Moira Lake Fish surveys 2018

Summary of findings report

Clayton Sharpe

JULY 2018

Contact us

Inquiries regarding the licence and any use of the document are welcome at:
NSW National Parks and Wildlife Service
23 Neil Street
Moama NSW 2731
03 5483 9100
riverina@environment.nsw.gov.au

This project was funded by The Living Murray. The Living Murray is a joint initiative funded by the New South Wales, Victorian, South Australian, Australian Capital Territory and Commonwealth Governments, coordinated by the Murray–Darling Basin Authority.

Citation:
Sharpe, C. (2018) Moira Lake Fish Surveys 2018. A summary of findings report for NSW National Parks and Wildlife Service by CPS Enviro P/L.

.

Disclaimer:
The results and comments contained in this report have been provided on the basis that the recipient assumes the sole responsibility for the interpretation and application of them. The author gives no warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or use of the results and comments contained in this report by the recipient or any third party.

Acknowledgements

NSW Office of Environmental and Heritage Regional Operations Group and National Parks and Wildlife Service initiated and provided funding for the surveys and reporting for this work to be undertaken. Alison Borrell (NSW NPWS) oversaw project management and the selection of field sites. Eden Sharpe (CPS Enviro) assisted with fieldwork. MDFRC processed zooplankton samples and provided data. Thankyou to NSW NPWS staff at Mathoura for their support with field logistics. All work was undertaken following NSW Fisheries Research Permit # P12/0004 and GUACEC ENV/04/14/AEC.

Cover image: Moira Lake, May 2018

Contents

INTRODUCTION and SURVEY METHODS

The Moira Lake wetland system is one of the largest and most significant wetlands of the mid-Murray River valley. The system consists of two large (total 1500ha), shallow open water lakes surrounded by marshy wetlands, rushes and reeds and grassy plains surrounded by River Redgum Forest. Moira Lake is the NSW component and Barmah Lake the Victorian and both are recognised under the Ramsar Convention as significant breeding sites for colonial nesting water birds (Leslie 2001) and native fish (Jones and Stuart 2006; Truman 2007).

Moira Lake is known to have supported a diverse and abundant native fish community, with accounts from the 1860's describing sophisticated Aboriginal fishing techniques and then the commercial harvesting of large quantities of native fish (~100 tons p.a.) by the Lake Moira Fishing Company, taking Murray cod, trout cod, golden perch and silver perch throughout the early Colonial period (~1860-1900) (Leslie 1995; Trueman 2007). Now, Moira Lake and the broader river region no longer support a commercial fishery and the lake does not even support detectible populations of those native species that were once commonly harvested (Raymond et al. 2018).

When Moira Lake has contained water, it has been surveyed for fish under the Murray-Darling Basin Authority's The Living Murray (TLM) Annual Fish Condition Monitoring Program. Moira Lake has been sampled 7 times during the period 2007-2018, with only one site in the lake has been surveyed annually (Raymond et al. 2018). Like the remainder of wetlands throughout Barmah-Millewa Forest (B-MF), the native fish community at Moira Lake has suffered dramatic declines in species diversity and abundance, especially so since the Millennium drought (Rourke and Tonkin 2009; Sharpe and Wilson 2012; Raymond et al. 2018; Pearce et al. 2018; Sharpe 2018). Now, only two native species are regularly recorded in the lake and always at very low abundance; carp gudgeons (*Hypseleotris* spp) and Australian smelt (*Retropinna semoni*). The 2018 TLM survey of the Moira Lake fish community only collected n= 5 carp gudgeon and n= 15 Australian smelt (Raymond et al. 2018). Exotic species diversity and abundance is however consistently higher with goldfish (*Casuras auratus*), carp (*Cyprinus carpio*), Eastern gambusia (*Gambusia holbrookii*) and oriental weatherloach (*Misgurnus anguillicaudatus*) all regularly recorded (Rourke and Tonkin 2009; Raymond et al. 2018). This is similar to TLM surveys undertaken at Barmah Lake, albeit that a few individuals of un-specked hardyhead (*Craterocephalus stercusmuscarum*) and Murray-Darling rainbowfish (*Melanotae fluviatilis*) have been occasionally recorded across the seven years of surveys (Raymond et al. 2018).

