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Gunbower Forest Fish Condition Monitoring

Prepared for: North Central CMA

Title: Gunbower Forest Fish Condition Monitoring

Reference: Bloink C. and Robinson W. (2016) *Gunbower Forest Fish Condition Monitoring*. A report to the North Central Catchment Management Authority by Ecology Australia.

This project was funded by The Living Murray initiative of the Murray-Darling Basin Authority. 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.

Ecology Australia file reference: 16-049 Gunbower Fish condition monitoring FIN01 03Nov2016.docx

Document History:

Status	Changes	By	Date
Draft 1	First Draft	W Robinson & C Bloink	29-08-2016
Draft 2	Fixed charts and comments addressed	C Bloink & W Robinson	05-10-2016
Final 1	References, Exec Summary, better charts and some additions	C Bloink & W Robinson	03-11-2016

Cover photo: Yarran Creek Regulator

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Acknowledgments

We gratefully acknowledge the assistance of:

- Stephen Saddlier — Ecology Australia
- Tomas Bird — University of Southampton
- Kathryn Stanislawski — North Central CMA

Summary

Background

Gunbower Forest comprises the Victorian component of the Gunbower-Koondrook-Perricoota Forest Icon Site, under The Living Murray (TLM) river restoration program. condition monitoring is required to assess each Icon Site's condition and evaluate progress against ecological objectives.

The Gunbower Forest fish community monitoring program has involved systematic monitoring of fish community data since 2008. The program includes sites located within and on the periphery of Gunbower Forest, with sites categorised into four macrohabitats including River (Murray River), Creek (Gunbower Creek), Lagoons (permanently inundated) and Wetlands (less permanently inundated).

Since 2012, the TLM condition monitoring program has undergone several internal reviews, to identify some ways that fish reporting could be refined to meet large scale reporting requirements, as well as maintaining the in-house applicability of the reports. This project aims to complete the process, and included:

- A comprehensive review of the entire dataset;
- The establishment/refinement of appropriate indices for reporting against objectives;
- The analysis of the 2016 dataset;
- The analysis of the 2008-2016 dataset and evaluation against ecological objectives; and
- The development of a database management system to manage data quality and streamline the calculation of indices.

Results and discussion

In 2016, the Wetland and Lagoon sites were characterised by supporting very high abundances of some small-bodied native fish species such as Carp Gudgeon and Unspecked Hardyhead. The Creek and River sites differed in that they supported a higher proportion of native species. River sites supported the highest proportion of native species that are historically expected to have occurred, and the Wetland sites supported the lowest proportion of native species that are historically expected to have occurred. In particular, the River and Creek sites were the only sites to support 'Long-lived apex predators' such as Murray Cod, and 'Flow dependent specialists' such as Golden Perch and Silver Perch, whereas, the Lagoon and Wetland sites generally supported small-bodied 'Foraging generalists'. None of the 'Floodplain specialists' species, such as Southern Pygmy Perch or Flatheaded Galaxias, have been recorded during the monitoring program, indicating these species to be either locally extinct or present in exceptionally low abundance.

Recruitment is evident for most native species that are present in the Wetland sites, however the higher scores for the age class and recruitment indices are expected to be an artefact of the low number of native species recorded from this macrohabitat and the broader habitat and spawning requirements of the small-bodied foraging generalist species that predominantly occur. In contrast, some of the large-bodied native species occurring in the Creek and River macrohabitats, such as Golden Perch and Silver Perch, require specific spawning and recruitment conditions (i.e. a flow pulse) to generate a spawning response, and undertake large scale spawning and recolonization migrations that are often impeded by instream barriers. Silver Perch recruitment (one individual) was detected in the Murray River in 2016, the first time recruitment of this species has been detected during the monitoring program. Murray Cod

recruitment occurred in both lotic macrohabitats (River and Creek) in 2016, the first time that this has occurred over the duration of the monitoring program.

Indices scores relating to threatened species are particularly low for the Wetland sites, because the sites support so few species and no longer support a range of threatened 'Floodplain specialist' species that are expected to have historically occurred. These include not only the Southern Pygmy Perch and Flatheaded Galaxias, but also the Southern Purple-spotted Gudgeon and the Olive Perchlet. The 'River' sites support the highest proportion of historically expected threatened species (e.g. Murray Cod, Golden Perch, Silver Perch, Murray-Darling Rainbowfish and Unspecked Hardyhead), followed by the 'Creek' sites. Notable threatened species captures in 2016 include Freshwater Catfish at Turner Lagoon and Trout Cod from Gunbower Creek.

Over the 2008–2016 monitoring period, the condition of the Gunbower Icon site components (macrohabitats) as indicated by the various indices has fluctuated considerably.

For many of the objectives and indices, particularly those relating to native fish abundance and native fish species richness, there has been a steady improvement in condition over time in the Creek and River macrohabitats, particularly since 2011. Large bodied native fish recruitment in particular appears to have improved since 2013, particularly for Murray Cod. This has reportedly coincided with a concerted effort since 2013 to optimise flow delivery to match the spawning and recruitment requirements of the apex predator guild (Murray Cod and Trout Cod), particularly in mitigating daily flow variability over spring/summer and reintroduction of flow over winter (Sharpe et al 2014).

A fractured population structure for Gunbower Creek Murray Cod had previously been reported for the 2006–2013 monitoring period, with a consistent absence of size classes representative of fish less than 3 years of age (Sharpe et al 2014). The average abundance of Murray Cod was higher in 2016 that in any previous year of the monitoring period for both the River and Creek macrohabitats. Although capture rates remain below those required to reliably assess the population structure, the rates are now sufficient to more reliably estimate it. The Gunbower Creek Murray Cod population now appears well represented by juvenile and sub-adult size classes, and not notably dissimilar to the Murray River population where juvenile and sub-adult size classes clearly dominate.

The capture of Trout Cod in 2016 was only the second time that the species has been detected over the duration of the monitoring program, with the previous capture being from Gunbower Creek in 2008. These captures, together with angling captures reported in Sharpe (2014) indicate the likely persistence of a low-density population.

There has been a slight reduction in native fish abundance over time at the four Lagoon sites (Cockatoo, Phyland, Turner and Upper Gunbower) however the proportion of native fish in these habitats has increased substantially since 2011 due to a large coinciding drop in exotic species abundance (i.e. Carp, Goldfish and particularly Eastern Gambusia). Threatened species occurrence rates have remained comparable over the course of the monitoring period for the Lagoon sites. Although only one Freshwater Catfish was recorded in 2016, the monitoring dataset suggests that a low-density population persists in Turner and Phyland Lagoons, with relatively strong recruitment being evident from Phyland Lagoon in 2015.

The Gunbower Icon site supports a relatively diverse fish community. Although caution is advised in examining the dataset for any particular year in isolation, the 2013-2016 period indicates that progress is being made towards many of the objectives and associated targets and none appear to be in decline.

The recruitment success of Murray Cod in recent years and likely re-establishment of a healthy population structure is a particular standout, as is the persistence of number of threatened species, albeit in low densities (e.g. Trout Cod in Gunbower Creek and Freshwater Catfish in Phyland Lagoon).

A summary of the objective attainment is provided below:

Detailed objectives (adapted from DELWP & NCCMA 2015)	Relevant Indices (this report)	Objective attainment
• An increase in the abundance of native fish – using the 2009 abundance as a baseline for Lagoons and the 2010 abundance for the River Murray	• $I_{\text{Native abundance}}$ • $I_{\text{Native species}}$ • $I_{\text{Native expected}}$ • I_{SA}	• River – attained • Creek – attained • Lagoon – partially attained (attained using relative abundance indices) • Wetland – long-term data cannot be assessed
• A range of age/size classes present for each native fish species – evidence of recruitment as indicated by Young of Year (YOY) native fish using the species-specific thresholds identified in Sharpe and Villizi 2014)	• $I_{\text{Age ategory}}$ • $I_{\text{Recruitment}}$ • I_{LBAC} • I_{LBYOY}	• River – attained • Creek – attained • Lagoon – attained (small-bodied fish) • Wetland – attained (small-bodied fish)
• A contribution to population recovery of threatened fish species – recovery inferred by an increase in the abundance of each threatened species from 2009 levels	• $I_{\text{Threatened species compliant}}$ • $I_{\text{Threatened species occurrence}}$	• River – attained • Creek – attained • Lagoon – not attained • Wetland – not attained although long-term data cannot be assessed

A summary of the target attainment is provided below:

Descriptive targets (adapted from DELWP & NCCMA 2015)	Objective attainment
• At least 4 of the 5 commonly occurring native species (i.e. Carp Gudgeon, Flat-headed Gudgeon, Australian Smelt, Dwarf Flat-headed Gudgeon and Golden Perch) occur in any year.	• Attained (all but Dwarf Flatheaded Gudgeon recorded in 2016)
• At least 3 of the 7 less commonly occurring (i.e. Bony Herring) and/or threatened native species (i.e. Murray-Darling Rainbowfish, Silver Perch, Murray Cod, Trout Cod, Un-specked Hardyhead, Freshwater Catfish) occur in any year.	• Attained (all seven species recorded in 2016)
• A decrease in the abundance of alien fish (i.e. non indigenous to Gunbower Island) since 2009 (Gunbower Creek and Lagoons) and since 2010 (Murray River)	• River – not attained • Creek – attained • Lagoon – attained

Recommendations

The following recommendations are made:

- Manage data quality and streamline the calculation of indices with the use of the database management system developed as part of this project;
- Include long-term analyses of recruitment and age class indices for small-bodied species in future reports, and increase consistency between the Objective 2 indices calculations for the current year and the long-term indices calculations;
- Include long-term analyses of 2015 Lagoon data in future reports;
- Revise the PERCH list derived for the Koondrook Perricoota Forest by NSW Fisheries (Hohnberg et al 2015). At a minimum, Dwarf Flatheaded Gudgeon should be assigned a rarity score of 1 for 'semi-permanent' habitats;
- Develop a consistent and statistically sound approach to the selection of Wetland sites for sampling in any given year;
- For condition monitoring purposes, continue to exclude the 2008 seasonally confounded data from analyses and use 2009 as the alternative point of reference;
- Ensure that a consistent approach is used for fish measurements. It is suggested that Total Length (TL) be used for round-tailed species and Caudal Fork Length (LCF) be used for fork-tailed species (for individuals with damaged tails, measure Standard Length and estimate TL or LCF and flag as an estimate). These can be clearly identified in the database;
- Ensure that a consistent approach is used for labelling of 'observed' individuals. It is suggested that this be used for individuals that were observed but not captured, either missed or not netted for other reasons (e.g. animal ethics considerations when encountering a large school of Australian Smelt). That is, fish collected in a shot or a net but not measured should be counted as caught;
- Consider limiting the length or area of the sampling reach (e.g. 500 m), particularly for River and Creek habitats; and
- Several of the indices included in this report have been used for the first time, and would benefit from review of their statistical properties (e.g. an evaluation of sensitivity and power).

1 Introduction

1.1 Background

Gunbower Forest comprises the Victorian component of the Gunbower-Koondrook-Perricoota Forest Icon Site, under The Living Murray (TLM) river restoration program managed by the Murray Darling Basin Authority (MDBA). There are six TLM Icon Sites, which are being restored in part via environmental watering and structural works associated with water delivery and fish movement.

As outlined in the Gunbower Icon Site Monitoring Plan (DELWP & NCCMA 2015), condition monitoring is required to assess each Icon Site's condition and evaluate progress against ecological objectives. Additionally, the monitoring informs management decisions, particularly around the use of environmental water and allows management of the Icon Sites under an adaptive management framework. The condition monitoring program is coordinated by the North Central CMA and has involved the systematic monitoring of fish community data since 2008, following preliminary investigations in 2005 (Richardson et al 2005) and 2007 (PIRVic 2007).

As outlined in the Gunbower Icon Site Monitoring Plan (DELWP & NCCMA 2015), two complementary monitoring programs are carried out under TLM:

- Murray River system scale monitoring – to determine improvements in the overall health of the system.
- Intervention monitoring – to determine the ecological response to specific management actions (e.g. monitoring fish movement responses in relation to watering)

This report represents the culmination preceding projects which comprehensively reviewed and refined the annual condition monitoring reporting for Gunbower Forest Icon Site (Robinson 2014, Sharpe and Vilizzi 2014 and Robinson2015).

1.1.1 Gunbower Forest monitoring components

The Gunbower Forest Icon Site, hereafter referred to as 'Gunbower Forest', is located in Northern Victoria between Torrumbarry and Koondrook and is also known as Gunbower Island because it is bound to the north by the Murray River and to the south by Gunbower Creek (an anabranch of the Murray River).

Gunbower Forest is a Murray River floodplain Ramsar site of international significance, covering an area of approximately 20,000 ha of Red Gum forest subject to periodic inundation, and a diversity of permanent and temporary wetlands including lakes, swamps, lagoons and flooded forest (Hale et al 2011). Managed flows into Gunbower Forest are delivered via a number of Gunbower Creek regulators that are used to deliver water to different parts of the forest (DELWP & NCCMA 2015).

The Gunbower Forest fish community monitoring program, includes sites located within and on the periphery of Gunbower Forest, with sites categorised into four macrohabitats including:

- Creek Gunbower Creek reaches identified in the Gunbower Creek Waterway Action Plan and delineated by major blockages such as weirs or bridges (Sharpe 2014);
- Lagoon Hydrologically connected to Gunbower Creek and considered to be permanently inundated;

- Wetland – Other less permanently inundated waterbodies selected by the North Central CMA;
- River – Murray River reaches upstream, downstream and approximately midway between the Gunbower Creek confluences at Torrumbarry (upstream) and Koondrook (downstream).

1.1.2 Gunbower Forest Fish community

Gunbower Forest currently supports a relatively diverse fish community including 12 native species, seven of which are listed as threatened species under state and/or federal biodiversity legislation. Additional species have either previously been recorded, or are thought to have previously occurred within this area. The vast majority of these additional species are considered to be locally extinct, although some could be present in very low abundance. Some potential may exist for natural re-establishment of some species, particularly those with active large-scale dispersal migrations; however, small-bodied threatened species with small-scale dispersal movements are considered likely to benefit from reintroduction via stocking or translocation (Mallen-Cooper et al 2014, Sharpe 2014). These species include the wetland/floodplain specialists Southern Pygmy Perch, Flat-headed Galaxias, Olive Perchlet and Purple Spotted Gudgeon. A list of the fish species recorded during the 2008-2016 monitoring program, or predicted to have once occurred based on the Pre-European Reference Condition for FisH (PERCH list) (Raadik & Lieschke 2010) is provided below in Table 1.

Table 1 Native fish species (green shading) and exotic fish species (orange shading) previously recorded during the 2008-2016 monitoring program or predicted to occur at Gunbower Island, including assigned habitat group (Young et al. 2003) and flow guild (Baumgartner et al. 2014).

