benefits of off-channel floodplain systems like Margooya Lagoon to be realised, connectivity must facilitate lateral movement in both directions. That is, without re-connection events after periods of development within the floodplain nursery habitat, the maturing fish will be unable to return to the river environment to contribute to future in-stream spawning events.

An assessment of fish movement between Margooya Lagoon and the Murray River during a small drainage event in April 2010 (using directional netting techniques) demonstrated that the juvenile Golden perch and Silver perch were not induced to leave the wetland by the drainage event. Conversely, in a subsequent assessment conducted as the lagoon was being topped up via pumping from the Murray River in June 2010, large numbers of these maturing Golden perch and Silver perch were captured in the connecting creek moving towards the regulator (and the Murray River). This suggests the fresh inflows induced movement of these species back to the Murray River, although the closed regulator on the creek at the time would have blocked the return of these individuals to the river.

Projected high flows in the Murray River in late 2010 presented an opportunity to repeat the lateral fish movement assessments and test several hypotheses based on these earlier findings.

1. Timing of water addition to off-channel nursery environments (such as Margooya Lagoon), to coincide with periods of elevated within bank flows in the Murray River during spring/summer, will increase the chance of larvae and juveniles of key native species (including Golden perch and Silver perch) that are spawned in the main river channel, being deposited in productive nursery environments.

2. That maturing Golden and/or Silver perch in off-channel environments such as Margooya Lagoon are not induced to return to the river upon managed draining of the wetland system.

3. That maturing Golden and/or Silver perch maturing in disconnected off-channel environments (such as Margooya Lagoon) are induced to return to the main river channel in subsequent re-filling connection events.

That Carp exclusion screens on wetland regulatory structures could present a barrier to the return of these species to the river environment.

Hypothesis 1 was tested by sampling larval drift in the Murray River adjacent to Margooya Lagoon throughout the period of elevated flows in late 2010–early 2011. It is generally recognised that elevated river flows and discharge induces in-stream spawning in Golden perch and Silver perch (King et al. 2009; Mallen-Cooper and Stuart 2003). Fortnightly drift sampling would thus allow an assessment of when key native species spawn relative to the flow hydrograph during a flood event.

Hypothesis 2 was tested by assessing the movement of fish between Margooya Lagoon and the Murray River (using directional netting techniques) in late October 2010 when the opening of the regulator resulted in the wetland draining. On this occasion, the head difference between the wetland and the river channel was greater than it had been during assessment of fish movement during a small drainage event in April 2010, which resulted in an increased velocity of flow draining from the wetland.

Hypothesis 3 was tested in November 2010 (using directional netting techniques) when Murray River flows increased and Margooya Lagoon began re-filling.

By late November 2010, water level had exceeded the height of the Margooya Lagoon regulator, providing unrestricted connectivity between the wetland and the river until April 2011 (see Figure 2).

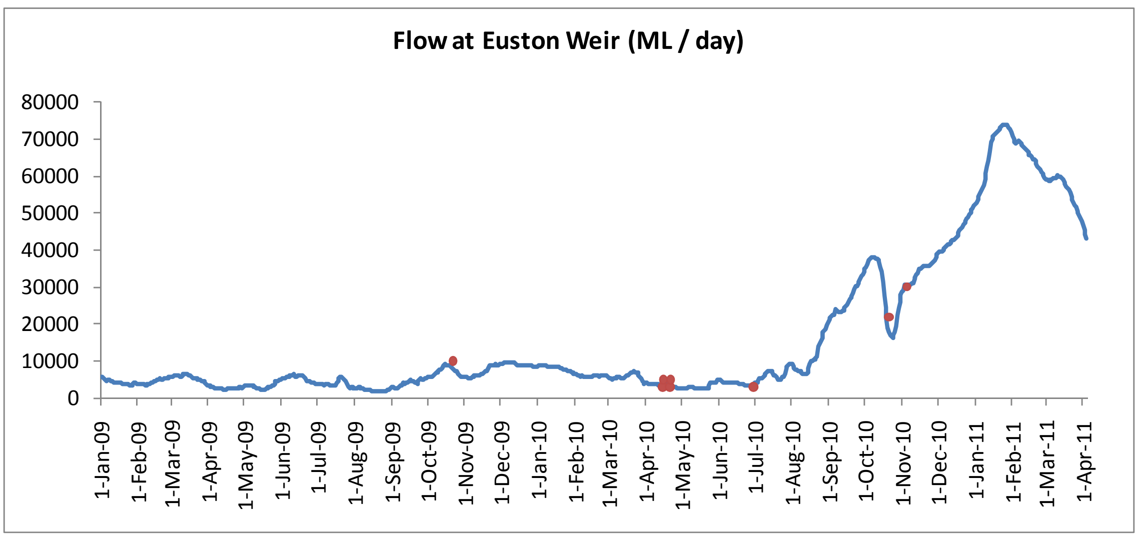


Figure 2. Murray River flows at Lock 15 (Euston Weir) from January 2009 to April 2011, with MDFRC surveys of Margooya Lagoon indicated by red circles.

Hydrological regime of Margooya Lagoon 2009-2011

A range of managed interventions was imposed through 2009 and 2010 to allow manipulation of inundation and retention of water in Margooya Lagoon. This report presents the findings of fish surveys conducted in Margooya Lagoon and in the connecting creek to assess fish movement in October and November 2010 and in stream spawning during the flood pulse of 2010/11. These interventions and the surveys conducted to monitor fish community responses are summarised below.