Like Barmah Lake, Moira Lake is now well-known and recognised as a prolific breeding ground for carp, rather than for its native fish values (Jones and Stuart 2006). Throughout the 1990's and 2000's, carp have been commercially harvested from Moira Lake as a management tool to reduce their impact on the wetland's ecological values, particularly vegetation, and to reduce the movement of new recruits and adults back to the Murray River (Jones and Stuart 2006). In 2018, 42.8 tons of carp were removed from the lake (Tim O'Kelly, NSW NPWS pers. comm.), while zero large bodied native fish were recorded in the TLM surveys undertaken during the same period (Raymond et al. 2018).

In 2015, Sharpe and Stuart (2015) working with NSW NPWS outlined an adaptive management approach to restoring native fish populations to Moira Lake. Their restoration model was built on consideration of the function of the wetland as a potential nursery ground for Murray cod, trout cod, golden perch and silver perch; all of which are regularly recorded in the Murray River adjacent to Moira Lake (Raymond et al. 2018), where their spawning has been regularly documented (Raymond et al.

2018). Sharpe and Stuart (2015) highlighted that recruitment strength for those species in the Murray River adjacent to Moira Lake is however irregular and poor, but that at other locations along the Murray River and in the Darling River those species regularly recruit, especially in association with large-scale floods (Koehn and Harrington 2006; Stuart and Sharpe 2018). Notably, recruitment success is high for those species when larvae and early juveniles are able to access large floodplain lakes, such as Menindee, Hattah and Yanga Lakes and now, floodplain lake habitats are thought to be especially important to native fish recruitment, especially so for golden perch, when larvae drift from main river channel spawning grounds into recently inundated floodplain lake habitats (Sharpe 2011; Mallen-Cooper et al. 2014). This model of floodplain recruitment thus formed the basis for the potential restoration of a diverse and robust native fish community at Moira Lake and its function as a floodplain nursery habitat for native fish in the mid-Murray River valley (Sharpe and Stuart 2015).

Recruitment success in floodplain lakes, and other habitats, is dependent upon larvae and very early life stages of native fish accessing abundant food; zooplankton, and suitable nursery habitat that is connected or reconnects to permeant adult habitats (Lake 1967; Rowland 1992; Harris and Gehrke 1990; Gehrke 1991; Balcombe and Arthington 2006; Sharpe 2011). Accordingly, hydrological connectivity and an intact and functioning food web are the key drivers for strong native fish recruitment and the function of these elements is essential for Moira Lake to be restored as a successful habitat for native fish.

This present study aimed to expand upon Sharpe and Stuarts (2015) native fish recovery model for Moira Lake by;

- Surveying and describing the Moira Lake Fish community
- Undertaking a benchmark examination of the micro-invertebrate (zooplankton) community and evaluating the potential for the Moira Lake food-web to support the recruitment of native fish
- An evaluation of hydrological data for Moira Lake (inflow and outflow periods, water level and depth) to examine and offer refinement to the hydrological management of the lake to optimise its to function as a nursery habitat for native fish.

Methods

Fish and zooplankton sampling

Sampling of the Moira Lake fish community was conducted from 20th April 2018. Two sites only were able to be surveyed due to very low water levels in the lake (~ 0.30m) and sampling by back pack electrofishing was the only effective technique. Fyke nets were trailed but were unable to be deployed for lack of water depth sufficient enough for fish to enter the entrance funnels of the nets. The backpack electrofisher was a Smith-Root LR12B and sampling at each site followed Sustainable Rivers Audit methods, whereby 8 x 150 second power-on electrofishing shots (300 volts) were made through open areas and amongst stands of giant rush (*Juncus ingens*). Fish stunned by the electrofisher were dip netted, identified to species and measured to the nearest 1.0 mm.

Pelagic micro-invertebrates (zooplankton) were sampled at each of three replicate sites at the same sites and time as for the fish surveys at Moira Lake. Zooplankton samples were also collected from an additional eight wetlands throughout Millewa Forest, the same as where fish community samples were taken by Sharpe (2018) (Table 1), for the purpose of providing context to the structure and abundance of the zooplankton community sampled at Moira Lake.