Common name	Species name	Habitat group (Young et al. 2003)	Flow Guild (Baumgartner et al. 2014)	Predicted to occur (PERCH)	Recorded during 2008-2016 monitoring			
					River	Creek	Lagoon	Wetland
Silver Perch	*Bidyanus bidyanus*	Flood spawners	Flow dependent specialists	✓	✓	✓		
Unspecked Hardyhead	*Craterocephalus stercusmuscarum fulvus*	Wetland specialists	Foraging generalists	✓	✓	✓	✓	
Carp Gudgeon complex	*Hypseleotris* sp.	Wetland specialists and Low-flow specialists	Foraging generalists	✓	✓	✓	✓	✓
Trout Cod	*Maccullochella macquariensis*	Main channel specialists	Long-lived apex predators	✓		✓		
Murray Cod	*Maccullochella peelii*	Main channel specialists	Long-lived apex predators	✓	✓	✓	✓	
Golden Perch	*Macquaria ambigua*	Flood spawners	Flow dependent specialists	✓	✓	✓		
Murray-Darling Rainbowfish	*Melanotaenia fluviatilis*	Low-flow specialists	Foraging generalists	✓	✓	✓	✓	
Bony Herring	*Nematalosa erebi*	Wetland specialists and Main channel generalists	Foraging generalists	✓	✓	✓		
Flat-headed Gudgeon	*Philypnodon grandiceps*	Wetland specialists	Foraging generalists	✓	✓		✓	✓

Common name	Species name	Habitat group (Young et al. 2003)	Flow Guild (Baumgartner et al. 2014)	Predicted to occur (PERCH)	Recorded during 2008-2016 monitoring			
					River	Creek	Lagoon	Wetland
Dwarf Flat-headed Gudgeon	*Philypnodon macrostomus*	Wetland specialists	Foraging generalists	✓		✓	✓	
Australian Smelt	*Retropinna semoni*	Wetland specialists and Main channel generalists	Foraging generalists	✓	✓	✓	✓	✓
Freshwater Catfish	*Tandanus tandanus*	Main channel specialists	Foraging generalists	✓			✓	
Southern Pygmy Perch	*Nannoperca australis*	Wetland specialists	Floodplain specialists	✓				
Southern Purple-spotted Gudgeon	*Mogurnda adspersa*	Not listed (Wetland specialist)	Floodplain specialists	✓				
Flat-headed Galaxias	*Galaxias rostratus*	Wetland specialists	Floodplain specialists	✓				
Olive Perchlet	*Ambassis agassizii*	Not listed (Wetland specialists)	Floodplain specialists	✓				
River Blackfish	*Gadopsis marmoratus*	Main channel specialists	Foraging generalists	✓				
Short-headed Lamprey	*Mordacia mordax*	Not listed (Main channel specialists)	Not listed (Foraging generalists)	✓				
Macquarie Perch	*Macquaria australasica*	Main channel specialists	Foraging generalists	✓				
Murray Hardyhead	*Craterocephalus fluviatilis*	Wetland specialists	Floodplain specialists	✓				
Mountain Galaxias	*Galaxias olidus*	Not listed (Main channel specialists)	Foraging generalists	✓				
Goldfish	*Carassius auratus*				✓	✓	✓	✓
Carp	*Cyprinus carpio*				✓	✓	✓	✓
Eastern Gambusia	*Gambusia holbrooki*				✓	✓	✓	✓
Oriental Weatherloach	*Misgurnus anguillicaudatus*					✓	✓	
Redfin	*Perca fluviatilis*						✓	

1.1.3 TLM condition monitoring program

Since 2012, the TLM condition monitoring program has undergone several internal reviews (e.g. Robinson 2014, Sharpe and Villizi 2014, Robinson 2015). Whilst reporting on the annual Gunbower Fish surveys was meeting local requirements, the most recent review (Robinson 2015) identified some ways that fish reporting could be refined to meet large Murray-Darling Basin scale reporting requirements, as well as maintaining the in-house applicability of the reports. This report aims to complete the process, including further development and refinement of suitable indicators to address the monitoring objectives, the implementation of recommendations and the documentation of all procedures.

1.2 Project objectives

This report aims to describe the current status, and trend, of the fish population at Gunbower Island in both statistical and narrative terms. The project objectives and tasks are to:

- Establish and document an appropriate and repeatable statistical analysis methodology;
- Analyse the 2016 data and compare it against the results of previous years;
- Assess the entire dataset against the ecological objectives developed for Gunbower Forest Icon Site;
- Evaluate any additional ecological findings that the data reveals; and
- Consolidate recommendations that will enhance the value of future monitoring and analysis

1.3 Project components

This project consists of the following components:

- A comprehensive review of the entire dataset (summarised in section 3);
- The establishment/refinement of appropriate indices for reporting against objectives (section 4.3);
- The analysis of the 2016 dataset (section 5.2);
- The analysis of the 2008-2016 dataset and evaluation against ecological objectives (section 6); and
- The development of a database management system to manage data quality and streamline the calculation of indices.

2 Monitoring objectives

The Gunbower Icon Site ecological objectives and associated targets are outlined in the Gunbower Condition Monitoring Plan (DELWP & NCCMA 2015), and those of relevance to fish monitoring are reproduced in Table 2. An additional objective and target relating to the movement of native fish is not listed in Table 2, as it is monitored through intervention monitoring rather than condition monitoring.

Table 2 Relevant objectives for Gunbower fish condition monitoring (adapted from DELWP & NCCMA 2015).

Overarching objective	Detailed objectives	Targets
Maintain healthy populations of native fish in wetlands and increase opportunities for riverine fish to access floodplain resources	• An increase in the abundance of native fish – using the 2008 abundance as a baseline for Lagoons and the 2010 abundance for the River Murray • A range of age/size classes present for each native fish species – evidence of recruitment as indicated by Young of Year (YOY) native fish using the species-specific thresholds identified in Sharpe and Villizi 2014) • A contribution to population recovery of threatened fish species – recovery inferred by an increase in the abundance of each threatened species from 2008 levels	• At least 4 of the 5 commonly occurring native species (i.e. Carp Gudgeon, Flat-headed Gudgeon, Australian Smelt, Dwarf Flat-headed Gudgeon and Golden Perch) occur in any year. • At least 3 of the 7 less commonly occurring (i.e. Bony Herring) and/or threatened native species (i.e. Murray-Darling Rainbowfish, Silver Perch, Murray Cod, Trout Cod, Freshwater Catfish) occur in any year. • A decrease in the abundance of alien fish (i.e. non indigenous to Gunbower Island) since 2008

A number of indicators and associated indices and points of reference were developed and trialled as part of the reviews (Robinson 2014, Sharpe and Villizi 2014, Robinson 2015), and are presented within the condition monitoring plan (DELWP & NCCMA 2015). Many of these were yet to be finalised. This project has involved a comprehensive revision and development of appropriate indices based primarily on the detailed objectives, with reference to the associated targets where practicable. The development of indicators and indices has in part, been influenced by the outcome of a comprehensive review of the entire dataset. The points of reference have been retained, with 2010 used as a point of reference for the Murray River, and 2009 used as a point of reference for the Gunbower and Lagoon macrohabitats. In consultation with Kathryn Stanislawski of NCCMA, 2009 was deemed to be a more appropriate point of reference than 2008, due to seasonal differences in the timing of sampling in 2008 compared with 2009–2016.

2.1 Monitoring locations

The Gunbower monitoring sites are categorised into four macrohabitats; Creek, Lagoon, Wetland and River (as per section 1.1.1). Between 21 and 28 sites have been monitored annually since 2008, with the exception of 2015 when the Living Murray condition monitoring program had reduced funding (K Stanislawski pers. comm. 2016). A list of the monitoring sites and the years in which each site has been

monitored is provided in Table 3. The location coordinates of these sites are listed in the monitoring plan (DELWP & NCCMA 2015).

Table 3 The Gunbower Forest fish community monitoring site names, macrohabitat categories and years in which they have been sampled.

Macrohabitat	Site name	2008	2009	2010	2011	2012	2013	2014	2015	2016	# of years
Creek	Gunbower Creek Reach 1	✓	✓	✓	✓	✓	✓	✓		✓	8
	Gunbower Creek Reach 2	✓	✓	✓	✓	✓	✓	✓		✓	8
	Gunbower Creek Reach 3	✓	✓	✓	✓	✓	✓	✓		✓	8
	Gunbower Creek Reach 4	✓	✓	✓	✓	✓	✓	✓		✓	8
	Gunbower Creek Reach 5	✓	✓	✓	✓	✓	✓	✓		✓	8
	Gunbower Creek Reach 6	✓	✓	✓	✓	✓	✓	✓		✓	8
	Gunbower Creek Reach 7	✓	✓	✓	✓	✓	✓	✓		✓	8
Lagoon	Cockatoo Lagoon	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
	Gum Lagoon	✓	✓	✓	✓	✓	✓	✓		✓	8
	Longmore Lagoon	✓	✓	✓	✓	✓	✓	✓		✓	8
	Phyland Lagoon	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
	Safe Lagoon	✓	✓	✓	✓	✓	✓	✓		✓	8
	Splatt Lagoon	✓	✓	✓	✓	✓	✓	✓		✓	8
	Taylor Lagoon	✓	✓	✓	✓	✓	✓	✓		✓	8
	Turner Lagoon	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
	Upper Gunbower Lagoon	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Wetland	Black Charlie Lagoon				✓	✓	✓	✓		✓	5
	Black Creek		✓								1
	Black Swamp	✓	✓			✓			✓	✓	5
	Charcoal Swamp				✓	✓					2
	Corduroy Swamp	✓	✓			✓			✓	✓	5
	Crayfish Lagoon	✓		✓	✓	✓	✓	✓	✓	✓	8
	Green Swamp	✓	✓		✓	✓	✓	✓	✓	✓	8
	Little Reedy Lagoon	✓	✓						✓	✓	4
	Reedy Lagoon			✓	✓	✓	✓	✓	✓	✓	7
	Yarran Creek	✓	✓		✓	✓					4
River	Murray River Cohuna			✓	✓	✓	✓	✓		✓	6
	Murray River Koondrook			✓	✓	✓	✓	✓		✓	6
	Murray River Torrumbarry			✓	✓	✓	✓	✓		✓	6
Number of sites sampled per year		22	22	21	25	28	24	23	10	26	

In terms of data continuity, the following observations are made:

- Four lagoon sites have been monitored every year since 2008;
- All Creek sites and the remaining Lagoon sites have been monitored every year since 2008, with the exception of 2015;
- Two wetland sites have been monitored in eight out of the nine year monitoring period;
- The River sites have been monitored annually since 2010, again with the exception of 2015; and
- Most Wetland sites have been monitored sporadically over the monitoring period, with their annual selection by NCCMA being prioritised according to water and habitat availability and funding (K Stanislawski pers. comm. 2016).

3 Data review

The complete dataset and the associated reports, were comprehensively reviewed and the outcomes were provided separately to NCCMA. The pertinent points of the review were:

- There are inconsistencies in the approach used for fish (length) measurements, and thereby hinder the ability to calculate length distributions, recruitment or biomass calculations;
- Effort data has not been fully recorded within the dataset (i.e. zero catches per net or per shot have not been recorded);
- There are data labelling issues and data formatting inconsistences in the existing data set;
- There are inconsistencies in the labelling of catch data as 'observed', with this referring both to fish observed but not captured during electrofishing operations, and also occasionally (e.g. 2016) being used for to denote unmeasured fish from fyke nets; and
- There is a lack of consistency and documented transparency around the methods used in selecting/prioritising some of the sites to be sampled

This project itself, in the creation of the database, was intended to rectify these issues, bringing data collection into a standardised manner and preventing further inconsistencies over time.

With regard to the final point, the subjective selection criteria used for the annual selection of Wetland sites (i.e. based on water and habitat suitability and availability funding considerations) has data analyses implications. Put simply, the Wetland data cannot be analysed at the macrohabitat scale, because it is unclear what proportion of the total population the sampled Wetlands represent in any given year. Consequently, the Wetland data are most appropriately used for snapshot reporting at an individual sites scale, rather than used in long-term or whole-of-Icon-site scale reporting. The River, Creek and Lagoon macrohabitat sites can be analysed for long-term trends.

4 Methods

4.1 Fish sampling

Fish have been sampled in accordance with the TLM consistent monitoring framework for fish, the most recent version of which is appended to the condition monitoring report (DELWP & NCCMA 2015). In summary, the sampling techniques have included:

- Boat or backpack electrofishing using the Sustainable Rivers Audit (SRA) protocols level of survey effort per site (12 x 90 seconds of 'power on' time for boat electrofishing, and 8 x 150 seconds for backpack electrofishing);
- At each of the electrofished sites, 10 unbaited bait traps are set at the beginning of electrofishing operations and retrieved following completion, with a minimum soak time of two hours; and
- Four pairs of a combination of large (i.e. coarse-meshed) and small (i.e. dual wing fine-meshed) fyke nets being set at four fixed locations within each site (i.e. eight fyke nets per site).

Sampling has been undertaken by:

- The Murray Darling Freshwater Research Centre (2008-2011);
- Biosis (2015); and
- CPS Environmental (2012-2014 and 2016)

As per the TLM and SRA approaches, the choice between the use of boat or backpack electrofishing at a given site depends upon waterbody size, depth and boat access considerations. An outline of the sites sampled and sampling techniques used in 2016 is provided in Table 4.

Table 4 Sites sampled and sampling effort in 2016.

Macrohabitat	Site	Electrofishing effort (shots of 'power on' seconds)		Bait traps (#)	Fyke nets (#)	
		Boat	Backpack		Coarse-meshed	Fine-meshed
Creek	Gunbower Creek Reach 1	12 x 90		10	4	4
	Gunbower Creek Reach 2	12 x 90		10	4	4
	Gunbower Creek Reach 3	12 x 90		10	4	4
	Gunbower Creek Reach 4	12 x 90		10	4	4
	Gunbower Creek Reach 5	12 x 90		10	4	4
	Gunbower Creek Reach 6	12 x 90		10	4	4
	Gunbower Creek Reach 7	12 x 90		10	4	4
Lagoon	Cockatoo Lagoon	12 x 90		10	4	4
	Gum Lagoon	12 x 90		10	4	4
	Longmore Lagoon	12 x 90		10	4	4
	Phyland Lagoon	12 x 90		10	4	4
	Safe Lagoon	12 x 90		10	4	4
	Splatt Lagoon	12 x 90		10	4	4
	Taylor Lagoon	12 x 90		10	4	4
	Turner Lagoon	12 x 90		10	4	4
	Upper Gunbower Lagoon	12 x 90		10	4	4
Wetland	Black Charlie Lagoon	12 x 90		10	4	4
	Black Swamp		8 x 150	10	4	4
	Corduroy Swamp		8 x 150	10	4	4
	Crayfish Lagoon	12 x 90		10	4	4
	Green Swamp		8 x 150	10	4	4
	Little Reedy Lagoon		8 x 150	10	4	4
	Reedy Lagoon		8 x 150	10	4	4
River	Murray River Cohuna	12 x 90		10	4	4
	Murray River Koondrook	12 x 90		10	4	4
	Murray River Torrumbarry	12 x 90		10	4	4

In terms of survey technique continuity over the monitoring period, the following should be noted:

- All River, Creek and Lagoon sites and one Wetland site (Black Charlie Lagoon) have been consistently boat electrofished;
- One Wetland site (Crayfish Island) has alternated between backpack (2010-2012, 2015) and boat (2013-2014, 2016) electrofishing;
- The remaining Wetland sites have always been backpack electrofished; and
- Electrofishing did not commence at five of the nine Lagoon sites (Splatt, Phyland, Gum, Cockatoo and Taylors) until 2012, or at any of the Wetland sites until 2010, with fyke netting being the only technique used previously.

4.2 2016 Index calculations

The fish condition monitoring objectives fall within three categories:

- Objective 1: Abundance of native fish
- Objective 2: Size classes of native fish species
- Objective 3: Threatened native fish species populations

The objectives are addressed separately for each macrohabitat (i.e. River, Creek, Lagoon & Wetland) by examining the scores of selected indices within each objective category. Examples of the calculations for each objective and the corresponding indices are included in Appendix 1.

4.2.1 Relative abundance vs raw catch data/CPUE

The index approach relies on the calculation of relative abundance rather than the use of raw catch data or Catch Per Unit Effort (CPUE). This approach is used because even when effort is standardised, capture efficiency and hence abundance and CPUE, tends to be spatially and temporally variable due to the influence of a wide range of environmental and other factors. Thus, the spatial or temporal differences in fish abundance or CPUE may represent actual differences in the fish community, or unrelated differences in capture efficiency, or a combination of both. The use of relative abundance (e.g. the abundance of a given species relative to the other species in a community) reduces the influence of capture variability on the analyses, in effect, partially standardising capture variability. It is not possible to fully standardise against capture variability because the variability may often not be uniform across all species.

The use of relative abundance also allows cautious comparisons and calculations between sites in the same habitats using data that are collected with different methods. For example, Wetland sites in 2016 were sampled either by boat or backpack due to differing waterbody depth, size and/or boat access. While this approach is not preferable in terms of data analysis, some cautious comparisons are possible if the influence of capture efficiency or habitat differences (e.g. depth) are reduced by the use of relative abundance, and if the influence of technique size/species bias is further reduced by analyses of grouped species (e.g. native vs exotic).

Raw catch data/CPUE has been used for several tables and for the charts presented in section 6.4 and 6.5. These tables and charts have been included for ease of interpretation and consistency with previous reports (e.g. Sharpe 2014). In this instance the use of the CPUE does not imply a calculation has occurred to standardise effort (e.g. fish captured per hour of electrofishing), rather to indicate that a standard level of sampling effort was used. For River, Creek and Lagoon habitats, that effort consisted of 12 x 90 seconds of boat electrofishing, 4 coarse-meshed fykes, 4 fine-meshed fykes and 10 bait traps. Although small differences in soak times would have occurred for bait traps and fyke nets, these differences are deemed to be largely inconsequential.

It should be noted that that ‘observed’ data has been included in all indices calculations, and in raw catch data/CPUE.