Table 1. Timing of filling – draining events and associated wetland surveys in Margooya Lagoon.

Date	Regulator status	Event	Survey type
Oct-09	open	Partial filling - moderate river flows	Wetland fish community
Nov-09	closed	Pumped filling event	Wetland fish community
Apr-10	open	Minor drainage event	Fish movement
Jun-10	closed	Surcharge refilling event - pumped	Wetland fish community Fish movement
Oct-10	open	Moderate drainage event	Wetland fish community Fish movement
Nov-10	open	Re-filled via increases in river flows	Fish movement
Dec 2010 - Mar 2011	NA	Floodwaters over-top regulator providing unrestricted connectivity	Murray River Larval Drift

Objectives

1. Determine if and when (relative to the river hydrograph) Golden perch and Silver perch larvae and juveniles (a 2010/2011 cohort) are present in the Murray River adjacent to Margooya Lagoon during a period of fluctuating flow in spring/summer 2010.

2. Assess the timing and direction of movement of native and non-native fish species into or out of Margooya Lagoon when the regulator in the connecting creek is opened during falling and rising river flow periods in the spring/summer 2010.

3. Provide management suggestions which assist in the operation of wetland regulatory structures to benefit native fish communities.

Methods

A survey of the fish community in Margooya Lagoon was conducted during a wetland draining period (i.e. the regulator was open when river levels were lower than wetland water level in October 2010) to determine if the juvenile cohorts of Golden perch and Silver perch detected in previous surveys remained in the lagoon or attempted to return to the Murray River. Sites and netting gear will be consistent with methodology incorporated in previous MDFRC surveys. Directional net placement was used in the connecting creek to determine the direction of movement of fish through the regulator and connecting creek (i.e. between the wetland and river environments). Measurement of maximum width of large-bodied species was used to determine whether fish passage through the Carp exclusion screen is viable.

Survey sites are shown in Figure 1 and are consistent with sites used in previous surveys (Ellis et al. 2009, 2010). Diagrams of the directional netting arrangements in the inlet creek are demonstrated in Figure 3.

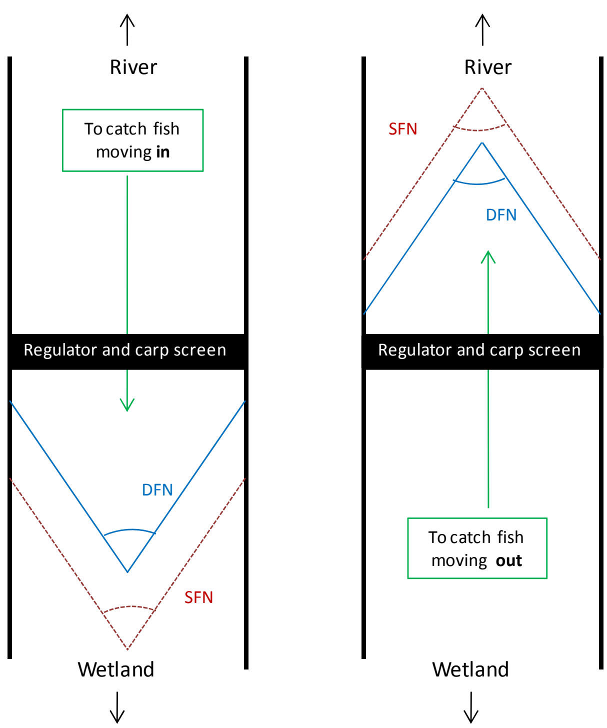


Figure 3. Directional net placement in the Margooya Lagoon inlet creek.

Water Quality

Water quality data was collected at each site during each survey using a U-52 multi-probe (Horiba Ltd, Australia). Temperature (°C), pH, turbidity (NTU), electrical conductivity (µS cm^{-1}) and dissolved oxygen (mg L^{-1}) were recorded at a depth of 0.2 m below the water surface. Measurements were taken between 9 am and 5 pm. Parameters were compared to suggested guidelines as described by ANZECC & ARMCANZ (2000).

Fish

At each site in the wetland two large mesh fyke nets (LFN) and two small mesh fyke nets (SFN) were deployed overnight (Table 1). Nets were set to include a diversity of structural habitat (open water, vegetation and woody material) to increase the probability of sampling a range of species and size classes. Large fyke nets (LFN) had a central wing (8 m x 0.65 m) attached to the first supporting hoop (∅ = 0.55 m) with a mesh entry of 0.32 m and stretched mesh size of 28 mm. Small fyke nets (SFN) had dual wings (each 2.5 m x 1.2 m), with a first supporting hoop (∅ = 0.4 m) fitted with a square entry (0.15 m x 0.15 m) covered by a plastic grid with rigid square openings (0.05 m x 0.05 m). Each SFN had a stretched mesh size of 2 mm.

Directional large fyke nets (DFN) were set across the Margooya Lagoon inlet channel to capture fish moving either direction into or out of the wetland. Each DFN had two wings (8 m x 1.5 m) attached to the first supporting hoop (∅ = 0.55 m) with a mesh entry of 0.32 m and stretched mesh size of 28 mm. SFN were set facing either direction to assess movement of small-bodied species between the wetland and the river.