Each sample was taken by passing 75 L^{-1} of water drawn with a 25L bucket from the water column through a 50 µm mesh. The sample was filtered to approximately 20 ml^{-1} and preserved in 70 % ethanol. In the laboratory, each field sample was filtered through 50 µm mesh and transferred to 50 ml distilled water, mixed and sampled by calibrated pipette to provide 10 x 1 ml subsamples. Each 1.0 ml subsample was then examined in a Sedgewick-Rafter Cell using a dissecting microscope with an inverted light source. Taxonomic resolution was set to the level of order or family and count data were converted to densities L^{1}.

Table 1. Sites sampled at Millewa Forest for plankton during April 2018.

Waterbody	Coordinates
Burial Lagoon	35°48'45.69"S 144°54'42.96"E
Fishermans Bend Lagoon	35°49'30.00"S 145° 4'51.32"E
South Reed Beds	35°50'19.97"S 144°56'25.38"E
Moira Lake 1	35°56'51.87"S 144°56'4.76"E
Moira Lake 2	35°56'45.17"S 144°55'46.08"E
Nine Pannel Lagoon LARGE	35°49'58.55"S 145° 3'24.02"E
Nine Pannel Lagoon SMALL	35°50'3.46"S 145° 3'45.66"E
Pinchgut Lagoon	35°49'30.20"S 145° 8'14.18"E
Toupna Creek @ Big Hole Rd	35°48'39.45"S 145°06'30.2"S
Toupna Creek @ Toupna Crossing	35 48'53.56" 145 09'55.07"