4.2.2 Objective 1: Abundance of native fish species

For each site, the following indices were calculated:

- $I_{Native\ abundance}$ = the proportion of fish abundance in each site that are native,
- $I_{Native\ species}$ = the proportion of fish species in each site that are native and,
- $I_{Native\ expected}$ = the proportion of historically expected native species present in each site.

The historically expected native species are derived from the Pre European Reference Conditions for fish (PERCH) list for the Central Murray (Middle zone) developed for the Sustainable Rivers Audit (SRA), and from PERCH values specifically derived for the Koondrook Perricoota Forest by NSW Fisheries (Hohnberg et al 2015) (Table 5). The SRA PERCH values have been used for permanently flowing streams ('River'), while the Koondrook Perricoota PERCH values have been used for all semi-permanently flowing ('Creek') and lentic habitats ('Lagoons' and 'Wetlands'). The PERCH score indicates the likelihood of collection of a species at a site using the SRA sampling methods if it occurred in similar abundance and extent to Pre-European levels. Note that the SRA and NSW Fisheries PERCH rarity scores were originally assigned on the basis of rarity ranges as follows:

- Rarity score = 1 – Rarely recorded at a site (<20% of sampling occasions);
- Rarity score = 3 – Usually recorded at sites where it is present (21-70% of sampling occasions);
- Rarity score = 5 – Almost invariably recorded at a site (71-100% of sampling occasions).

For indices calculation purposes, the rarity ranges have been converted to a discrete values, to indicate expected occurrence as a percentage at a given site (using current sampling methods), as follows:

- Rarity score = 1 – Expected to be recorded at 10% of sites;
- Rarity score = 3 – Expected to be recorded at 45% of sites; and
- Rarity score = 5 – Expected to be recorded at 85% of sites.

Table 5 Historic native fish species for Gunbower Forest Icon site and their PERCH score for Permanent (River) and Semi Permanent (Creek, Wetland and Lagoon) habitats. The longevity of each species is categorised as either Short-lived (SL), Long-lived (LL) or Intermediate lived (IL). The length thresholds for Young of Year (YOY) and adults are also provided (these are required for calculating other indices).

Common name	PERCH scores		Longevity (Robinson 2012)	YOY size threshold (TL - mm) (Sharpe and Vilizzi 2014 or Robinson 2012*)	Adult size threshold (TL - mm) (Sharpe and Vilizzi 2014)
	Permanent habitats (River)	Semi-Permanent habitats (i.e. Creek, Lagoon and Wetland)			
Murray Cod	5	3	LL	115	425
Trout Cod	5	1	LL	115	
Golden Perch	5	3	LL	118	268
Silver Perch	5	1	LL	117	
Freshwater Catfish	3	3	LL	100	
Bony Herring	3	1	IL	93	
River Blackfish	3		IL	70*	
Short-headed lamprey	3				
Macquarie Perch	3		LL	75*	
Murray-Darling Rainbowfish	3	5	SL	39	
Murray Hardyhead	1	1	SL	40*	
Un-specked Hardyhead	3	5	SL	39	
Australian Smelt	5	3	SL	42	
Carp Gudgeon	5	5	SL	30	
Flathead Gudgeon	3	5	IL	50	
Southern Pygmy Perch	3	3	SL	30*	
Purple spotted Gudgeon	1	1	IL	49*	
Flat-headed galaxias	3	3	IL	80*	
Mountain Galaxias	1	1	IL	30*	
Olive Perchlet	3	3	SL	31*	
Dwarf Flathead Gudgeon	1		SL	28	
Expected Species per site	**10.45**	**7.15**			

4.2.3 Objective 2: Size classes of native species

This objective is addressed using a new method based on the Index of Population Structure developed by Sharpe and Vilizzi (2014) and aims to provide a measure of recruitment occurrence. The length thresholds for YOY (Table 5) are used to determine whether each measured fish is a Young of Year (YOY)(i.e. 0+ year old fish), or older. The number of age-categories that are present at each site are calculated for each species. Ideally a site will support older and YOY age categories for a large number of species. All available data from the dataset was used to determine the best achievable values for native species richness and for native species age categories present (Table 6).

Table 6 Reference values for the total number of native species age categories recorded from the monitoring sites within each macrohabitat (based on 90th percentiles).

Macrohabitat	Number of site sampling events	Reference number of native species present	Reference number of native species age categories present
River	18	8	13
Creek	58	7	11
Lagoon	72	6	9
Wetland	43	3	6

Using the values in Table 6, two indices were calculated for each site:

- $I_{\text{Age category}}$ = the proportion of native fish species age categories present compared to the reference value for that macrohabitat, and;
- $I_{\text{Recruitment}}$ = the proportion of native fish species present that had YOY × (the number of native species collected ÷ the best achievable number of species collected for that macrohabitat).

The premise of $I_{\text{Age category}}$ is that a site can be healthy by supporting many species that that are only periodically recruiting. This is complemented by $I_{\text{Recruitment}}$, where a healthy site in any year is deemed to support many species that are recruiting.

4.2.4 Objective 3: Threatened native fish species

For this objective, two indices are calculated to compare the number of sites where threatened species were recorded, against the number of sites that are historically expected to have supported threatened species. The number of sites that are expected to have supported threatened species is based on the SRA PERCH list (Central Murray - Middle zone)(River), and Koondrook Perricoota Forest PERCH list (Creek, Lagoon and Wetland) as outlined in Table 7.

Table 7 Threatened native fish species recorded and/or predicted to have historically occurred at Gunbower Forest, including the proportion of sites each species is historically expected to have been found at using the SRA sampling protocols, based on PERCH lists developed for SRA and for Koondrook Perricoota Forest.

Common name	Recorded during 2008-2016 monitoring (extant)	The proportion of 'permanent' sites (i.e. River) that each species is historically expected to have been found at using SRA protocols (%)	The proportion of 'semi-permanent' sites (Creek, Lagoon, Wetland) that each species is historically expected to have been found at using SRA protocols (%)
Murray Cod	✓	85	45
Trout Cod	✓	85	10
Silver Perch	✓	85	10
Golden Perch	✓	85	45
Freshwater Catfish	✓	45	45
Murray-Darling Rainbowfish	✓	45	85
Un-specked Hardyhead	✓	45	85
Southern Pygmy Perch	×	45	45
Southern Purple-spotted Gudgeon	×	10	10
Flat-headed Galaxias	×	45	45
Olive Perchlet	×	45	45
Macquarie Perch	×	45	0
Murray Hardyhead	×	10	10
Average number of threatened native fish species expected in any site	All spp.	6.75	4.8
	Extant spp.	**4.75**	**3.25**

Summing the proportion of sites that each threatened (extant) species is expected to occur in gives an expectation of 4.75 species per site in permanent habitats (Rivers) and 3.25 species per site in semi-permanent habitats (Creek, Lagoons and wetlands). If subsequent years of monitoring were to detect

additional extant species, then the expected number of species per site would need to be updated accordingly.

Using the information provided above, the following site-based index is calculated:

- $I_{\text{Threatened species present}}$ = The number of threatened species present ÷ expected number present for each site

Further, an overall score for each habitat for the year is calculated:

- $I_{\text{Threatened species occurrence}}$ = The average proportion of sites that the threatened species occur in for that habitat

4.3 2008-2016 Index calculations and comparisons

The objectives relevant to the temporal changes are the same as applies to the 2016 data. However, the focus is to examine trends through time and the qualifying aspects of the objectives (e.g. 'an increase in…') in relation to points of reference (e.g. 2009 for Lagoons). Further, the nature of the data collected require some changes to individual indices. The age classes objective in the long-term trend analyses is restricted to the two large-bodied species Murray Cod and Golden Perch, as these are the species of greatest interest in terms of recruitment, and they also have consistent length measurement data back to 2008. The indices that have been developed and refined as part of this are summarised in Table 8 and discussed in more detail in sections 4.3.1 to 4.3.3. Examples of the calculations for each objective and each of the corresponding indices are included in Appendix 1. All of the indices scores are set to a maximum of one and a minimum of zero. These indices meet the Icon Site condition monitoring reporting requirements, however they are not definitive for the dataset and additional indices could be developed as required.

Table 8 A summary of the objectives and indices used to evaluate the Gunbower Forest Icon site 2008 to 2016 dataset. All indices range between 0 and 1.

Objective	Indices	Simplified description
1. An increase in the abundance of native fish species	Native species abundance	Average native fish species abundance compared to 2009 abundance
	Native species relative abundance	Average abundance of native fish relative to total fish abundance (i.e. $I_{Native\ abundance}$ as used for 2016 data)
	Native fish relative species richness	Average proportion of fish species that are native (i.e. $I_{Native\ species}$ as used for 2016 data)
2. A range of age/size classes for large bodied native species present	Large-bodied fish age categories	Average number of YOY and non-YOY age categories present in sites (a high quality site has 5 of 6 categories present)
	Large-bodied fish YOY extent	Number of sites where YOY fish of large-bodied species are present
3. A contribution to population recovery of threatened fish species	Threatened species compliance	Proportion of threatened species that occur in the expected number of sites
	Habitat threatened species occurrence	Average proportion of sites that extant threatened species occur in

4.3.1 Objective 1: An increase in the abundance of native fish species

As outlined in Table 8, this objective is addressed using three indices, the first of which uses CPUE abundance, while the latter two use relative abundance (refer to section 4.2.1). The *Native species abundance* (I_{SA}) index is based on the Index of Species Abundance (ISA) used by Sharpe and Villizi (2014). The same measure is used for exotic species to put the native species score into context. This index is complemented by two simple indices ($I_{Native\ abundance}$ and $I_{Native\ species}$ as used for the 2016 data) which compare the proportion of native fish by relative abundance and by species richness through time:

- I_{SA} = Average status of CPUE (+1 =higher, -1 = lower) for native fish species that were present in 2009.

4.3.2 Objective 2: A range of size classes for each native fish species present in sites

There are difficulties in evaluating this objective for small-bodied species using all available data, due to inconsistencies in the approach over time (e.g. standard length, fork length or total length) used for fish measurements. However, as outlined in the annual reports, the species of particular interest are Murray Cod and Golden Perch, and both YOY and adult length thresholds are readily available for these species from 2008 onwards (refer to Table 5). The length data for these species and the threshold lengths for adults and YOY are used to calculate a Large Bodied age categories (LBAC) index.

The approach used to address this objective in this current report is to determine the status of each measured large-bodied fish (YOY, Sub-adult, or Adult) and to calculate a Large Bodied age categories index for each site. The LBAC index is calculated as the number of age categories per site, divided by 5, which means that a site with 5 or more of the possible 6 age categories present is deemed in excellent condition (score =1).

- I_{LBAC} = number of Murray cod and Golden Perch YOY, Sub-adult, and adult age categories present ÷ 5

An additional index to determine how many of the sites sampled had YOY present for each of the large bodied species (*large-bodied native species YOY extent (LBYOY)*) is also calculated. The index is calculated only for the River and Creek macrohabitats, because the Lagoons and Wetland macrohabitats are much less likely to support YOY of these species (particularly Murray Cod). The premise of this index is that a healthier creek or river would have YOY present in more sites. It is a developmental index and it does not have a reference value and it's statistical properties are not evaluated yet. However it's interpretation is simple and can be used an indicative measure of recruitment for these habitats.

- I_{LBYOY} = average proportion of (creek or river) sites containing Murray cod and Golden Perch YOY

A worked example of the calculations of both large-bodied indices using real data are included in Appendix 1.

4.3.3 Objective 3: A contribution to population recovery of threatened fish species

This objective is addressed using a similar 'species extent' based method to those described in the Robinson (2015) and based on Sharpe and Villizi (2014), but differs in that only the seven threatened species that have been recorded during the 2008-2016 monitoring period are included. Other threatened species with potential to occur (e.g. Southern Pygmy Perch) have not been included because their potential to re-occur without direct intervention may be limited. These species can easily be included for future analyses if required.

The number of sites that each of the seven threatened species occurs in was calculated, and each species was compared and scored against the number of sites that the species is expected to occur in (using the current sampling methods). An "occurrence score" between 0 and 1 was calculated for each species, and two indices were subsequently calculated; *Proportion of Threatened Species Compliance*, and; *Threatened Species Occurrence*:

- $I_{\text{Threatened species occurrence}}$= The average proportion of sites that the threatened species occur in for that habitat
- $I_{\text{Threatened species compliant}}$ = The proportion of the seven threatened species that occur in at least as many sites as expected

The *threatened species compliance* index differs from the 2016 snapshot *threatened species present* index as it is calculated to apply to the entire macrohabitat rather than the individual site (see appendix 1 for calculation examples).

5 Results of the 2016 survey

5.1 Overview

The 2016 survey captured a total of 50,901 fish from 16 species (11 indigenous and 5 exotic). Two small-bodied species, Carp Gudgeon *Hypseleotris* spp. and Eastern Gambusia *Gambusia holbrooki* comprised 89% of the total abundance. Large-bodied species comprised only 1.7% of the total abundance and Carp *Cyprinus carpio* was by far the most abundant large-bodied species (1.4%). The fish community differed considerably between macrohabitats, with fish being far more abundant at Wetland and Lagoon sites than River or Creek sites. Exotic species were much more prevalent at Wetland sites, comprising around 40% of the total abundance, primarily due to very large numbers of Eastern Gambusia. Four species were recorded in very low abundance, together comprising just 0.02% of the total abundance. These included Bony Herring *Nematalosa erebi*, which was only recorded from River macrohabitat, Trout Cod *Maccullochella macquariensis* (was only recorded from Creek macrohabitat) and two species (Freshwater Catfish *Tandanus tandanus* and the exotic Redfin *Perca fluviatilis*), which were only recorded from Lagoon macrohabitat.

A summary of the 2016 monitoring results is provided in Table 9. These tables are intended only to provide an overview of the species and relative abundances captured by the surveys, rather than absolute estimates of abundance at a macrohabitat or whole of icon site scale.

Table 9 Cluster-sampled overview summary of Gunbower Icon Site 2016 survey catch results (native species denoted by green shading and exotic species denoted by orange shading). Note that the table does not and is not intended to provide an estimation of absolute abundance at a macrohabitat or whole of icon site scale

Common name	River	Creek	Lagoon	Wetland	Total
Carp gudgeon	300	980	11,976	19,557	32,813
Eastern gambusia	5	76	44	12,408	12,533
Un-specked hardyhead	3	125	3,309	8	3,445
Common carp	76	93	172	372	713
Australian smelt	55	135	371	49	610
Flathead gudgeon		4	354	108	466
Oriental weatherloach			8	86	94
Murray cod	35	36	1		72
Murray-Darling Rainbowfish	25	11	2	14	52
Goldfish	15	5	8	18	46
Golden perch	24	9			33
Silver perch	10	4			14
Redfin			5		5
Bony herring	3				3
Freshwater catfish			1		1
Trout cod		1			1
Number of fish caught	**551**	**1,479**	**16,251**	**32,620**	**50,901**
# indigenous	455	88.2	98.5	60.5	88.2

Common name	River	Creek	Lagoon	Wetland	Total
Number of species caught	11	12	12	9	12
# indigenous	8	9	7	5	9

Recruitment was evident (i.e. YOY were recorded) for eleven of the sixteen species recorded. Recruitment was evident from every macrohabitat for three native small-bodied species (Carp Gudgeon, Un-specked Hardyhead, and Australian Smelt) and two large-bodied exotic species (Carp and Goldfish). Murray Cod recruitment was evident in both the Murray River and Gunbower Creek. A summary of recruitment recorded for each species in each macrohabitat is provided in Table 10.

Table 10 Summary of recruitment in the macrohabitats surveyed, based on the presence of individuals below the YOY thresholds outlined in Table 5. (native species denoted by green shading and exotic species denoted by orange shading).

Common name	River	Creek	Lagoon	Wetland
Carp Gudgeon	✓	✓	✓	✓
Eastern gambusia	×	✓	✓	✓
Un-specked hardyhead	✓	✓	✓	✓
Common carp	✓	✓	✓	✓
Australian smelt	✓	✓	✓	✓
Flathead gudgeon		×	✓	✓
Oriental weatherloach			×	✓
Murray cod	✓	✓	×	
Murray-Darling Rainbowfish	✓	✓	×	✓
Goldfish	✓	✓	✓	✓
Golden perch	×	×		
Silver perch	×	✓		
Redfin			×	
Bony herring	×			
Freshwater catfish			×	
Trout cod		×		

5.1.1 River

The 2016 survey of the River sites captured 551 fish from eleven species (8 native and 3 exotic)(see Table 11). Three small-bodied species, Carp Gudgeon, Australian Smelt *Retropinna semoni* and Murray-Darling Rainbowfish *Melanotaenia fluviatilis* together comprised 69% of the total abundance. The most abundant large-bodied species were Carp (13.8% of the total abundance) and Murray Cod (6.4%).