All nets were set in the afternoon and collected the following morning. The cod-end of LFN and DFN was suspended out of the water by use of floats to avoid mortality of captured air-breathing animals.

Fish identifications followed McDowall (1996) and Lintermans (2007). Carp gudgeon were identified to genus level only (i.e. *Hypseleotris* spp.) owing to the current taxonomic uncertainty at the species level (Bertozzi et al. 2000). All fish captured were counted. Standard lengths (SL to the nearest 1.0 mm) were recorded for a sub-sample of 30 individuals of each species from each net to allow interpretation of species size-class frequency. The head width for juvenile Silver perch, Golden perch, Carp and goldfish was recorded to determine if the fish were small enough to pass through the Carp exclusion screen on the Margooya Lagoon inlet/outlet regulator (screen mesh size 35 mm).

All native fish were returned alive to the point of capture, while exotic species were euthanized by immersion in Aqui-S following ACEC guidelines. Fauna classified as by-catch in netting surveys (freshwater yabbies, shrimp and turtles) were identified and counted before being returned to their point of capture. Ethics approval was obtained prior to sampling through La Trobe University Animal Ethics Committee (Permit No. AEC07-20-MD-V2).

Larval drift

Understanding the timing and cues for spawning events will increase our potential to ensure juvenile native species have the opportunity to disperse into managed wetland systems. Fortnightly sampling of drift material in the Murray River adjacent to Margooya Lagoon from mid-October 2010 to April 2011 was conducted to determine if and when (relative to the river hydrograph) Golden perch and Silver perch were spawning in the main river channel during the elevated spring/summer flows of 2010/11. Four conical drift nets were deployed from overhanging and exposed snags in the Murray River channel overnight and retrieved the following morning. Collected material was transferred to ethanol and larval fish were sorted and identified in the laboratory. Each net had an opening of 50 cm and a mesh size of 0.52 mm to capture drifting material.

Figure 4. Drift net used in Murray River sampling adjacent to Margooya Lagoon.

Results

Water Quality

Mean water quality measurements for recent MDFRC surveys of Margooya Lagoon are presented in Table 2. Mean turbidity in Margooya Lagoon has been relatively low since the construction of the regulator on the inlet creek and was only high during the initial re-filling event in December 2009. Electrical conductivity (EC) recorded in Margooya Lagoon during MDFRC surveys was at all times below the suggested maximum of 2200 µS cm^{-1} @ 25 ºC for Lowland River systems (ANZECC & ARMCANZ 2007 and was comparable to those recorded in other local Mallee wetlands (Ellis. et al. 2009; Ho et al. 2004). The mean pH of Margooya Lagoon during the April 2010 surveys was also generally within the range reasonably expected according to the guidelines described by ANZECC & ARMCANZ (2000).

The mean temperature in Margooya Lagoon was also within the suggested range (ANZECC & ARMCANZ 2007) and fluctuated on a daily and seasonal basis. Dissolved oxygen (DO mg L^{-1}) concentrations were recorded between the hours of 11.00 am and 5.30 pm. The mean DO of Margooya Lagoon was greater than the recommended minimum concentrations for freshwater ecosystems of 6 mg L^{-1} (ANZECC & ARMCANZ 2000) during all surveys except the one conducted in December 2009 when warm temperature and organic loading resulted in oxygen depletion. Despite the oxygen depletion associated with the blackwater event in the Murray River channel during summer 2010/11, DO in Margooya Lagoon in November was still above guidelines described by ANZECC & ARMCANZ (2000).

Table 2: Mean water quality measurements for MDFRC surveys of Margooya Lagoon including data for November 2011.

Survey Date	Turbidity (NTU)	EC (uS.cm^{-1})	pH	Temperature (°C)	DO (mg/L)
14/05/2004	48	373	8.38	14.5	-
22/10/2009	177.1	298.8	7.0	24.6	9.1
16/12/2009	3.0	133.2	6.8	29.0	3.9
14/04/2010	58.3	175.8	7.7	18.2	7.0
30/06/2010	55.3	99.4	7.3	9.7	7.9
5/11/2010	21.3	166.6	6.8	20.6	6.1

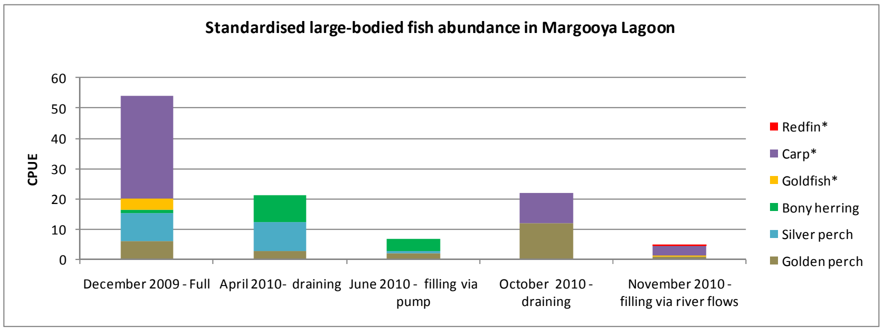
Fish Communities in Margooya Lagoon

Standardised fish catch (20 x LFN/SFN soak hours) for large- and small-bodied fish species captured during surveys conducted in Margooya Lagoon are presented in Table 3 and presented graphically in Figure 5. Species presence/absence in a survey conducted in 2004 by MDFRC is also included in Table 3 for reference.