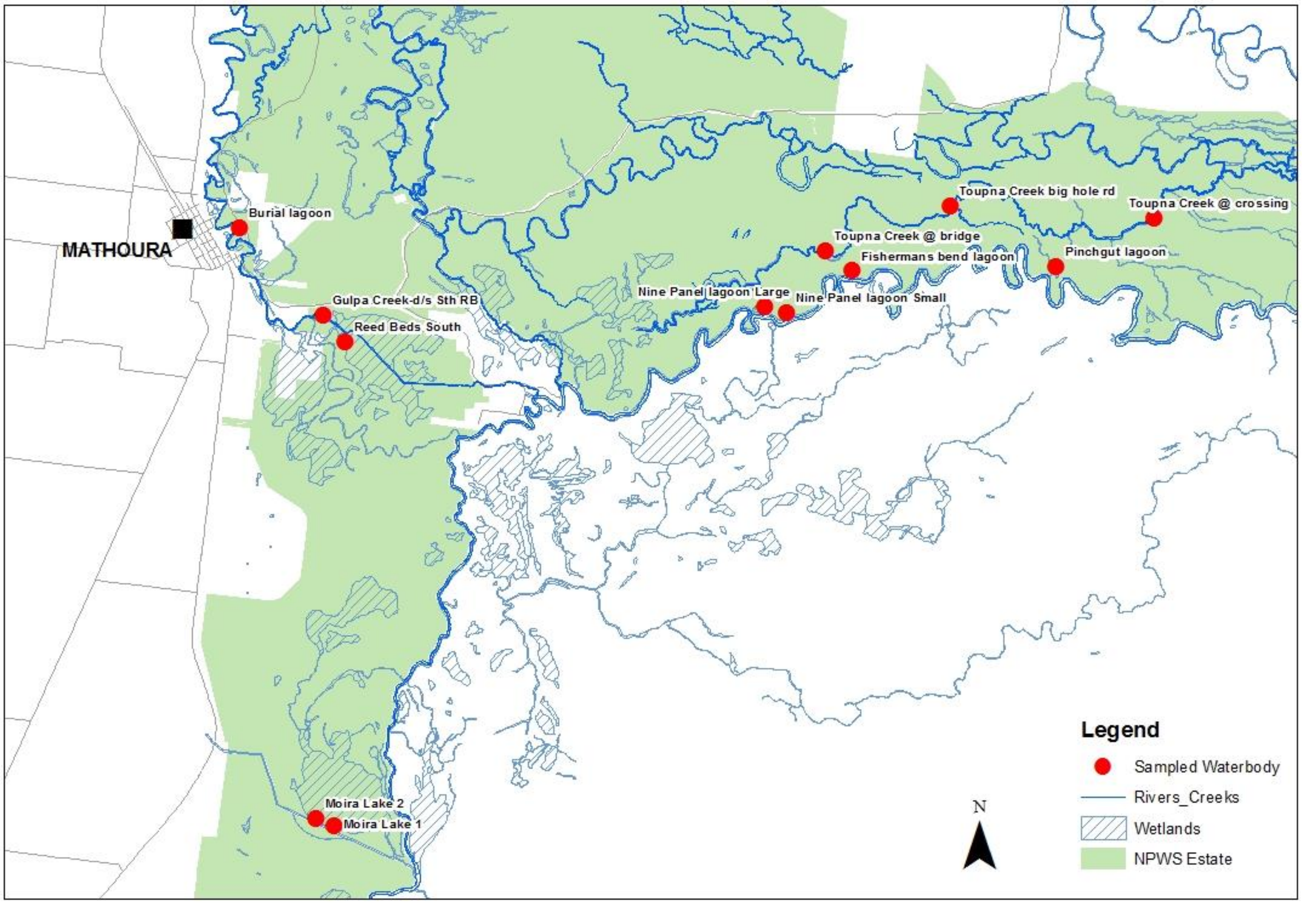

Figure 1: Map of locations of wetlands, and Moira Lake where plankton samples were taken.

Results and Discussion

Fish species diversity and abundance at Moira Lake

A total of 21 fish from two native and three exotic species were collected in Moira Lake (Table 2). The natives were carp gudgeon (*Hypseleotris* spp.) and Australian smelt (*Retropinna semoni*) and the exotics Eastern gambusia (*Gambusia holbrooki*), goldfish (*Carassius auratus*) and carp (*Cyprinus carpio*) (Table 2). Abundances for each species sampled was very low, and reflected that found for each year of survey by the TLM condition monitoring program undertaken at Moira Lake (Raymond et al. 2018) and for ten other wetlands at Millewa Forest surveyed in April 2018 by Sharpe (2018).

Of the ten other waterbodies surveyed for fish in 2018 by Sharpe (2018), eight of were the same as where plankton samples were collected by this study (Table 2). The Millewa Forest small bodied fish survey project (Sharpe 2018) found that while carp gudgeon were present at each wetland sampled, their abundance at Nine-Panel Lagoon (Large), Pinchgut Lagoon and Burial Lagoon, in that order, far exceed that recorded elsewhere (Table 2). Notably, despite the extensive survey effort applied by Sharpe (2018) and in Moira Lake by the present study, all other native species were represented by less than 100 individuals across all sites combined, with only six un-specked hardyhead (*Craterocephalus stercusmuscarm fulvus*), fifteen flathead gudgeon (*Philipnodon grandiceps*) and ninety-nine Australian smelt being collected in Millewa Forest wetlands (Table 2). Across all of the wetlands surveyed at Millewa Forest, including Moira Lake, no large-bodied native species were encountered.

Low native species diversity and abundance in wetlands of the mid-Murray Valley is not unique to Millewa Forest; the same pattern was reported across numerous mid-Murray-Valley wetlands during the same period by Pearce et al. (2018,) who described the status of the mid-Murray Valley native fish community as generally “very poor”. Like the Millewa Forest fish surveys (Sharpe 2018) and the present study, none of the sites sampled by Pearce et al. (2018) exhibited more than four native species and at most sites only two native species were encountered. While the study by Pearce et al. (2018) made excellent recommendations for restoring endangered southern pygmy perch (*Nanoperca australis*) and flatheaded galaxias (*Galaxias rostratus*) populations, they also highlighted the pressing need for managers to recognise and proactively address the decline of native fish species in general; with decline being a trend that is now a feature of floodplain wetland native fish communities throughout the Murray River valley.

Table 2. Fish abundances and diversity from sites sampled at Millewa Forest during April and May 2018 by Sharpe (2018), including for Moira Lake by the present study.