Table 11 2016 survey catch results for River sites (n = 3) (native species denoted by green shading and exotic species denoted by orange shading)

Common name	Murray River Cohuna	Murray River Koondrook	Murray River Torrumbarry	Total
Carp Gudgeon	109	30	161	300
Common carp	38	11	27	76
Australian smelt	39	16		55
Murray cod	23	8	4	35
Murray-Darling Rainbowfish	8	1	16	25
Golden perch	10	9	5	24
Goldfish	3		12	15
Silver perch	7	2	1	10
Eastern gambusia	5			5
Un-specked hardyhead			3	3
Bony herring	3			3
Total	**245**	**77**	**229**	**551**

Recruitment was evident (i.e. YOY were recorded) for eight of the eleven species recorded at the River sites. At some sites, a high proportion of Australian Smelt and Carp Gudgeon were considered recent recruits (YOY). Murray Cod recruitment was evident at two sites and Golden Perch recruitment was evident at one site.

Table 12 The proportion (%) of measured fish considered to be YOY in River sites based on the thresholds outlined in Table 5 (native species denoted by green shading and exotic species denoted by orange shading).

Common name	Murray River Cohuna	Murray River Koondrook	Murray River Torrumbarry
Australian smelt	56.4	100	
Bony herring	0.0		
Carp gudgeon	25.8	76.7	50.0
Common carp	75.0	36.4	60.0
Eastern gambusia	0.0		
Golden perch	25.0	0.0	0.0
Goldfish	33.3		50.0
Murray cod	25.0	0.0	25.0
Murray-Darling Rainbowfish	12.5	0.0	43.8
Silver perch	28.6	0.0	0.0
Un-specked hardyhead			33.3

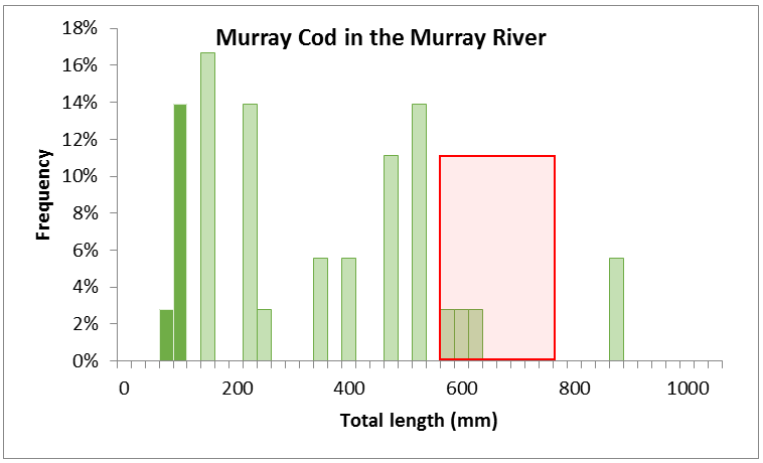

Figure 1 Indicative estimate of length frequency distribution (n=22) for Murray Cod (including legal angling size range as indicated by the red box, and YOY size classes as indicated by dark green bars), equally weighted across all Murray River sites.

5.1.2 Creek

The 2016 survey of Gunbower Creek captured 1,479 fish from 12 species (nine native and three exotic)(see Table 13). Three small-bodied native species, Carp Gudgeon, Australian Smelt and Un-Specked Hardyhead *Craterocephalus stercusmuscarum fulvus* together comprised 84% of the total abundance. Carp were the most abundant large-bodied species (6.3% of total abundance).

Table 13 2016 survey catch results for Creek sites (n = 7) (native species denoted by green shading and exotic species denoted by orange shading)

Common name	Gunbower Creek							Total
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	
Carp gudgeon	372	60	174	87	101	77	109	980
Australian smelt	8		2	7	8	24	86	135
Un-specked hardyhead	8		6	22	35	8	46	125
Common carp	9	37	23	10	3	4	7	93
Eastern gambusia	30	11		3	10	14	8	76
Murray cod	12	3	3	1	2	15		36
Murray-Darling Rainbowfish	5				2	4		11
Golden perch		1	2			5	1	9
Goldfish	1		1	2	1			5
Flathead gudgeon	2			2				4
Silver perch						4		4
Trout cod	1							1
Total	**448**	**112**	**211**	**134**	**162**	**155**	**257**	**1479**

Recruitment was evident for eight of the 12 species captured at the Creek sites (Table 14). At some sites, a high proportion of Australian Smelt, Unspecked Hardyhead, Goldfish and Carp were considered to be recent recruits (YOY). Murray Cod recruitment was evident at one site.

Table 14 The proportion (%) of measured fish considered to be YOY in Gunbower Creek sites (n = 7) based on the thresholds outlined in Table 5 (native species denoted by green shading and exotic species denoted by orange shading).

Common name	Gunbower Creek						
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Australian smelt	0.0		50.0	28.6	50.0	37.5	52.9
Carp gudgeon	63.5	47.1	33.3	28.7	71.2	8.0	64.7
Common carp	0.0	40.0	9.1	0.0	66.7	0.0	0.0
Eastern gambusia	3.3	18.2		0.0	20.0	14.3	37.5
Flathead gudgeon	0.0			0.0			
Golden perch		0.0	0.0			0.0	
Goldfish	100.0		100.0	50.0	0.0		
Murray cod	0.0	0.0	0.0	0.0	0.0	28.6	
Murray-Darling Rainbowfish	40.0				50.0	0.0	
Silver perch						0.0	
Trout cod	0.0						
Un-specked hardyhead	75.0		100.0	90.0	88.6	100.0	100.0

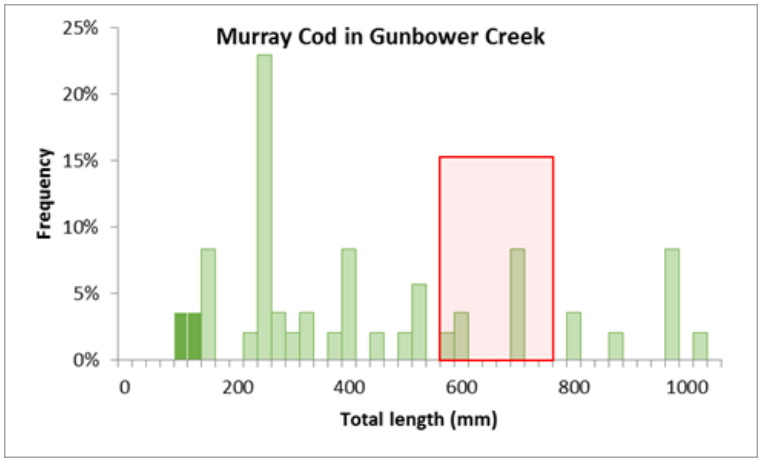

Figure 2 Indicative estimate of length frequency distribution (n=25) for Murray Cod (including legal angling size range as indicated by the red box, and YOY size classes as indicated by dark green bars), equally weighted across the four Gunbower Creek sites (Reach 1, 2, 3 and 6) where three or more individuals were captured .

5.1.3 Lagoon

The 2016 survey of the Lagoon sites captured 16,251 fish from 12 species (7 native and five exotic)(see Table 15). Two small-bodied native species, Carp Gudgeon and Un-specked Hardyhead together comprised 98.5% of the total abundance. Carp were by far the most abundant large-bodied species, comprising just over 1% of the total abundance.

Table 15 2016 survey catch results for Lagoon sites (n = 9) (native species denoted by green shading and exotic species denoted by orange shading)

Common name	Cockatoo Lagoon	Gum Lagoon	Longmore Lagoon	Phyland Lagoon	Safe Lagoon	Splatt Lagoon	Taylor Lagoon	Turner Lagoon	Upper Gunbower Lagoon	Total
Carp gudgeon	2125	5596	716	2046	121	189	416	218	549	11,976
Un-specked hardyhead		212	187	60	1090	116		1355	289	3,309
Australian smelt	1	5	39	18	125	66		15	102	371
Flathead gudgeon	1	7	226	94		15		10	1	354
Common carp	11	21	11	100	9	2	10	7	1	172
Eastern gambusia			11	1		2	1	29		44
Oriental weatherloach	1						6		1	8
Goldfish		1	2	2	2			1		8
Redfin				2				3		5
Murray-Darling Rainbowfish					1	1				2
Murray cod		1								1
Freshwater catfish								1		1
Total	**2,139**	**5843**	**1,192**	**2323**	**1,348**	**391**	**433**	**1,639**	**943**	**16,251**

Recruitment was evident for seven of the 12 species captured at the Lagoon sites (Table 16). At some sites, a high proportion of Flat-headed Gudgeon, Australian Smelt, Unspecked Hardyhead and the introduced Eastern Gambusia and Goldfish were considered to be recent recruits (YOY).

Table 16 The proportion (%) of measured fish considered to be YOY in Lagoon sites in 2016 based on the thresholds outlined in Table 5 (native species denoted by green shading and exotic species denoted by orange shading).

Common name	Cockatoo Lagoon	Gum Lagoon	Longmore Lagoon	Phyland Lagoon	Safe Lagoon	Splatt Lagoon	Taylor Lagoon	Turner Lagoon	Upper Gunbower Lagoon
Australian smelt	0.0	0.0	23.1	0.0	14.4	15.2		53.3	3.9
Carp Gudgeon	3.3	0.9	5.3	1.2	37.2	7.9	6.5	19.6	7.8
Common carp	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eastern gambusia			18.2	100.0		0.0	0.0	41.4	
European perch				0.0				0.0	
Flathead gudgeon	100.0	28.6	20.4	26.6		73.3		72.7	0.0
Freshwater catfish								0.0	
Goldfish		0.0	0.0	50.0	0.0			0.0	
Murray cod		0.0							
Murray-Darling Rainbowfish					0.0	0.0			
Oriental weatherloach	0.0						0.0		0.0
Un-specked hardyhead		29.7	34.8	90.0	5.9	48.3		4.0	17.0

5.1.4 Wetland

The 2016 survey of the Wetland sites captured 32,620 fish from 9 species (five native and four exotic)(Table 17). Two small-bodied species, Carp Gudgeon and Eastern Gambusia, together comprised 98% of the total abundance. Carp were by far the most abundant large-bodied species captured, comprising 1.1% of the total abundance.

Table 17 2016 survey catch results for Wetland sites (n = 7) (native species denoted by green shading and exotic species denoted by orange shading)

Common name	Black Charlie Lagoon	Black Swamp	Corduroy Swamp	Crayfish Island	Green Swamp	Little Reedy Lagoon	Reedy Lagoon	Total
Carp gudgeon	1,177	2,516	5,889	1,616	2,083	5,597	679	19,557
Eastern gambusia	28	1,549	3,728	678	1,089	4,205	1,131	12,408
Common carp	1	5	8	304	12	10	32	372
Flathead gudgeon	107			1				108
Oriental weatherloach		13			7	28	38	86
Australian smelt	8	2	6	11	4	11	7	49
Goldfish			2		3	4	9	18
Murray-Darling Rainbowfish					3	11		14
Un-specked hardyhead				6			2	8
Total	**1,321**	**4,085**	**9,633**	**2,616**	**3,201**	**9,866**	**1,898**	**32,620**

Recruitment was evident for all nine species captured at the Wetland sites (Table 18). All Goldfish and a high proportion of Australian Smelt and Unspecked Hardyhead were considered to be recent recruits (YOY).

Table 18 The proportion (%) of measured fish in Wetland sites in 2016 considered to be YOY based on the thresholds outlined in Table 5 (native species denoted by green shading and exotic species denoted by orange shading).

Common name	Black Charlie Lagoon	Black Swamp	Corduroy Swamp	Crayfish Island	Green Swamp	Little Reedy Lagoon	Reedy Lagoon
Australian smelt	0.0	100.0	33.3	72.7	50.0	100.0	14.3
Carp gudgeon	2.1	1.5	0.0	5.7	1.6	0.9	2.8
Common carp	0.0	0.0	37.5	9.9	16.7	10.0	15.6
Eastern gambusia	14.3	1.7	0.2	3.4	0.2	0.5	0.9
Flathead gudgeon	9.3			0.0			
Goldfish			100.0		100.0	100.0	100.0
Murray-Darling Rainbowfish					33.3	27.3	
Oriental weatherloach		0.0			0.0	3.6	0.0
Un-specked hardyhead				66.7			100.0

5.2 2016 TLM Icon Site Indices

5.2.1 Objective 1: The abundance of native fish species

The proportion of native fish caught ($I_{Native\ abundance}$)

Lagoon habitats averaged more than 98% native fish by abundance in 2016 ($I_{Native\ abundance} > 0.98$) (Figure 3). These high averages were due to large abundances of Carp Gudgeon and Un-specked Hardyhead. River and Creek sites averaged scores of 0.83 and 0.86 native fish, but wetlands sites only contained an average score of 0.63 native fish due to high numbers of Eastern Gambusia (Figure 3 and Figure 4).

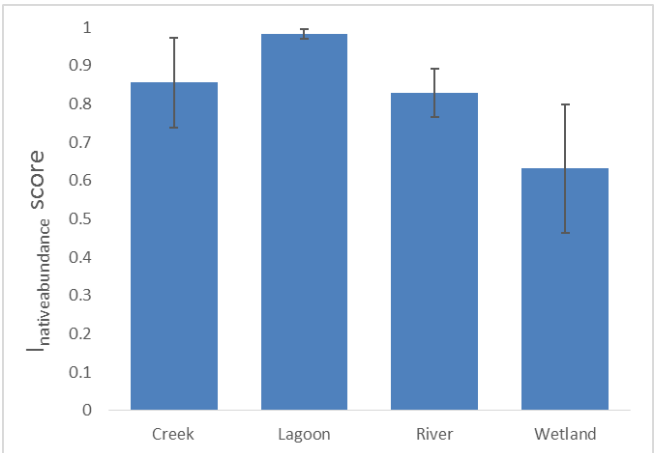

Figure 3 The average proportion of native fish caught ($I_{Native\ abundance}$) in 2016 for each macrohabitat

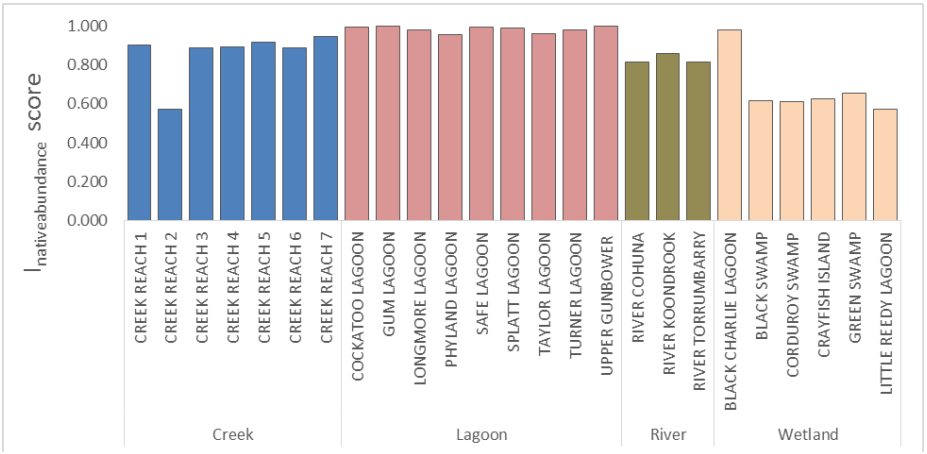

Figure 4 The proportion of native fish caught ($I_{Native\ abundance}$) in 2016 for each site

The proportion of native fish species caught ($I_{Native\ species}$)

The proportion of fish species that were native was highest and most consistent between sites in the River ($I_{Native\ species}$ = 0.77) and Creek (0.67) macrohabitats (Figure 5). Wetlands (0.48) and Lagoons (0.58) had a higher proportion of exotic species, although all sites sampled had at least 43% native species ($I_{Native\ species}$ = 0.43) except for Taylor's Lagoon, where only one native and three alien species were recorded (Figure 6).