Silver perch were initially relatively abundant when Margooya Lagoon was refilled after construction of the regulator in 2009, but were absent from the catch in surveys after June 2010. Lower abundances of Golden perch and Silver perch were captured in wetland sites of Margooya Lagoon during wetland draining events than in wetland filling events. The exotic Carp and goldfish were initially abundant in Margooya Lagoon in December 2009, but were absent from the catch in April and June 2010. Juvenile Carp re-entered the lagoon during the October draining event and were captured in the October and November 2010 surveys. Carp gudgeon and Gambusia were the most abundant small-bodied species throughout the surveys.

Table 3: Standardised fyke net (catch per 20 net hours) catch for each fish community survey in Margooya Lagoon. * denotes exotic species.

Common name	**Scientific name**	May 2004 prior to reg.	Dec 2009 Full	April 2010 draining (slow)	June 2010 filling (pumped)	October 2010 draining (moderate)	November 2010 filling (river flows)
Golden perch	*Macquaria ambigua*		6	3	2	12	1
Silver perch	*Bidyanus bidyanus*		9	10			
Bony herring	*Nematalosa erebi*	✓	1	9	4		
Goldfish*	*Cyprinus carpio*	✓	4				
Carp*	*Carassius auratus*		34			10	3
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	✓		125	6	100	12
Carp gudgeon	*Hypseleotris spp.*	✓	54	535	61	938	292
Flathead gudgeon	*Philypnodon grandiceps*	✓					
Australian Smelt	*Retropinna semoni*		1	2			
Oriental Weatherloach*	*Misgurnus anguillicaudatus*		12	2			4
Gambusia*	*Gambusia holbrooki*	✓	1	637	7	57	400



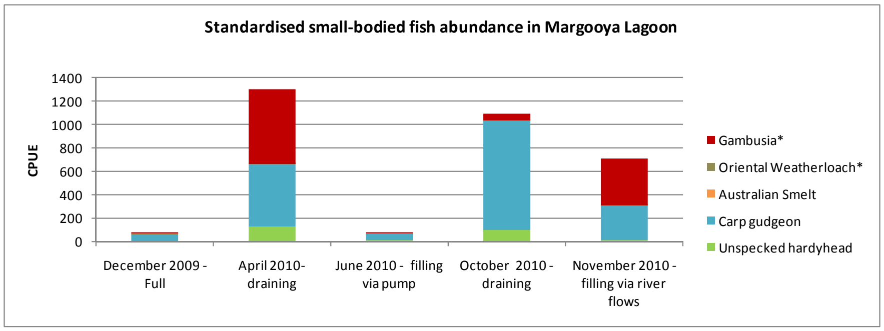


Figure 5. Total standardised fish abundance (catch per 20 net hours, LFN and SFN combined) for large- and small-bodied species caught in Margooya Lagoon in each MDFRC survey. * denotes exotic species

Lateral fish movement

The standardised abundances of large-bodied species recorded moving ‘in’ or ‘out’ of the wetland during the directional surveys is shown in Figure 6. The native Golden perch (and to a smaller extent Silver perch) were only recorded attempting to exit the wetland during filling events (both pumped and natural flow events). Only two adult Golden perch were captured attempting to enter the wetland from the Murray River and only during October and November 2010. Juvenile Carp (small enough to pass through the Carp exclusion screen) were captured entering the wetland from the Murray River during the October 2010 draining event in far greater abundances than Carp exiting the wetland.

No particular pattern of lateral movement was detected for small-bodied species in either the filling or draining events included in this survey (Figure 7).

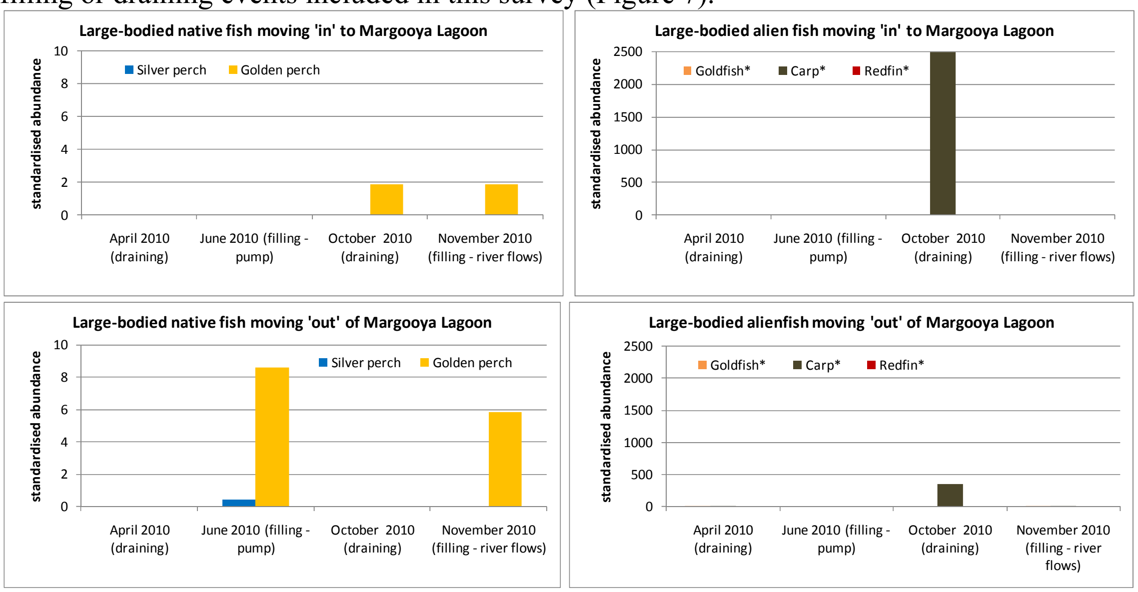


Figure 6. Standardised abundance (catch per 20 net hours, LFN and SFN combined) for large-bodied species caught entering and exiting Margooya Lagoon from/to the Murray River during directional surveys. Native species are in shown on the left, with exotic species on the right.* denotes exotic species.