	Native					Non-native						
Waterbody	**Australian smelt**	**Carp gudgeon**	**Flathead gudgeon**	**Un-specked hardyhead**	**Native Total**	**Common carp**	**Eastern gambusia**	**European perch**	**Goldfish**	**Oriental weatherloach**	**Non-native Total**	**Grand total**
Burial Lagoon	2	1209		2	**1213**	1	38		1		**40**	**1253**
Fishermans Bend Lagoon		22	16		**38**	7	2	6		4	**19**	**57**
Gulpa Creek d/s Sth Reed Beds	6	27			**33**	3	1				**4**	**37**
Moira Lake 1	4				**4**		8		1		**9**	**13**
Moira Lake 2	2	4			**6**	2					**2**	**8**
Nine Pannel Lagoon LARGE	1	2691	2		**2694**	1	2			1	**4**	**2698**
Nine Pannel Lagoon SMALL	4	589	5		**598**		3	1			**4**	**602**
Pinchgut Lagoon	3	1452			**1455**	2	8		6		**16**	**1471**
ReedBeds South	55	285		4	**344**	10	36		9	2	**57**	**401**
Toupna Creek @ Big Hole Rd	22	98			**120**	4	8		4		**16**	**136**
Toupna Creek @ Toupna Bridge		11			**11**	19	90		1		**110**	**121**
Toupna Creek @ Toupna Crossing		28			**28**	10		7	11		**28**	**56**
Grand Total	**99**	**6416**	**23**	**6**	**6544**	**59**	**196**	**14**	**33**	**7**	**309**	**6853**

Zooplankton surveys

From the three replicate 75 L zooplankton samples collected at Moira Lake there was an average of 175.44 (s.e. 36.58) animals L^{-1} representing six taxonomic levels (Table 3). The Calanoida copepods were the most numerous, with an average density (animals L^{-1}) of 126.89 L^{-1} followed by Rotifers at 40.22 L^{-1}. All other taxa were present at considerably lower densities (Table 3). Notably, in Moira Lake the Cladocerans (Bosmina, Illyocryptidae), which form a key component of zooplankton dependent life history stages for native fish, were recorded only at very low density (Table 3).

Table 3. Taxa of zooplankton and density per litre sampled from Moira Lake in April 2018.

		Taxonomic Level										
		Phylum	Family cladocera	Family copepod	Family cladocera	Family copepod	Family cladocera	Family cladocera	Family copepod	Class	Family cladocera	Density
Site		Rotifer	Bosmina	Calanoida	Chydoridae	Cyclopoida	Daphniidae	Illyocryptidae	Nauplii	Ostracoda	Sididae	Total / L
Moira Lake	#/ L	60.33	7.00	143.67	0.00	1.67	0.00	0.67	1.00	0.00	0.00	214.33
Moira Lake		35.67	5.67	164.00	0.00	1.67	0.00	1.67	1.00	0.00	0.00	209.67
Moira Lake		24.67	2.67	73.00	0.00	1.33	0.00	0.00	0.67	0.00	0.00	102.33
	AVERAGE	40.22	5.11	126.89	0.00	1.56	0.00	0.78	0.89	0.00	0.00	175.44
	s.e.	10.55	1.28	27.58	0.00	0.11	0.00	0.48	0.11	0.00	0.00	36.58

The taxonomic diversity and density of zooplankton at Moira Lake reflected that for other wetlands sampled at Millewa Forest (Table 4; Figure 1). Rotifera were recorded at each wetland sampled, albeit at relatively low density (Table 4, Figure 1). Copepods were the most abundant taxon and were highest at Nine-Panel Lagoon (Table 4; Figure 1). Fishermans Bend and Burial lagoon recorded the greatest number of Cladocerans relative to other wetlands, where 170.58 ± 44.02 and 101.91 ± 101.71 animals L^{-1} were collected, respectively (Table 4, Figure 1). Ostracods were only recorded at three wetlands; South Reedbeds, Toupna Creek and Pinchgut Lagoon (Table 4, Figure 1).

Table 4. Average (from three samples) and standard error (s.e.) density L^{-1} of zooplankton taxa sampled across Millewa Forest in April 2018.