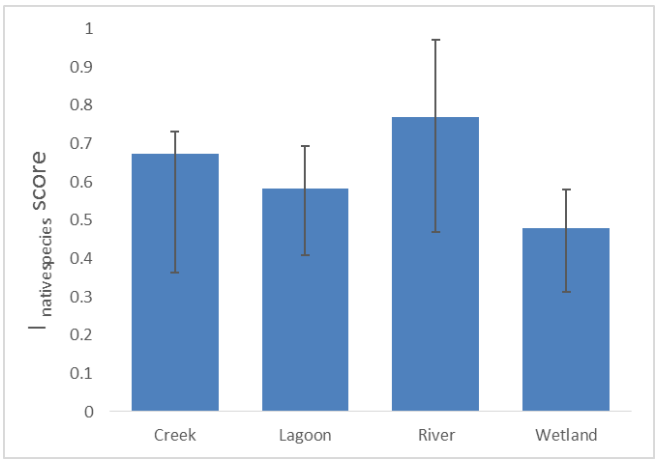

Figure 5 The average proportion of native fish species caught ($I_{Native\ species}$) in 2016 for each macrohabitat

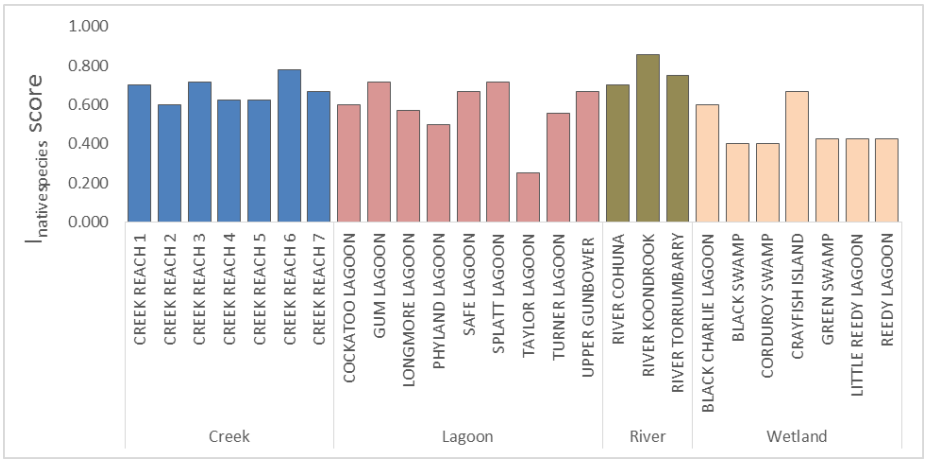

Figure 6 The proportion of native fish species caught ($I_{Native\ species}$) in 2016 for each site

The proportion of historically expected native fish species present ($I_{Native\ expected}$)

A low proportion of the historically expected native fish species were recorded from Wetland sites (average $I_{Native\ expected}$ score of 0.40). The River sites supported the highest proportion of historically expected species, with an average score of 0.60 (Figure 7). Most sites scored around 0.50 for expected species in 2016, with the best sites being Gunbower Creek Reaches 1 and 6 (0.67), and Gum, Splatt and Turner Lagoons (0.69) (Figure 8). Taylor Lagoon was again the worst site (0.14) with few expected native species collected, whilst Creek Reach 2 was the next worst at 0.29 (Figure 8).

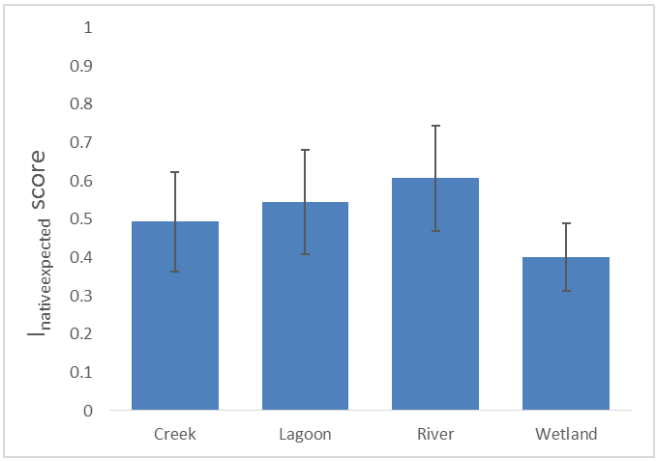

Figure 7 The average proportion of expected native fish species caught ($I_{Native\ expected}$) in 2016 for each macrohabitat

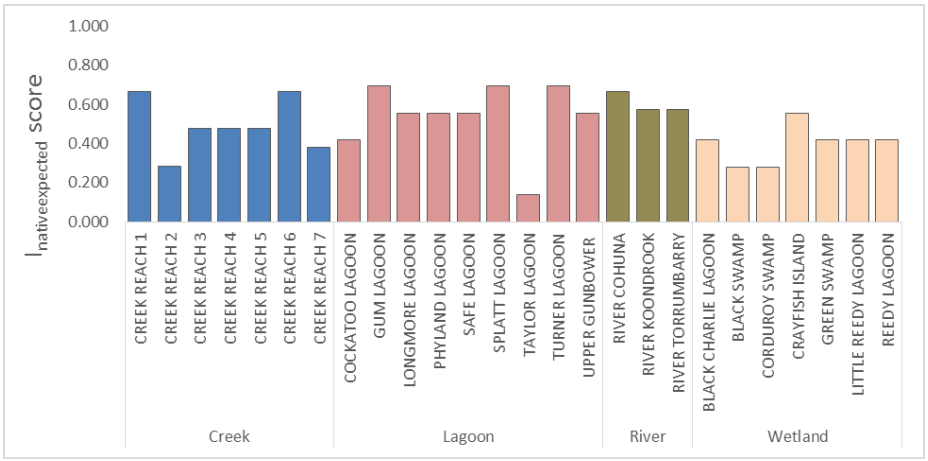

Figure 8 The proportion of historically expected native species present ($I_{Native\ expected}$) in 2016 for each site

5.2.2 Objective 2: Size classes of native species

The proportion of native fish species age categories present compared to reference ($I_{Age\ category}$)

$I_{Age\ category}$ scores averaged between 0.69 and 0.76 for all the habitats (Figure 9). The individual sites were quite varied, ranging between 0.36 and 0.91 for Creek macrohabitat, 0.22 and 0.89 in Lagoons, 0.54 and 1.0 in River, and 0.33 and 1.0 in Wetlands (Figure 10). Taylors Lagoon and Creek Reach 2 again recorded low scores.

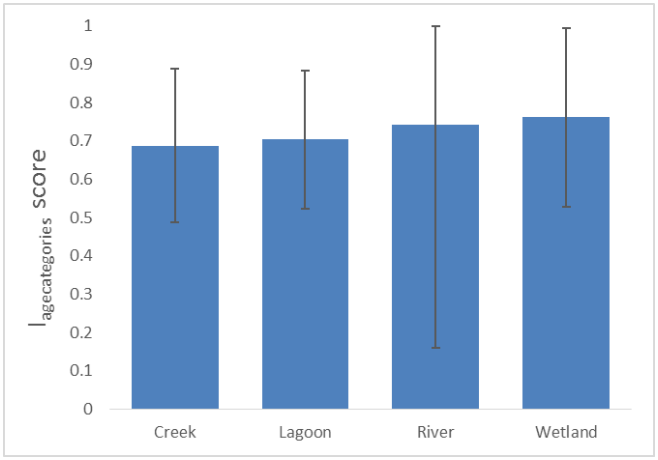

Figure 9 The average proportion of native fish species age categories present ($I_{Age\ categories}$) in 2016 compared to the best achievable for each macrohabitat

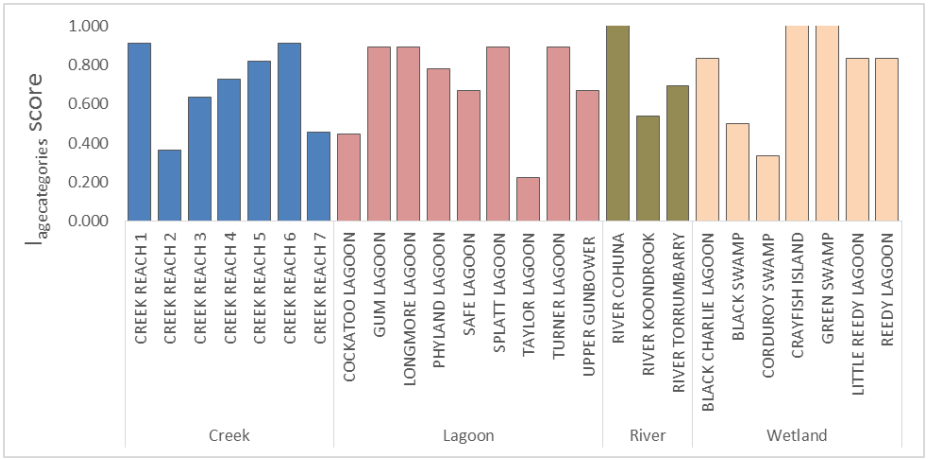

Figure 10The proportion of native fish species age categories present ($I_{Age\ categories}$) in 2016 compared to the best available for each site

The proportion of native fish species with YOY present compared to reference ($I_{Recruitment}$)

Whilst this is only a developmental index, some key points can be made from the 2016 data. Notably, that it is possible to score a 1, as both Reedy and Little Reedy lagoons scored perfectly on this index (Figure 12). The recruitment index followed the same pattern as the age categories index, in that there was a trend of better scores in the Wetland sites on average and lower scores in the Creek sites (Figure 11 and Figure 12). Four of the best five performing sites were in Wetlands, and the Lagoon sites tended to score better than the Creek sites (Figure 11). The three River sites were highly variable and notably, the Koondrook site scored very poorly (0.125) and was the lowest scoring site in 2016. Taylor Lagoon and Creek Reach 2 scored poorly once again, and on a site-by-site basis these two sites clearly have poor proportions of native fish and poor recruitment.

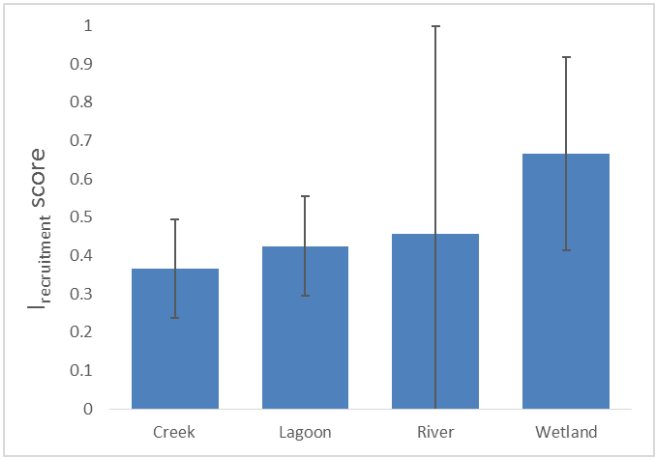

Figure 11 The average proportion of native fish species with YOY compared to the best achievable for each macrohabitat ($I_{Recruitment}$).

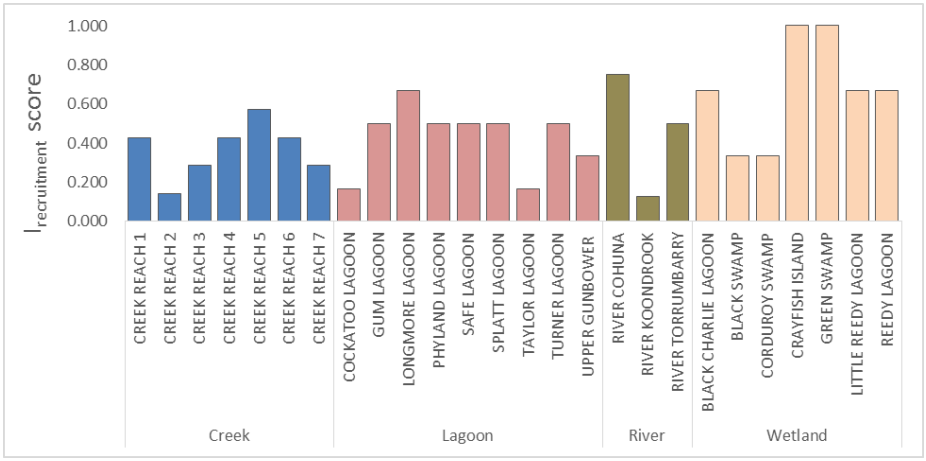

Figure 12 The proportion of native fish species with YOY compared to the best achievable for each macrohabitat ($I_{Recruitment}$) at each site.

5.2.3 Objective 3: Threatened native fish species

The number of threatened species present compared with expected ($I_{\text{Threatened species present}}$)

The River and Creek macrohabitats were the obvious standouts for the presence of threatened species, with all sites scoring better than 0.60, and River and Creek averaging 0.82 and 0.89 respectively (Figure 13 and Figure 14). The Lagoon sites averaged scores of only 0.37 and the Wetland sites averaged only 0.18. Threatened species were not recorded from two of the Lagoon sites and three of the Wetland sites in 2016 (Figure 14).

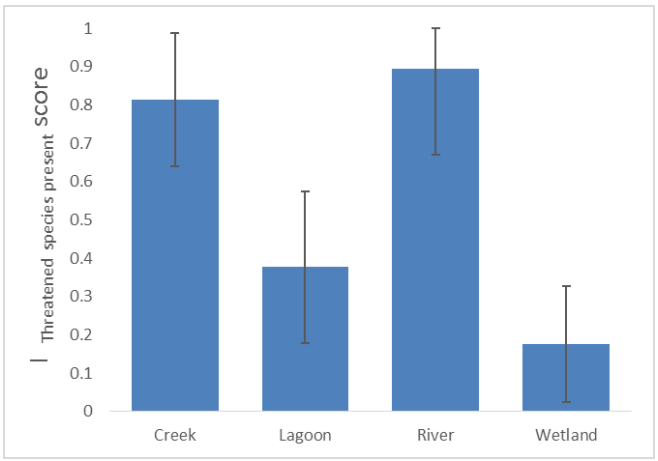

Figure 13 The number of threatened native fish species present compared to the number expected for each site ($I_{\text{Threatened species present}}$) averaged for each macrohabitat.

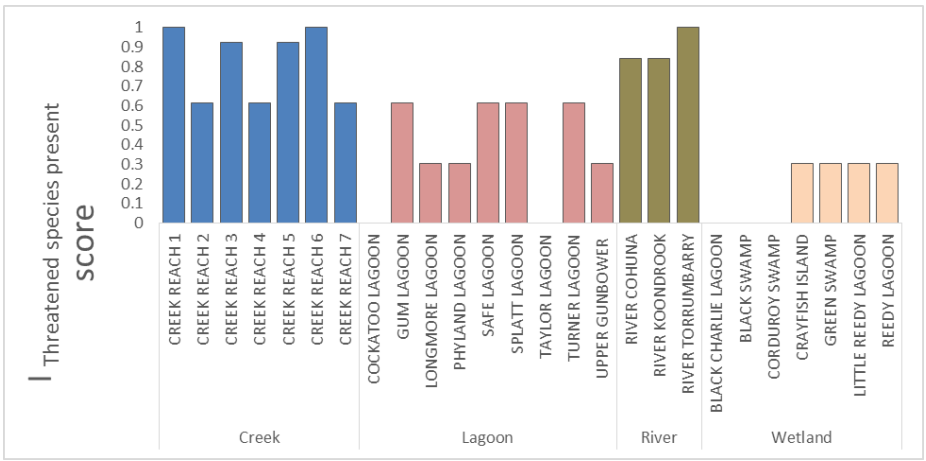

Figure 14 The number of threatened native fish species present compared to the number expected for each site ($I_{\text{Threatened species present}}$).

The proportion of sites that the threatened species occur in for each macrohabitat ($I_{Threatened\ species\ occurrence}$)

Threatened species are doing much better in Gunbower Creek and River macrohabitats than in Wetland or Lagoon macrohabitats in 2016. The threatened species that were present in 2016, occurred in the vast majority of sites that they were expected to, with scores of 0.92 and 0.95 respectively (Figure 16). In contrast, of the threatened species that were present in 2016, few occurred in the Wetland and Lagoon sites that they were expected to, with scores of 0.33 and 0.42 respectively (Figure 15).