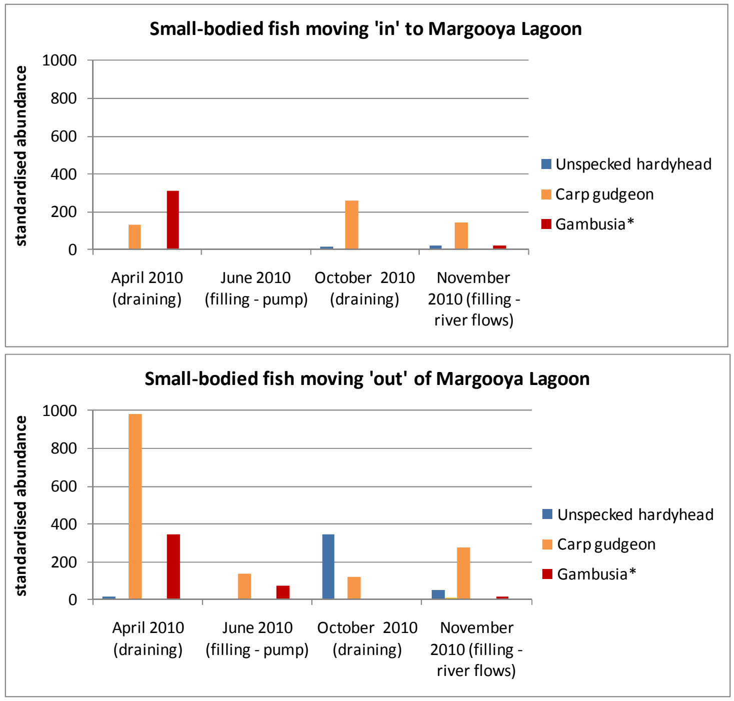


Figure 7. Standardised abundance (catch per 20 net hours) for abundant small-bodied species caught entering and exiting Margooya Lagoon from/to the Murray River during directional surveys.

Restriction of native fish passage by the Carp exclusion screen

The rapid growth rates of juvenile Golden perch and Silver perch in Margooya Lagoon during 2010 is documented by Ellis (2010). The head width frequency distribution for Golden perch and Silver perch captured in progressive surveys of Margooya Lagoon are demonstrated in Figure 8. The Carp exclusion screen on the regulator has a mesh size of 35 mm, which means fish with a head size greater than 35 mm (to the right of the red dashed line in Figure 8) are likely to be impeded or excluded from returning to the Murray River by the screen.