Site	Rotifer	s.e.±	Copepoda	s.e.±	Copepoda Nauplii	s.e.±	Cladocera	s.e.±	Ostracoda	s.e.±	TOTAL
Moira Lake	40.22	10.55	128.44	27.68	0.89	0.11	5.89	1.61	0.00	0.00	175.44
9-Panel small	44.67	7.58	132.11	41.80	0.56	0.29	0.00	0.00	0.00	0.00	177.33
9-Panel Lagoon	43.16	21.70	711.91	178.49	0.00	0.00	2.80	0.89	0.00	0.00	757.87
Burial Lagoon	7.91	6.05	212.93	107.35	0.49	0.25	101.91	101.71	0.00	0.00	323.24
Fish Bend Lagoon	160.96	58.51	6.56	1.74	1.09	0.44	170.58	44.02	0.00	0.00	339.18
South Reed Beds	0.55	0.17	2.64	0.85	0.00	0.00	0.02	0.02	0.02	0.02	3.23
Toupna @ Toup Crossing	0.37	0.19	66.86	21.54	0.08	0.05	0.18	0.18	0.00	0.00	67.49
Toupna @ Big Hole	6.17	1.57	0.19	0.05	0.00	0.00	1.13	0.65	0.01	0.01	7.51
Pinchgut Lagoon	6.1	3.03	96.81	13.16	0.09	0.09	3.41	0.60	0.14	0.08	106.56

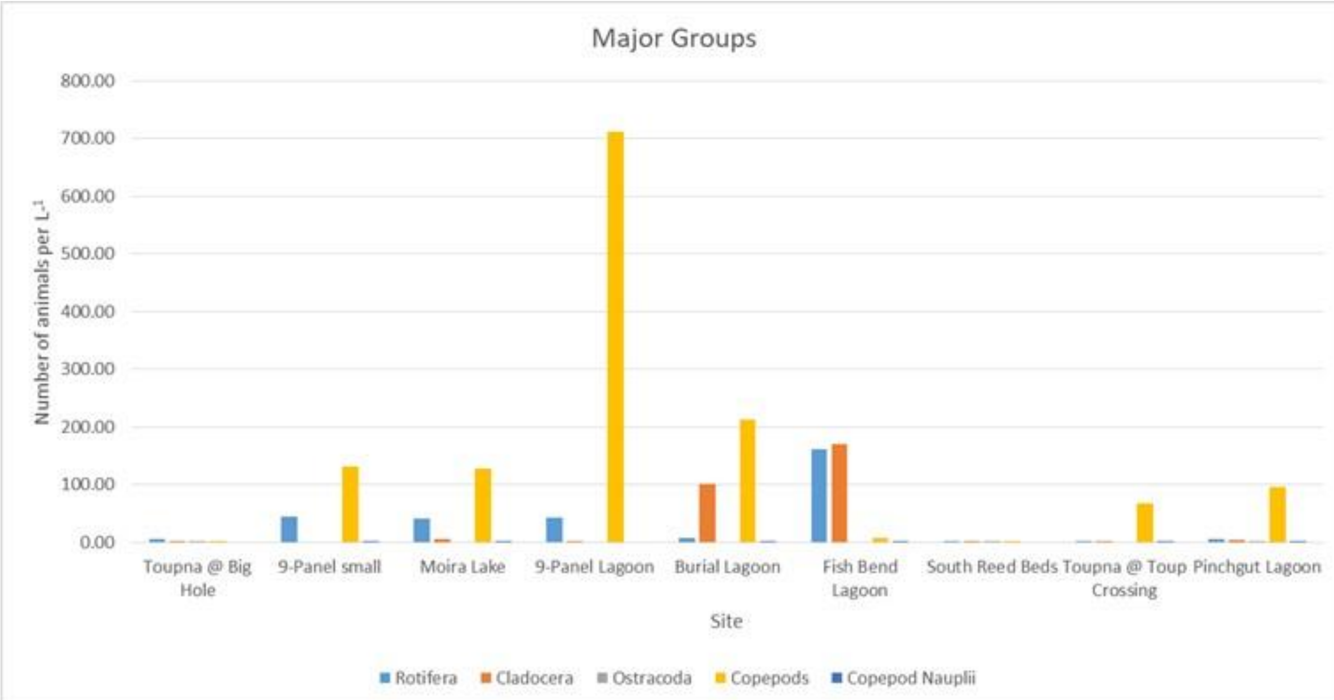

Figure 2. Density (animals L^{-1}) of major zooplankton groups sampled across nine wetlands at Millewa Forest in April 2018. Zooplankton density was highest at Nine Panel Lagoon where the sample community was dominated by Copepods.