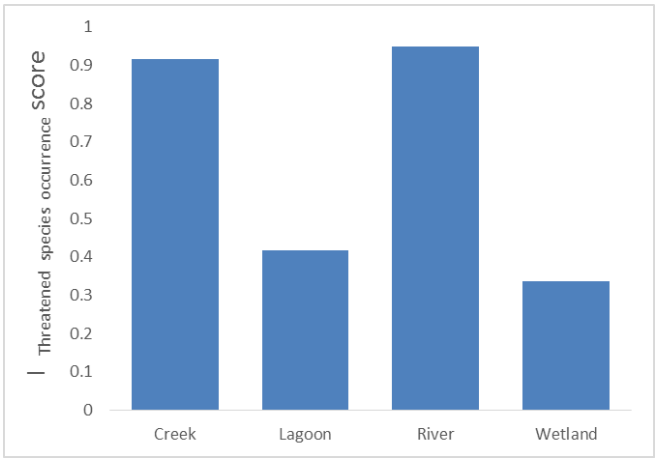

Figure 15The proportion of sites that the threatened species occur in for each macrohabitat ($I_{Threatened\ species\ occurrence}$).

6 Results of 2008-2016

6.1 Objective 1: An increase in the abundance of native fish species

6.1.1 River

Native species abundance (I_{SA})

Native fish abundance at the Murray River sites dropped from 2010 levels through to 2013, but have been above 2010 levels in 2014 and 2016 (Figure 16). Alien fish abundance at the Murray River sites were higher for all five alien species in 2011 and then dropped considerably in 2012 and have remained at or above 2010 levels throughout the monitoring period, with abundances generally increasing since 2012.

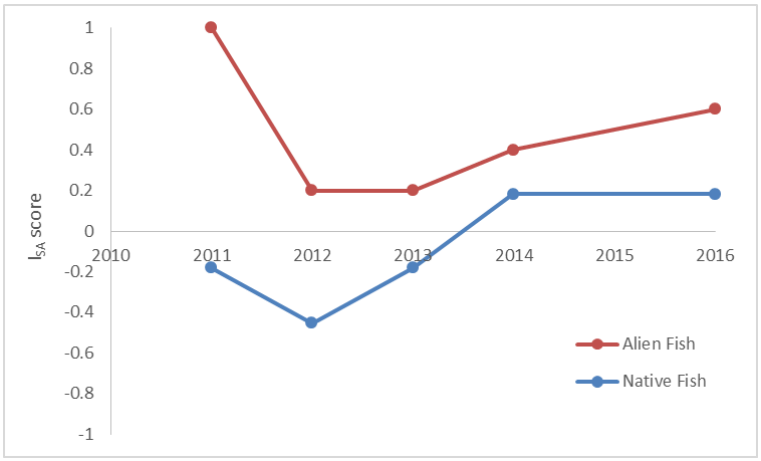

Figure 16 *Index of species abundance* (Sharpe and Villizi 2014) at Murray River sites using 2010 abundances as a point of reference.

Native fish relative abundance ($I_{Native\ abundance}$) and Native fish relative species richness ($I_{Native\ species}$)

Native fish have comprised a high proportion of the fish collected ($I_{Native\ abundance}$ score > 0.80) at Murray River sites in most years, after a severe drop (0.12) in 2011 and subsequent increase (0.72) in 2012 (Figure 17).

Native fish species have made up a high proportion of the species collected ($I_{Native\ species}$ scores of 0.76–0.78) in River sites since 2013, after lower proportion in 2012 (0.59) (Figure 17).

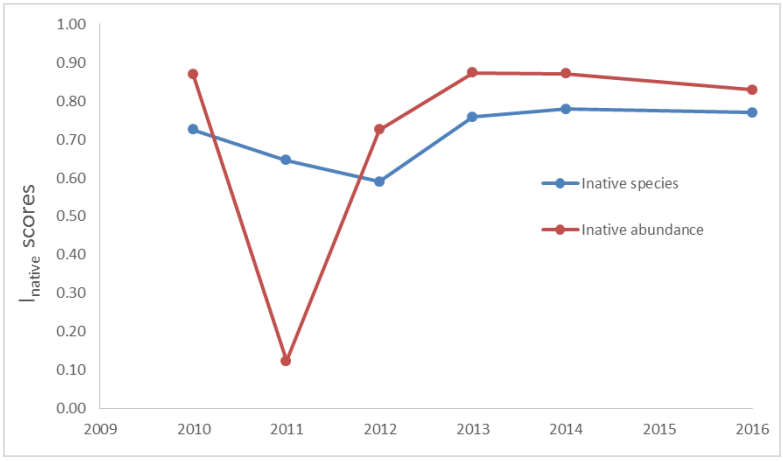

Figure 17 Average native fish relative abundance ($I_{Native\ abundance}$) and relative species richness ($I_{Native\ species}$) indices scores at Murray River monitoring sites.

6.1.2 Creek

Native species abundance (I_{SA})

Native fish abundances in 2016 were above 2009 levels and have continued a consistent upward trend since 2011, when levels had returned to 2009 levels after a considerable increase in 2010 (Figure 18). Alien fish species abundances in 2016 were at the same levels as in 2009 (Figure 18) and have remained around that level since the peaks in 2010 and 2011.

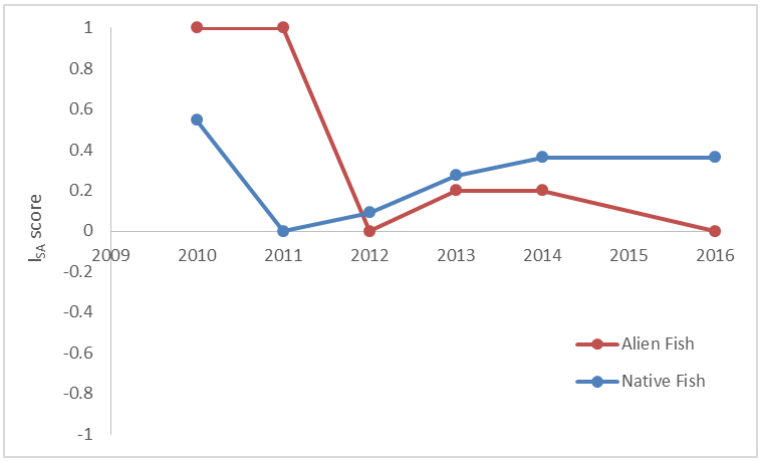

Figure 18 *Index of species abundance* (Sharpe and Villizi 2014) in Gunbower Creek sites using 2009 abundances as a point of reference.

Native fish relative abundance ($I_{\text{Native abundance}}$) and Native fish relative species richness ($I_{\text{Native species}}$)

A high proportion of the fish collected from Gunbower Creek sites in 2016 were native ($I_{\text{Native abundance}}$ score of 0.86) and this maintains the generally high relative abundance seen in most years, with the exception of the low proportions in 2010 (0.53) and 2011 (0.22) (Figure 19).

The high proportion of fish species collected from Gunbower Creek sites in 2016 were native ($I_{\text{Native species}}$ score of 0.67) (Figure 19) and this corresponds to a generally consistent trend and stability after the low year of 2011 (0.53) when alien species were more prominent (Figure 19).

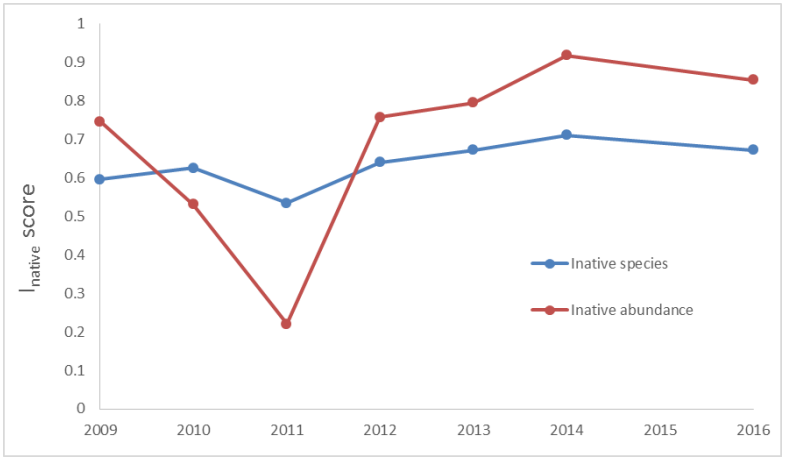

Figure 19 Average native fish relative abundance ($I_{\text{Native abundance}}$) and relative species richness ($I_{\text{Native species}}$) indices scores at Gunbower Creek monitoring sites.

6.1.3 Lagoon

Native species abundance (I_{SA})

Native and alien fish abundances in the four Lagoon sites with contiguous data (Cockatoo, Phyland, Turner and Upper Gunbower Lagoons) were at their highest relative to 2009 reference levels in 2010 and 2011 (Figure 20). Alien fish species have been close to the 2009 levels since 2012, whilst native fish species abundances have been slightly less than 2009 for the last couple of years (Figure 20).

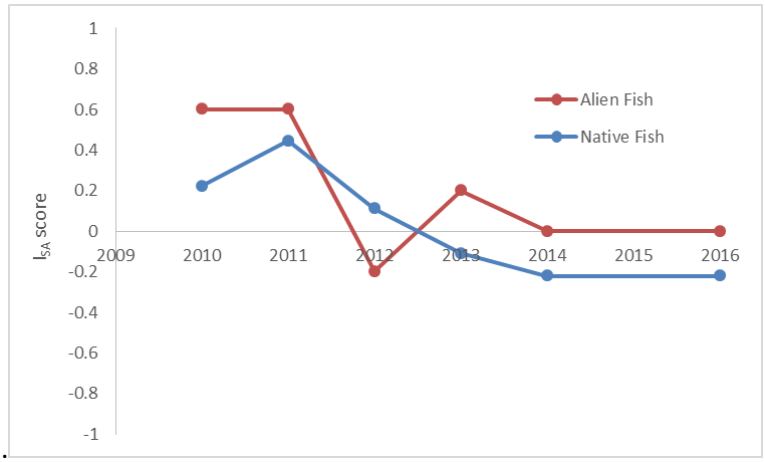

Figure 20 *Index of species abundance (Sharpe and Villizi 2014)* at Lagoon sites using 2009 abundances as a point of reference.

Native fish relative abundance ($I_{Native\ abundance}$) and Native fish relative species richness ($I_{Native\ species}$)

Native fish relative abundance averaged 0.98 at the four Gunbower Lagoon sites in 2016, the highest since monitoring began in 2008 (0.96) (Figure 21). The average proportion of fish that are native within the lagoon sites has shown a steady increase since the low score of 0.15 in 2011 (Figure 21). Native fish relative species richness averaged 0.62 at the four Gunbower Lagoon sites in 2016, and has generally remained consistent through time (Figure 21).

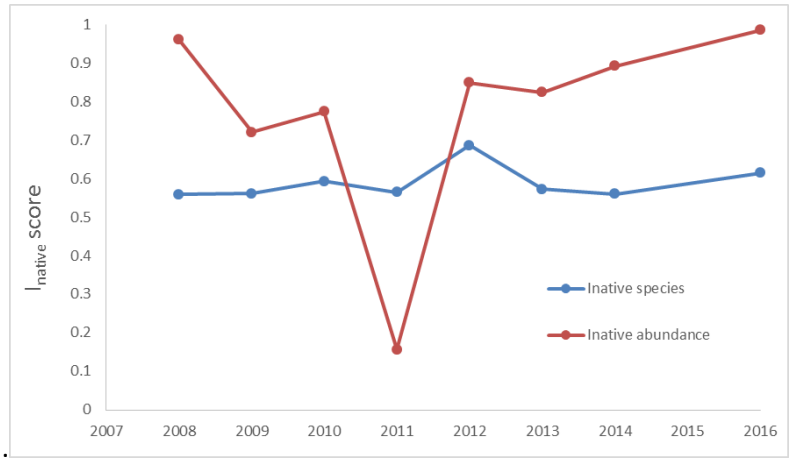

Figure 21 Average native fish relative abundance ($I_{Native\ abundance}$) and relative species richness ($I_{Native\ species}$) indices at Lagoon monitoring sites.

6.2 Objective 2: A range of size classes for each native fish species present

6.2.1 River

Large-bodied fish age categories (I_{LBAC})

A high proportion of expected age categories (I_{LBAC} averaged 0.80) of large-bodied native fish were collected from River sites in 2016, the highest since monitoring began (Figure 22). There has been a steady increase evident in the index scores, since the low recorded in 2011.

Large-bodied fish YOY extent (I_{LBYOY})

Murray Cod Young of Year (YOY) were collected at two sites and Golden Perch YOY at one site in the Murray River in 2016. This represents the first time that Murray Cod YOY have been recorded since 2010 and the first time Golden Perch YOY have been detected throughout the monitoring period. Consequently, the YOY index for 2016 of 0.5 is the best for the River macrohabitat since monitoring began (Figure 22).

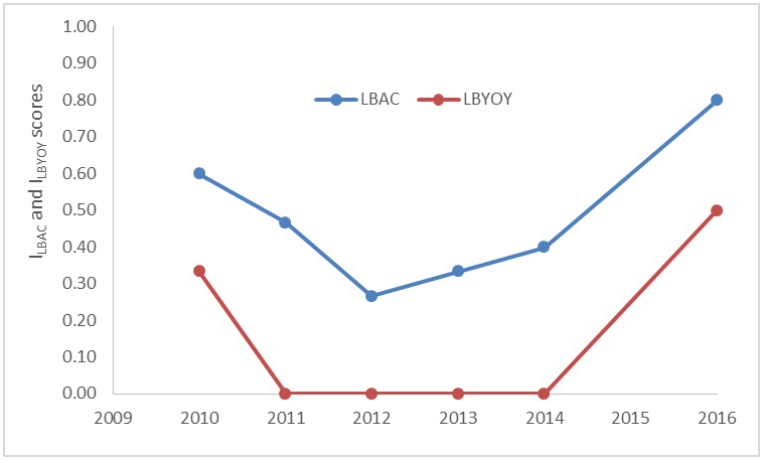

Figure 22 Average *large-bodied fish age categories* and *YOY extent* indices at Murray River monitoring sites.

6.2.2 Creek

Large-bodied fish age categories (I_{LBAC})

An average of 47% of expected Murray Cod and Golden Perch age categories were observed in Gunbower Creek sites in 2016 (Figure 23). This is the highest result since monitoring began, with a steady increase evident in the index scores, since the low recorded in 2011.

Large-bodied fish YOY extent (I_{LBYOY})

No Golden Perch or Murray Cod Young of Year (YOY) were detected at Gunbower Creek sites before 2013 (Figure 23). Golden Perch YOY have only been detected in 2013, while Murray Cod YOY were detected in two sites in 2013 and 2014 and at just one site in 2016.

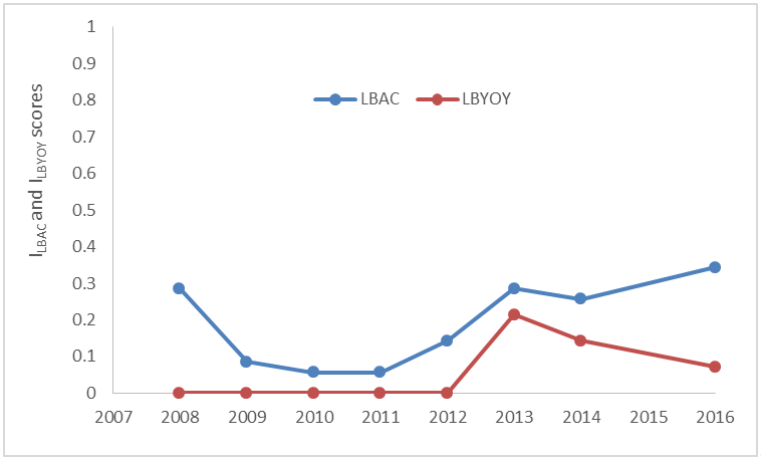

Figure 23 Average *large-bodied fish age categories* and *YOY extent* indices at Gunbower Creek monitoring sites

6.3 Objective 3: A contribution to population recovery of threatened fish species

6.3.1 River

Threatened species compliant ($I_{Threatened\ species\ compliant}$), and

Threatened species occurrence ($I_{Threatened\ species\ occurrence}$)

Four of the seven threatened species occurred at River sites in 2016 (Freshwater Catfish and Trout Cod were not collected). These species occurred in at least as many sites as expected (Refer to Table 7). The score ($I_{threatened\ species\ compliant}$) of 0.57 (i.e. 4/7 species) is the equal best since monitoring began (Figure 24).

The same four threatened species present in 2016 have been present at River sites in every year, but have scored an average of 95% for occurring in the expected number of sites for the past two years (Figure 24). Overall, threatened species occurrence at River sites are at the highest levels since monitoring began and a substantial improvement from the declines evident in 2011 and 2012 (Figure 24).