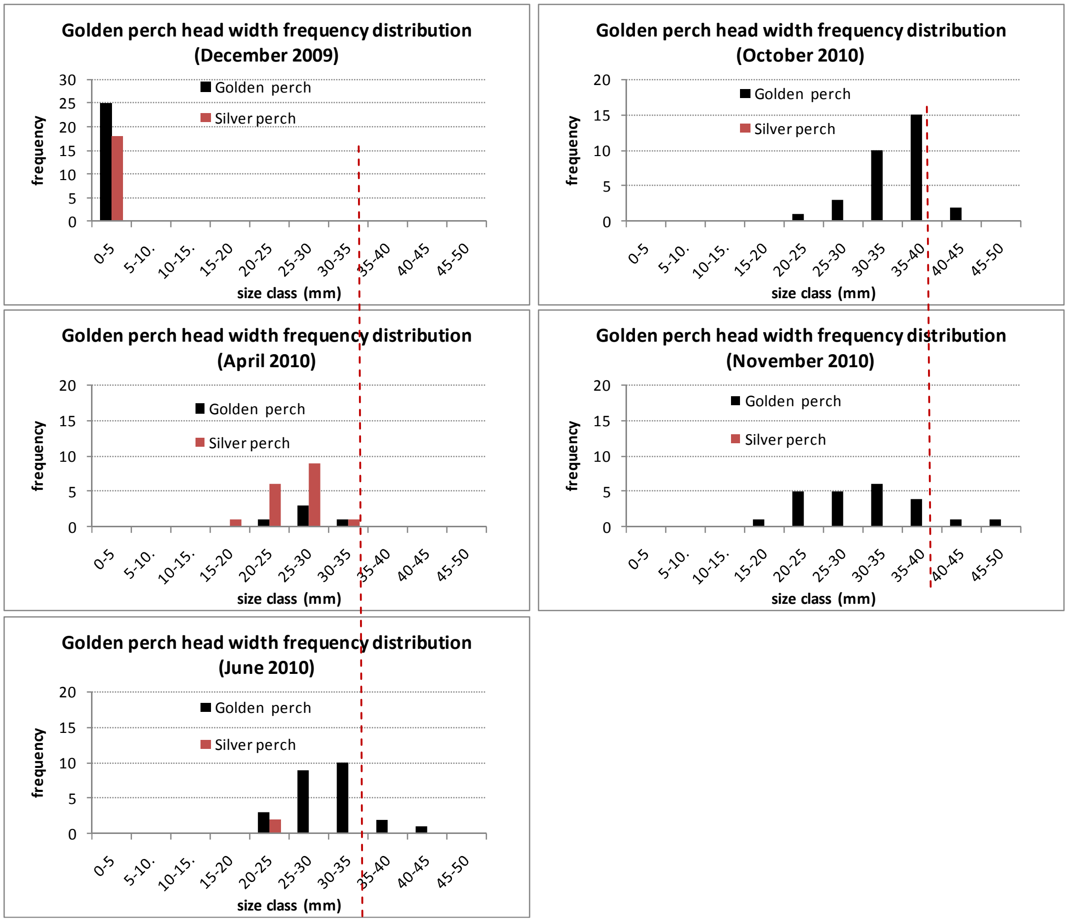


Figure 8. Head width frequency distributions for Golden perch captured in netting surveys (the Carp exclusion screen has a mesh size of 35 mm, indicated by the red line).

Larval fish in drift surveys

Total larval/juvenile fish catch in drift nets and dissolved oxygen (DO) concentration in the Murray River adjacent to Margooya Lagoon from September 2010 to April 2011 is shown in Figure 9, with the river flow rate (at Euston Weir) overlaid.

Very few larval fish were detected throughout the drift survey period. Several larval Murray cod and Carp larvae were recorded in the drift samples in October 2010 and one Silver perch larvae was recorded in early December 2010. Between December 2010 and April 2011 a severe and prolonged blackwater event resulted in daytime oxygen levels of less than 3 mg/L. During this period, most fish in the larval drift nets were juvenile Carp gudgeon and Gambusia. A single Murray cod larvae was recorded in February 2011, outside the normal breeding season for the species (Lintermans 2007).

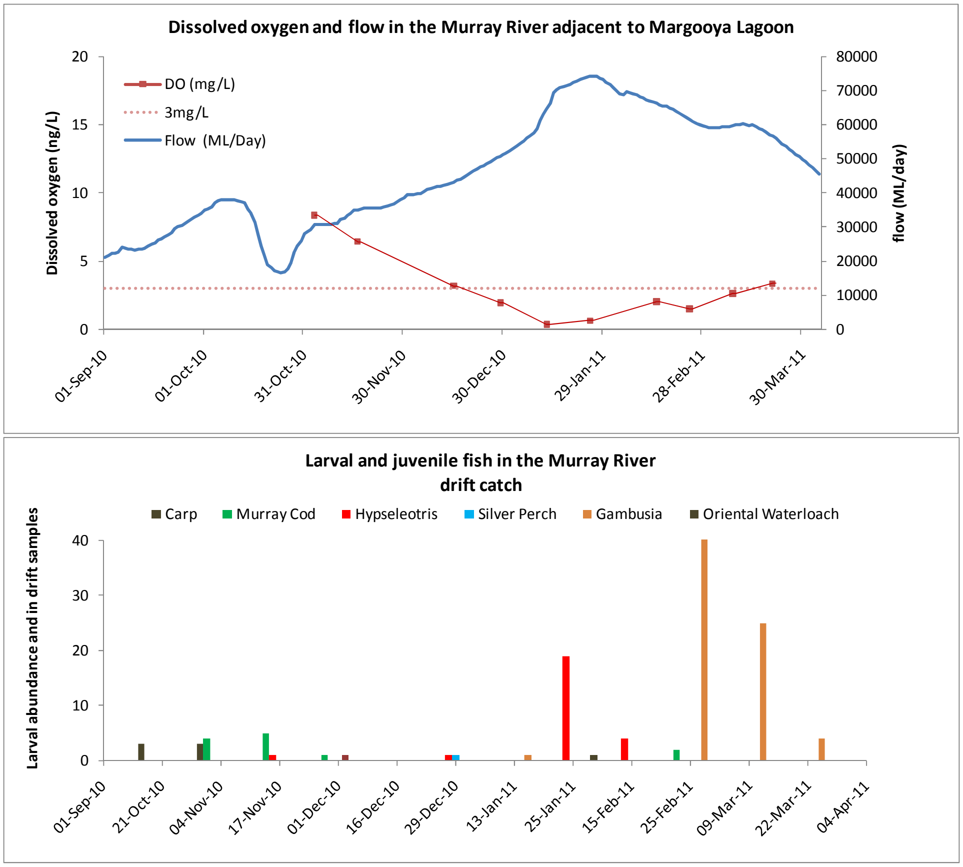


Figure 9. Murray River flow rate and dissolved oxygen concentration and larval fish abundance in drift samples from September 2010 to April 2011 (Data sourced from MDBA and MDFRC). A dashed pink line indicates a dissolved oxygen concentration of 3mg/L.