The zooplankton communities recorded at Moira Lake and for each Millewa Forest Wetland by this study are of type considered palatable to the larvae and other life history stages of native fish that depend on zooplankton for survival (Rowland 1992; 1996). Densities were however approaching a critically low level that has been identified as essential to sustain native fish growth and survival. Rowland (1996) demonstrated that a critical zooplankton density of >100 individuals L^{-1} (Rotifer, Copepoda and Cladocrea combined) was required for the survival of early life history stages of native fish, in particular for golden perch (*Macquaria ambigua*) larvae. Consideration of the densities of zooplankton recorded by this present study, in that they were generally very low (in relation to the findings of Rowland (1996), highlights a potential link between the poor status of native fish communities and the poor status of zooplankton communities at Moira Lake and across Millewa Forest.

Rowland (1996) established that densities of 500-1000 L^{-1} individual zooplankton L^{-1} was optimal for the survival of golden perch larvae (13.7% of larvae at 30 days age). Likewise, Sharpe (2011) examined growth rates and relative mortality of golden perch early juveniles in the Darling River and its floodplains and concluded that zooplankton densities <100 L^{-1} coincided with significantly low survivorship in the Darling River but that survival and juvenile growth was high on the floodplain where zooplankton densities were significantly higher (1204.67 L^{-1} – 3717.33 L^{-1}). In relation to small bodied species, Humphries (1995) identified that zooplankton and other micro invertebrates dominated and were an important component in the diet of southern pygmy perch (*Nanopera* australis), hence the availability and densities of zooplankton in wetlands may be a key driver associated with the current status of not only the large bodied, but also small bodied native fish species across Millewa forest. The current study has shown that the densities of zooplankton in wetlands across Millewa Forest were approaching critically low levels required to sustain the zooplankton dependent life stages of large bodied native fish and other zooplankton dependent species.

In Moira Lake and other wetlands at Millewa Forest, zooplankton densities were only higher than the optimal 500 individuals L^{-1} reported by Rowland (1996) at Nine Panel Lagoon (large) and this wetland supported by far the highest density of native fish (Table 4). At Moira Lake, zooplankton densities were considerably lower (at 175.44 L^{-1}; Table 4), as was the abundance of native fish (n= 21) and zooplankton were only marginally higher in density than the critical 100 individuals L^{-1} Rowland (1996) established as obligatory to avoid 100% early juvenile native fish mortality. These findings suggest that overall, the densities of zooplankton communities present in wetlands throughout Millewa Forest are not sufficient to support strong recruitment of the early life stages of native fish, and strong populations of zooplanktivourous small bodied fish more generally, such as unspecked hardyhead, Murray-Darling rainbowfish or southern pygmy perch. Indeed, the low densities of zooplankton observed by this study reflect the dramatic and persistently low abundance and diversity of small bodied native fish in wetlands throughout Millewa Forest (Raymond et al. 2018; Sharpe 2018) and in particular at Moira Lake.

Zooplankton densities in freshwater wetlands of the Murray-Darling Basin are known to fluctuate in response to boom and bust cycles that are driven by antecedent wetting and drying cycles (Jenkins and Boulton 2007) and seasonality (Sheil (1978; Beesley et al. 2011). Nutrient transformations that occur in drying wetland sediments drive a bottom-up trophic cascade when wetlands are re-inundated (Boulton and Brock 1999; Scholz et al. 2002; King 2003). Upon re-wetting, functional successional processes ultimately support abundant, palatable zooplankton communities and the survival of larval fishes and strong recruitment to populations is therefore dependent upon functional succession processes that are driven by appropriate wetting and drying regimes which promote abundant zooplankton communities (Jenkins and Boulton 2003; Bunn et al. 2006). For Moira Lake to be restored as a functional nursery ground for native fish, and for restoration of its fish community more generally, the hydrological processes that culminate in diverse and abundant zooplankton communities must be identified and restored.

Recommendations

For Moira Lake and other wetlands across Millewa Forest, understanding antecedent wetting and drying regimes is required so that management intervention can aim to optimise regimes to restore successional wetland processes and ultimately the restoration diverse and abundant zooplankton and native fish communities. This understanding requires a record of hydrology data for each wetland, including for Moira Lake. This includes as a minimum, the daily gauging of water levels (complete dry through to bank full and then maximum level) and the timing, magnitude and duration of inflows/outflows from distributor creek channels. For Moira Lake, this information is lacking, and understanding of hydrology of the system is limited to a register of the opening and closing dates of regulator structures, recorded by NPWS staff. Before the effects of the antecedent hydrological regime of Moira Lake upon trophic succession processes can be interrogated, and recommendations made for refinement, appropriate hydrological data must be made available.