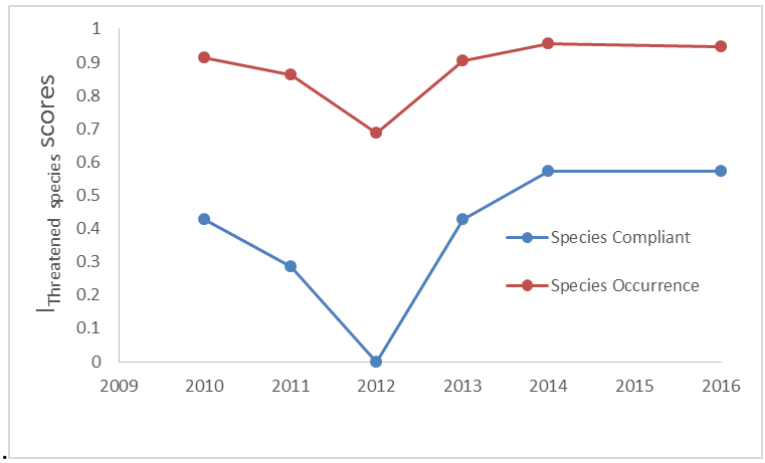

Figure 24 Average *Threatened species compliant* ($I_{Threatened\ species\ compliant}$) and *Threatened species occurrence* ($I_{Threatened\ species\ occurrence}$) indices scores at Murray River monitoring sites.

6.3.2 Creek

Threatened species compliant ($I_{\text{Threatened species compliant}}$); and

Threatened species occurrence ($I_{\text{Threatened species occurrence}}$)

Freshwater Catfish were the only one of the seven threatened species not to occur in Gunbower Creek in 2016. All the other threatened species occurred in at least as many sites as expected, except Murray-Darling Rainbow fish which only occurred in about half the sites expected. Nevertheless, the average threatened species occurrence score ($I_{\text{Habitat threatened species}}$) was 0.92 in 2016 and has remained at similarly high levels since the 2012 recovery from low levels of 2011 (Figure 25).

With five of the seven species occurring at least as many sites as expected, the compliance index score ($I_{\text{Threatened species compliant}}$) in 2016 was 0.71, the equal best since monitoring began (Figure 25).

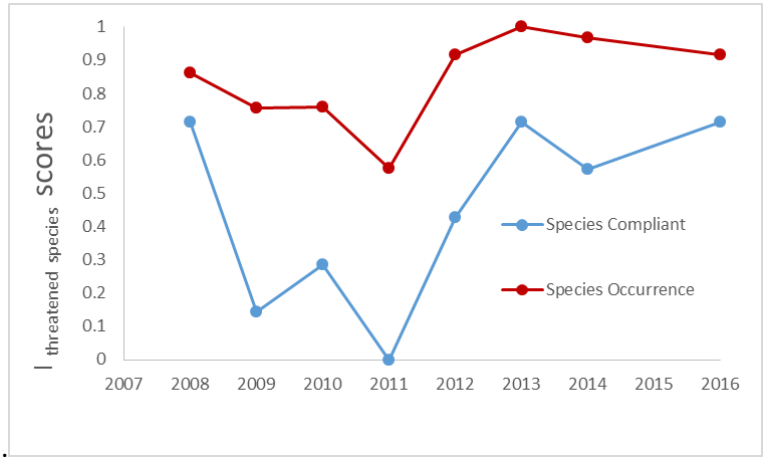

Figure 25 Average *Threatened species compliant* ($I_{\text{Threatened species compliant}}$) and *Threatened species occurrence* ($I_{\text{Threatened species occurrence}}$) indices scores at Gunbower Creek monitoring sites.

6.3.3 Lagoon

Threatened species compliant ($I_{Threatened\ species\ compliant}$); and

Threatened species occurrence ($I_{Threatened\ species\ occurrence}$)

Freshwater Catfish, Un-specked Hardyhead and Murray-Darling Rainbowfish are the only threatened species recorded from the four selected Lagoon sites over the monitoring period. However, over the course of the monitoring period, none of these species have occurred in the number of Lagoon sites expected to indicate their recovery (see *Threatened species compliance* index scores in Table 7).

The threatened species that were recorded in the Lagoon sites in 2016, occurred in about 30% of the sites that they were expected to occur in (Figure 26). The 2016 scores were similar to most other years, but represented a slight reduction from the high reached in 2014.

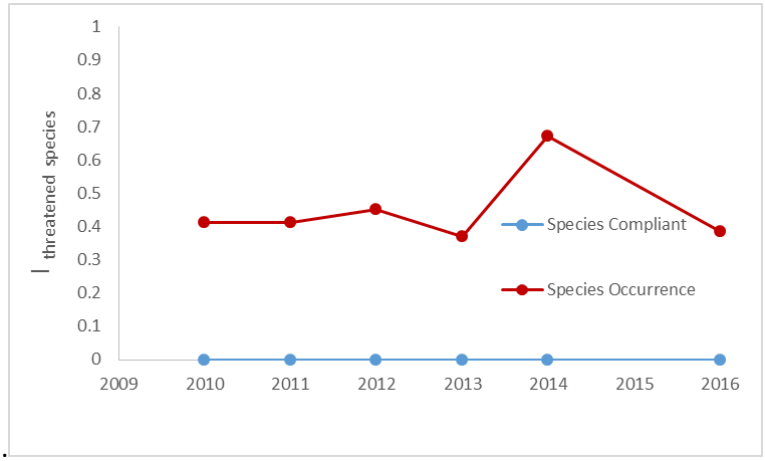

Figure 26 Average *Threatened species compliant* ($I_{Threatened\ species\ compliant}$) and *Threatened species occurrence* ($I_{Threatened\ species\ occurrence}$) indices scores at Gunbower Lagoon monitoring sites.

6.4 Large-bodied fish species catch data summaries

Note that the Catch Per Unit Effort (CPUE) referred to in figures throughout section 6.4 and 6.5, refers to the standard effort used at these macrohabitats (as described in section 4.1 and Table 4).

6.4.1 Bony Herring

Bony Herring have primarily been captured from the Murray River sites, but were also captured in large numbers from Longmore Lagoon (Figure 27). Examination of the raw dataset reveals that recruitment (as indicated by capture of YOY) has been recorded in 2012 and 2014.

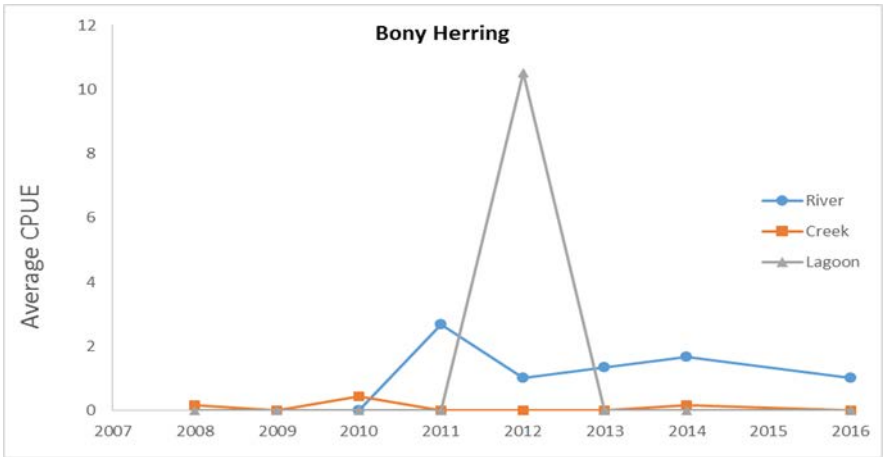

Figure 27 Average CPUE of Bony Herring from River Sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.4.2 Freshwater Catfish

Freshwater catfish have only been recorded from the Lagoon sites, particularly Gum Lagoon, Phyland Lagoon and Turner Lagoon. Examination of the raw dataset reveals recruitment has been detected in 2010 (Turner Lagoon), and 2013 and 2015 (Phyland Lagoon).

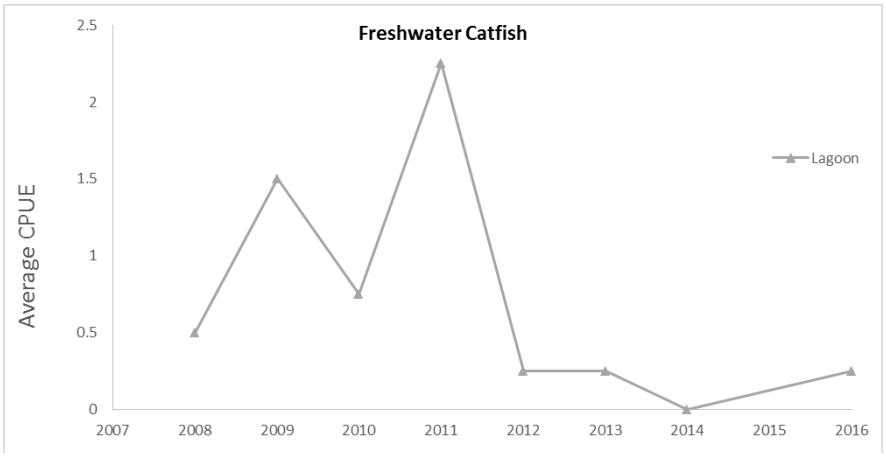

Figure 28 Average CPUE of Freshwater Catfish from four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.4.3 Golden Perch

Golden Perch are typically recorded only from the River and Creek sites. The average abundances recorded from the River sites in 2016 were the highest encountered over the 2008-2016 monitoring period. The raw dataset shows evidence of recruitment (YOY capture) has only been detected in 2013, from one of the Gunbower Creek sites.

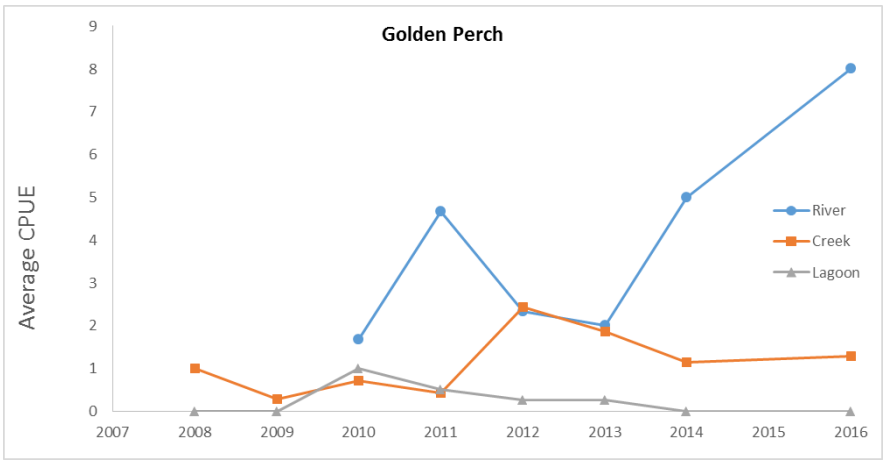

Figure 29 Average CPUE of Golden Perch from River Sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.4.4 Murray Cod

Murray Cod are typically recorded only from the River and Creek sites. The average abundances recorded from both the River and Creek sites in 2016 were the highest encountered over the 2008-2016 monitoring period. The raw dataset shows evidence of recruitment has only been detected at the River sites in 2010 and 2016, and at the Creek sites in 2013, 2014 and 2016.

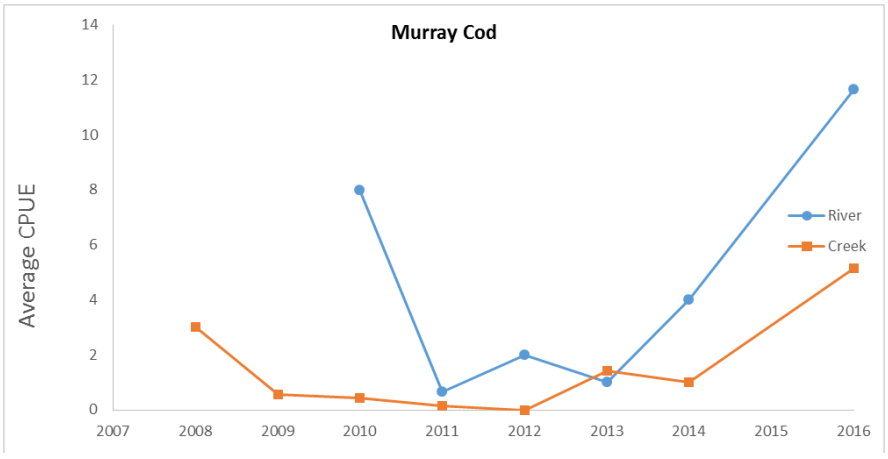

Figure 30 Average CPUE of Murray Cod from River Sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower).

6.4.5 Silver Perch

Silver Perch have only been recorded from the River and Creek macrohabitats. The average abundance recorded from Murray River sites in 2016 is the highest recorded over the monitoring program. The raw dataset shows evidence of recruitment was detected in 2016 (Gunbower Creek) for the first time over the monitoring period.

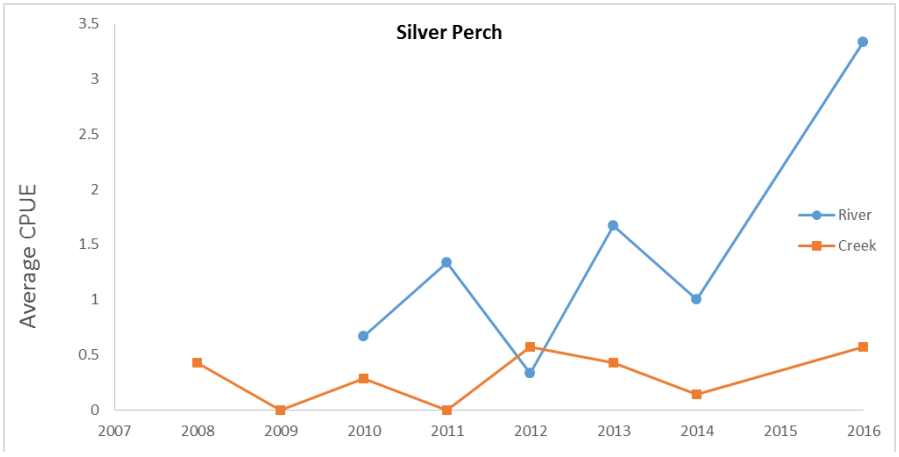

Figure 31 Average CPUE of Silver Perch from River Sites and Creek sites.

6.4.6 Trout Cod

Trout Cod have only been recorded twice over the monitoring period, and only from Gunbower Creek (2008 and 2016). The raw dataset shows no recruitment has been detected.

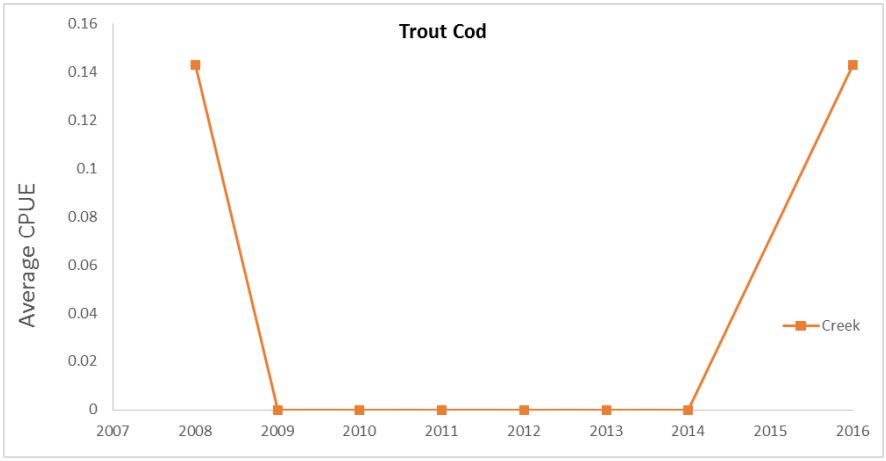

Figure 32 Average CPUE of Trout Cod from Creek sites.

6.4.7 Carp

Carp are typically abundant in all macrohabitats (Figure 33). The raw dataset shows evidence of carp recruitment has been detected every year and from all macrohabitats, but was particularly high in the River and Wetland macrohabitats in 2011.