Discussion

Drying of a wetland promotes nutrient transformation and the consolidation of sediments and allows for the establishment of terrestrial plant species which provide habitat and nutrients for aquatic biota upon re-inundation. The re-inundation of dry sediment often triggers the release of a pulse of carbon, phosphorous and nitrogen into the water column, increasing primary productivity (Baldwin and Mitchell 2000; Zukowski et al. 2003; Scholz and Gawne 2004). This in turn increases macrophyte growth, providing food, habitat and breeding opportunities for species at higher trophic levels including macro and microinvertebrates, fish, frogs and turtles. This post inundation response was demonstrated by Margooya Lagoon (Ellis et al. 2009). Matching this pulse in production with seasonal spawning patterns of native fish has the potential to confer significant benefit to native fish recruitment success.

Lateral Fish Movement

Lyon et al. (2010) suggests that lateral fish movements approximated water level fluctuations. That is, as water levels rise, fish leave the main river channel and move into newly flooded off-channel habitats and on falling levels, fish move back to the permanent riverine habitats. Several exceptions to this trend were detected throughout the surveys of Margooya Lagoon, with several variations observed.

In particular, Golden perch and Silver perch were first detected as juveniles in Margooya Lagoon in December 2009. The Murray River demonstrated elevated flows during late November and early December 2009. Elevated river flows are frequently reported to induce spawning in Golden perch and Silver perch (King et al. 2009; Mallen-Cooper and Stuart 2003) and eggs and larvae from in-channel spawning were subsequently transported into Margooya Lagoon during the environmental pumping event in 2009.

However, these cohorts of Golden perch and Silver perch young were not detected moving back to the riverine habitat in later wetland draining events (April and October 2010). We suggest the young Golden perch and Silver perch were not induced to leave during either of the two partial drainage events, because the wetland continued to provide productive nursery habitat, in which both species demonstrated rapid growth (Ellis 2010). Further, Mallen-Cooper (2001) suggests an initial drop (i.e. a head difference) of 10-20 cm should provide a cue for large-bodied species to leave the wetland, while small-bodied species are likely to continue to leave as further drying ensues. The small flow observed upon opening of the regulator during both drainage events included in this study may therefore have been insufficient to stimulate Golden perch and Silver perch to leave the wetland. Future assessments of lateral movement should aim to include quantification of head difference and flow rates to fine tune management of drawdown and filling events.

Golden perch and Silver perch young were recorded congregated at the regulator and Carp exclusion screen, attempting to return to the riverine habitat during wetland filling events in both June and November 2010. We suggest these fish were induced to return to the riverine habitat on subsequent re-filling events (i.e. rising water levels) as a means of in-channel migration typical of the species during increases in flow (Harris and Rowland 1996).

Conversely, juvenile Carp were detected moving from the river habitat into Margooya Lagoon in large abundances during the October 2010 draining event. A flow increase in early spring 2010 (September to October) appeared to have induced large scale Carp breeding across the lower Murray River system. The juveniles resulting from these breeding events were detected moving upstream in large numbers during the spring of 2010 (Ellis, personal observation). Water draining from Margooya Lagoon cued juvenile Carp to enter the wetland during this period. A summary of the managed intervention and resulting patterns in fish movement detected during the surveys at Margooya Lagoon is shown in Table 4.

Table 3: Imposed intervention and resulting patterns in Golden perch and Silver perch movement to and from Margooya Lagoon during 2009-2010.

	30-September-2009	20-October-2009	16-December-2009	15-April-2010	29-June-2010	21-October-2010	04-November-2010
Regulator status	closed	open	closed	open	closed	open	open
Carp screen status	closed	closed	closed	closed	closed	closed	closed
Fish movement capability	Blocked	exclusion of large fish by carp screen	Blocked - transfer to wetland only through pump	exclusion of large fish by carp screen	Blocked - transfer to wetland only through pump	exclusion of large fish by carp screen	Unimpeded - overbank flooding
Filling/draining		Small inflow from Murray River	Pumped full from Murray River	Partial draining	Pumped full to top up	Regulator opened - significant drainage	Filling from overbank river flows
Head Difference (between wetland and river)	Wetland Dry	0 cm	100cm	5 cm	30cm (negative)	Initially 120cm (negative). Only 10cm (negative) at time of survey *	0 cm
Golden and Silver perch movement		Not surveyed	Transfer of juvenile golden and silver perch into wetland	did not move towards river	DID move towards river	did not move towards river	DID move towards river
Movement of Small bodeid natives	not surveyed	not surveyed	not surveyed	More small bodied natives moving out than into the wetland (predominantly carp gudgeon and small numbers of unspecked hardyhead	no pattern detected	More small bodied natives moving out than into the wetland (predominantly carp gudgeon and small numbers of unspecked hardyhead	no pattern detected
Pest species movement	not surveyed	not surveyed	not surveyed	More carp and weaherloach move into wetland from river than out.	no pattern detected	Juvenile carp move into wetland from river *en masse*	no pattern detected
Comments	Managed dry phase	Insufficient inflows to provide suitable habitat for most fish species (ie. Less than 20cm deep)	Presence of juvemile Golden perch and Silver perch suggests instream spawning events	Minor drainage - may have been insufficient head to trigger movement; or fish passage potentially impeded by debris and blackwater in connecting creek	Young Golden perch and Silver perch moved towards river, probably induced by fresh inflows. Larger individuals blocked by carp exclusion screen.	Minor drainage - Survey conducted after drainage had already occurred for 24 hours, and there may have been insufficient head to trigger movement by the time the survey was conducted.	Young Golden perch and Silver perch moved towards river, probably induced by fresh inflows. Larger individuals blocked by carp exclusion screen.