It is the major recommendation of this study that a network of representative, automated, remotely accessible water level gauging stations be installed at Moira Lake, and volumetric gauges be installed at the lakes' flow distribution creek channels (Swifts, Bunnydigger and Moira Creek).

REFERENCES

Beesley, L., Price, A., King, A., Gawne, B., Nielsen, D., Koehn, J., ... & Hladyz, S. (2011). Watering floodplain wetlands in the Murray–Darling Basin for native fish. Waterlines report, National Water Commission, Canberra.

Boulton, A.J. and Brock, M.A. (1999). *Australian Freshwater Ecology; Processes and Management*. Gleneagles Publishing, Glen Osmond, South Australia.

Brown, P., Sivakumaran, K. P., Stoessel, D., & Giles, A. (2005). Population biology of carp (Cyprinus carpio L.) in the mid-Murray River and Barmah Forest Wetlands, Australia. Marine and Freshwater Research, 56(8), 1151-1164.

Bunn, S. E., Thoms, M. C., Hamilton, S. K. & Capon, S. J. (2006). Flow variability in dryland rivers: boom, bust and the bits in between. River Research and Applications 22, 179-186.

Harris, J. J. & Gehrke, P. (1994). Modelling the relationship between streamflow and population recruitment to manage freshwater fisheries. Agricultural Systems and Information Technology 6, 28-30.

Jenkins, K. & Boulton, A. (2003). Connectivity in a dryland river: short-term aquatic microinvertebrate recruitment following floodplain inundation. Ecology 84, 2708-2723.

Jenkins, K. M. & Boulton, A. J. (2007). Detecting impacts and setting restoration targets in arid-zone rivers: aquatic micro-invertebrate responses to reduced floodplain inundation. Journal of Applied Ecology 44, 823-832.

Lintermans, M (2007). Fishes of the Murray-Darling Basin: An Introductory Guide. Murray-Darling Basin Commission, Canberra. 157pp

McDowall, R.M. (1996). Freshwater Fishes of South –eastern Australia. Reed Books, Sydney.

Pearce L, Silva LGM, Mabon S, Horta A, Duffy D, Ning N, Baumgartner LJ. (2018). Finding forgotten fishes, the search for two endangered species in the NSW Murray Catchment. Institute for Land, Water and Society, Charles Sturt University. 81 pp

Rourke, M. and Tonkin, Z. (2009). Barmah-Millewa fish condition monitoring: 2007-2009 milestone report. NSW department of Industry and Investment and Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg, Victoria. Unpublished report submitted to the Murray-Darling Basin Authority.

Raymond, S. Duncan, M. Tonkin, Z. and Robinson, W. (2018). Barmah-Millewa Fish Condition Monitoring: 2018. Arthur Rylah Institute for Environmental Research Unpublished Client Report for the Murray Darling Basin Authority. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Scholz, O., Gawne, B., Ebner, B. & Ellis, I. (2002). The effects of drying and re-flooding on nutrient availability in ephemeral deflation basin lakes in western New South Wales, Australia. River Research and Applications 18, 185-196.

Shiel, R. J. "Zooplankton communities of the Murray-Darling system." Proceedings of the Royal Society of Victoria 90 (1978): 193-202.

Sharpe, C. and Wilson, E. (2012). Fish surveys at 39 sites throughout Millewa Forest, NSW, with focus on the distribution of Southern pygmy perch (Nannoperca australis). May/June 2012. Summary of Findings Report for the NSW Office of Environment and Heritage by CPS Environmental Research.

Sharpe, C. (2014). Millewa Forest Fish surveys 2014. Summary of Findings Report prepared for the NSW Office of Environment and Heritage by CPS Enviro, Irymple Victoria.

Sharpe, C. and Stuart, I. (2015). Background concepts to the restoration of diverse native fish communities at Barmah-Millewa Forest. CPS Enviro and Kingfisher Research For NSW National Parks and Wildlife Service.

Sharpe, C. (2018) Millewa Forest fish surveys 2018. Summary of Findings Report for NSW National Parks and Wildlife Service by CPS Enviro P/L