Larval abundance during the 2010/11 blackwater event

Aquatic dissolved oxygen (DO) concentrations fluctuate diurnally, being higher in the daytime when algae and aquatic plants contribute dissolved oxygen to the system during photosynthesis. Few fish species can tolerate prolonged exposure to DO levels below 3 mg/L, especially large-bodied or more active fish with a higher oxygen demand (NSW Fisheries 2000).

Breakdown of organic matter by aerobic bacteria in aquatic systems consumes oxygen. Large increases of organic matter in the water column (known as organic loading or blackwater) which can occur during flood events, can cause dissolved oxygen concentrations to drop to levels lethal to fish. Soon after flooding, a large pulse of carbon and nutrients is released from sediments and organic litter into the overlying water, which is used by aerobic bacteria for growth. If the consumption of oxygen occurs at a greater rate than oxygen replenishment from the atmosphere and photosynthesis, the water column can become anoxic (Baldwin et al. 2001).

Throughout the Murray River flood pulse from September 2010 to April 2011, a protracted blackwater event resulted in low DO concentrations in the Murray River. Oxygen-stressed and dead fish including Golden perch, Silver perch, Bony herring, Murray cod and Carp were recorded throughout the blackwater event along the Murray River (Figure 10). The blackwater event in 2010/11 appears to have suppressed the spawning of native fish, particularly Golden perch and Silver perch which are normally induced to spawn during flow pulses (King et al. 2009).

Figure 10. Dead Silver perch and oxygen-stressed Golden perch in the Murray River blackwater event of 2010/11.

Fortunately, large scale Golden perch spawning and recruitment was demonstrated in the Darling and Darling Anabranch river systems (Bogenhuber and Linklater 2011). Floodwaters have since washed many of these Darling River fish into the Murray River system, which have been detected in fish monitoring programs conducted by the MDFRC both upstream and downstream of the Murray–Darling River confluence. The presence of these Darling River Golden perch will to some degree offset the suppressed breeding of Golden perch in the Murray River through the 2010/11 flow pulse and blackwater event described in this report.

Murray cod larvae were detected in the Murray River drift sampling in October 2010, prior to the onset of the blackwater event, but the impact of the blackwater on developing Murray cod will not be evident until presence or absence of recruits spawned this season are detected in future fish surveys in the region.

Recommendations

Assessments of fish movement between the Murray River and Margooya Lagoon detected movement of Golden perch and Silver perch towards the Murray River from the lagoon on filling events but not on drainage events. Thousands of juvenile Carp were; however, recorded entering the wetland during a spring drainage event. Consequently, we make the following recommendations with regard to the managed hydrological regime of Margooya Lagoon, to enhance its suitability to native fish.

Filling events

Although the blackwater event in the Murray River in 2010/11 appears to have suppressed spawning of native fish, timing the re-filling events to coincide with elevated river flow levels provides a greater opportunity to facilitate transfer of juvenile native fish into the wetland from the river channel (Figure 10).

Although recruitment of native fish can and does occur within the main river channel during periods of low flow (Humphries *et al.* 1999), by transferring some of these juveniles to productive managed off channel habitats, we may be able to increase the survival and recruitment rate in a localised area. Pumping wetlands full during elevated within-bank river flow pulses is likely to facilitate transfer of drifting juveniles (particularly Golden perch) from the river to the wetland habitat – juveniles which otherwise are likely to remain within the main channel of the river, given their low swimming and dispersal capabilities. Furthermore, filling events in spring and summer are likely to produce a greater ecological response in ephemeral wetland systems than autumn/winter filling events, as they are likely to coincide with the natural reproductive patterns of many native aquatic organisms.

Reconnection events during high river flows

Reconnecting Margooya Lagoon to the Murray River (by re-opening of the regulator) when river flows are rising, will potentially infer multiple benefits in terms of fish passage. Inflows of fresh river water are likely to stimulate the movement of native fish (particularly Golden perch and Silver perch) back into the river system. Inflows may also facilitate movement of larval native fish into the wetland (from the river channel).

Reconnecting during low river flows (drainage events)

Although the opening of the Margooya Lagoon regulator during drainage events (low river flows) did result in movement of many small native fish from the wetland to the river channel, it did not induce the movement of juvenile Golden and Silver perch from the wetland, increasing the risk of stranding for these developing fish. By timing the drainage event (i.e. opening the regulator) to occur when water levels in the wetland are considerably higher than the river, the greater out-flow to the river due to differences in water level are more likely to provide a cue for native species to leave the wetland. Mallen-Cooper (2001) suggests an initial drop of 10-20 cm is required for movement back to the river to be induced.

Thousands of juvenile Carp were recorded entering Margooya Lagoon from the Murray River through the Carp exclusion screen during the spring 2010 draining event. By conducting drawdown events during autumn and winter, the likelihood of juvenile Carp small enough to pass through the Carp screen, being present in large numbers in the Murray River, would be reduced. Given large numbers of Carp entered Margooya Lagoon during the spring of 2010, the regulator should also remain closed to prevent the return of these Carp to the Murray River. Surveys of the Margooya Lagoon fish community are recommended to determine the persistence and impact of these Carp on submerged habitat and water quality in the wetland. If no juvenile Golden perch and Silver perch have entered during the flood pulse and Carp remain abundant in Margooya Lagoon, the wetland should be allowed to enter a new dry phase thus eradicating adult Carp.

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