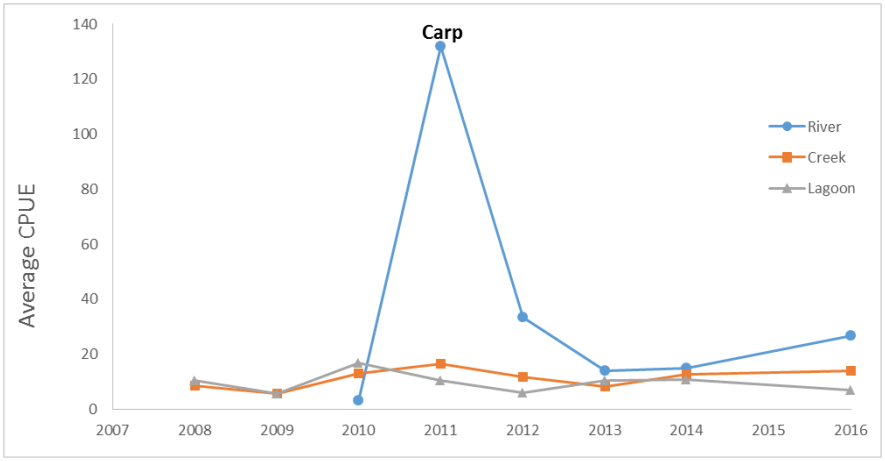

Figure 33 Average CPUE of Carp from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.4.8 Redfin

With the exception of 2011, Redfin tend to be most abundant in Lagoon habitats. The raw dataset shows evidence of Redfin recruitment has only been detected in 2008, all from Lagoon sites. Although it should be noted that 2008 was the only year that sampling took place in December rather than autumn.

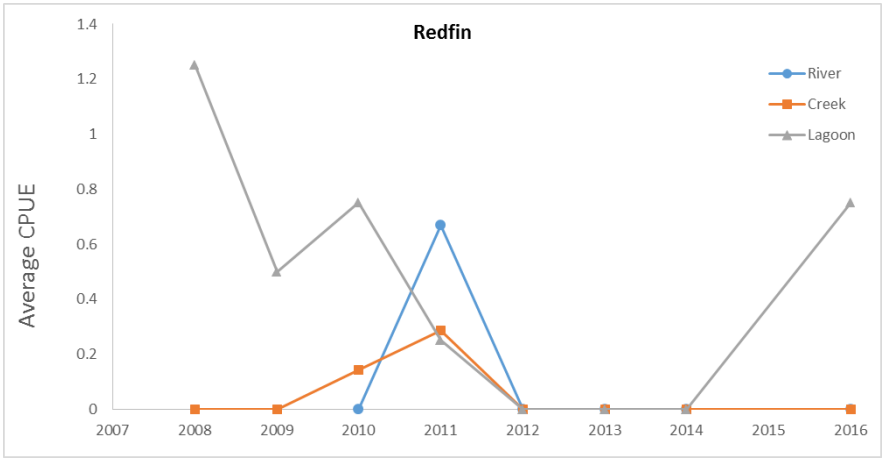

Figure 34 Average CPUE of Redfin from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.4.9 Goldfish

Goldfish have been regularly captured from all macrohabitats and were particularly abundant at Creek sites in 2011. The raw dataset shows Goldfish recruitment has been evident every year and from all macrohabitats, particularly Lagoon and Wetland habitats.

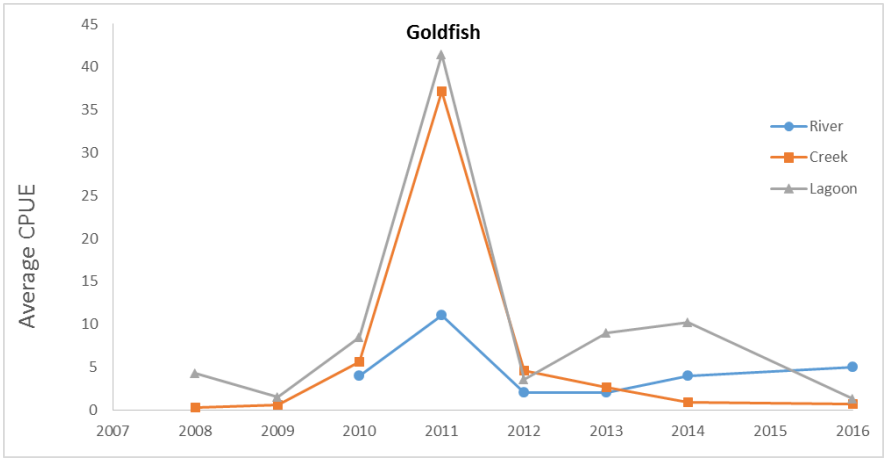

Figure 35 Average CPUE of Goldfish from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.4.10 Oriental Weatherloach

Oriental Weatherloach have been recorded from all macrohabitats, however their abundance appears to have declined since 2008 and the raw dataset shows no evidence of recruitment has been detected since 2010.

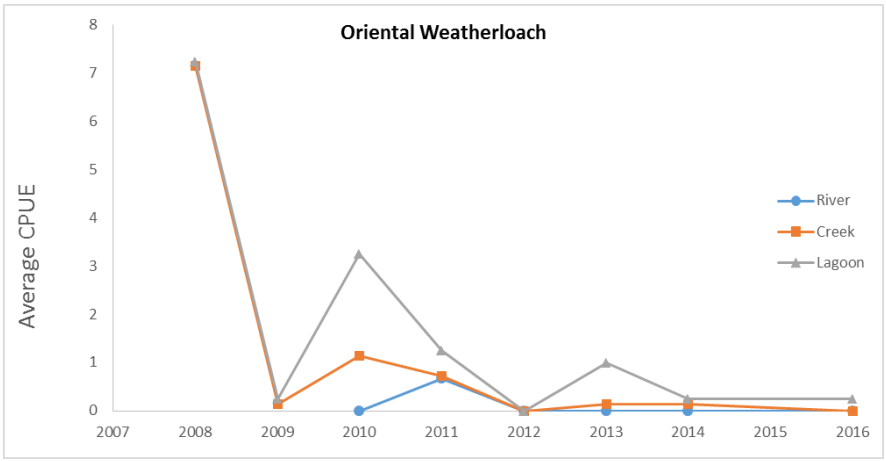

Figure 36 Average CPUE of Oriental Weatherloach from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.5 Small-bodied fish species catch data summaries

6.5.1 Australian Smelt

Australian Smelt are typically abundant in all macrohabitats. The raw dataset shows recruitment has been detected every year and from all macrohabitats, with the exception of the Wetland macrohabitat in 2011 and 2012.

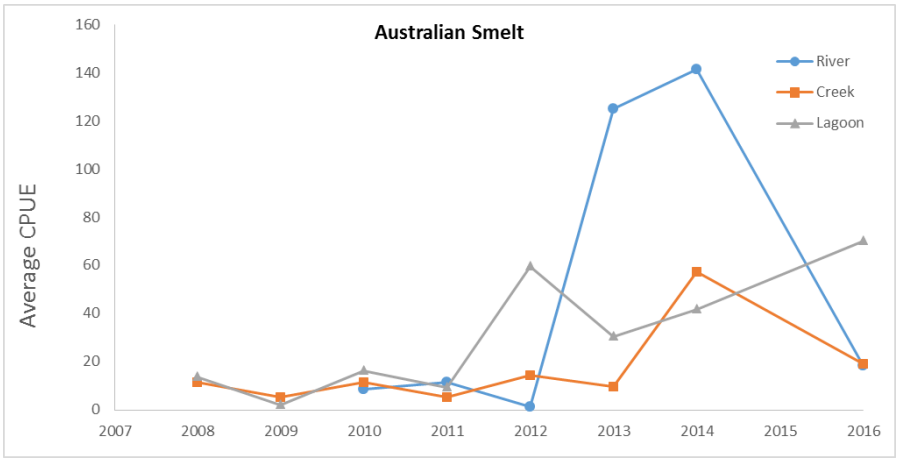

Figure 37 Average CPUE of Australian Smelt from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.5.2 Carp Gudgeon

Carp Gudgeon are typically abundant at all macrohabitats and evidence of recruitment (as evident in raw dataset) has been widespread every year, particularly at Gunbower Creek and Lagoon sites.

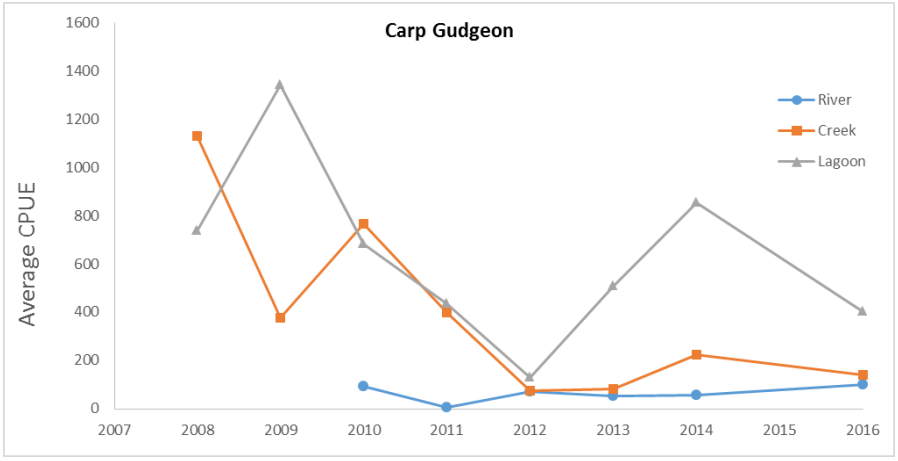

Figure 38Average CPUE of Carp Gudgeon from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.5.3 Dwarf Flatheaded Gudgeon

Dwarf Flatheaded Gudgeon were most abundant in 2010, but have otherwise rarely been recorded, particularly from the Murray River sites. The raw dataset shows evidence of recruitment for this species has been detected from Creek, Lagoon and Wetland sites, most recently from Phyland Lagoon and Gunbower Creek in 2014.

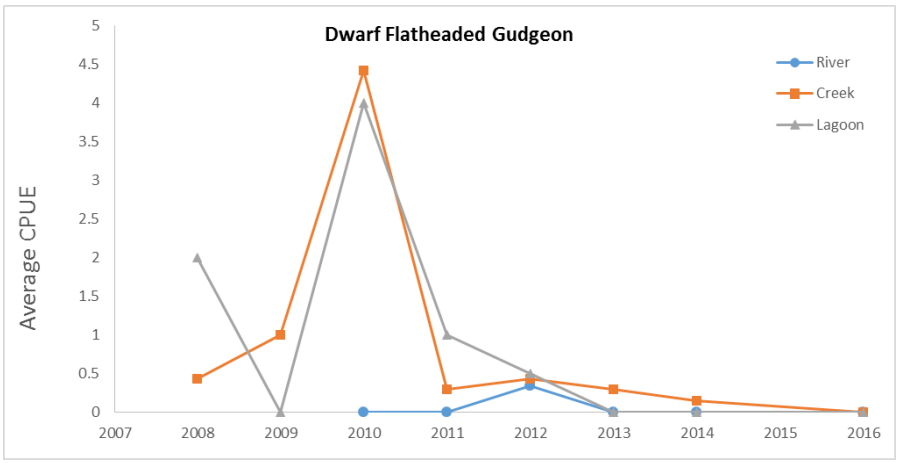

Figure 39 Average CPUE of Dwarf Flatheaded Gudgeon from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.5.4 Flatheaded Gudgeon

Flatheaded Gudgeon are an abundant species in Lagoon habitats, but have rarely been captured from River or Creek habitats since 2010. Flatheaded Gudgeon were abundant in Gunbower Creek in 2008, although that was the only year that sampling occurred in December rather than autumn.

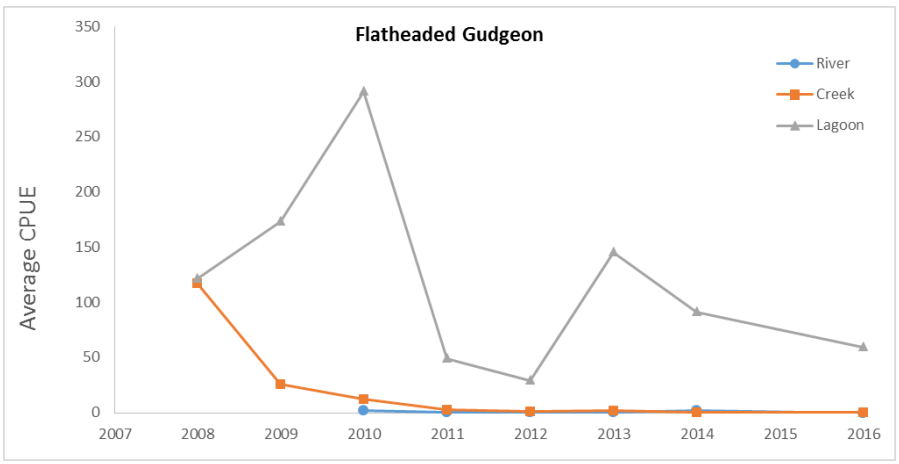

Figure 40 Average CPUE of Flatheaded Gudgeon from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.5.5 Murray-Darling Rainbowfish

Murray-Darling Rainbowfish abundance has fluctuated considerably over time. The raw dataset shows evidence of recruitment has typically been detected annually from all macrohabitats except Wetland.

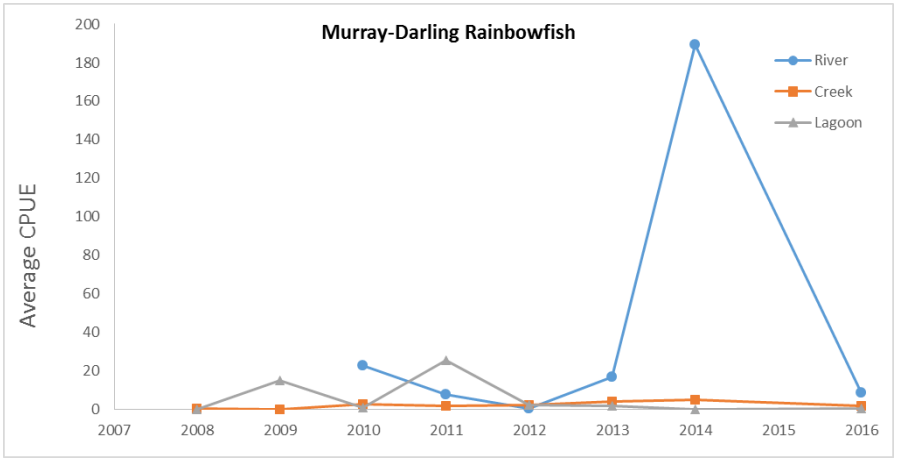

Figure 41 Average CPUE of Murray-Darling Rainbowfish from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.5.6 Unspecked Hardyhead

Unspecked Hardyhead have typically been most abundant at Creek and Lagoon sites. The 2016 average abundance at the four selected Lagoon sites, was much higher than had previously been recorded.

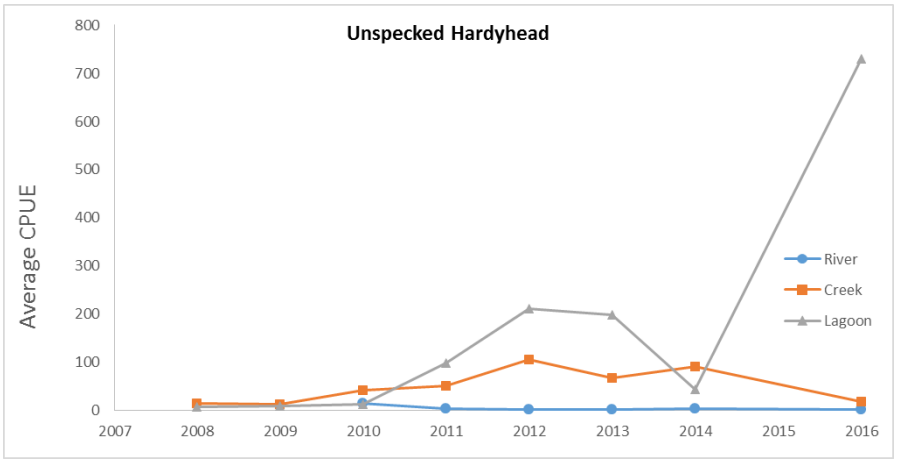

Figure 42 Average CPUE of Unspecked Hardyhead from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

6.5.7 Eastern Gambusia

The average abundance of Eastern Gambusia has generally been highest at Lagoon sites and lowest at River sites, however the species abundance is typically very high at Wetland sites. The raw dataset shows evidence of recruitment is typically detected annually from all macrohabitats.

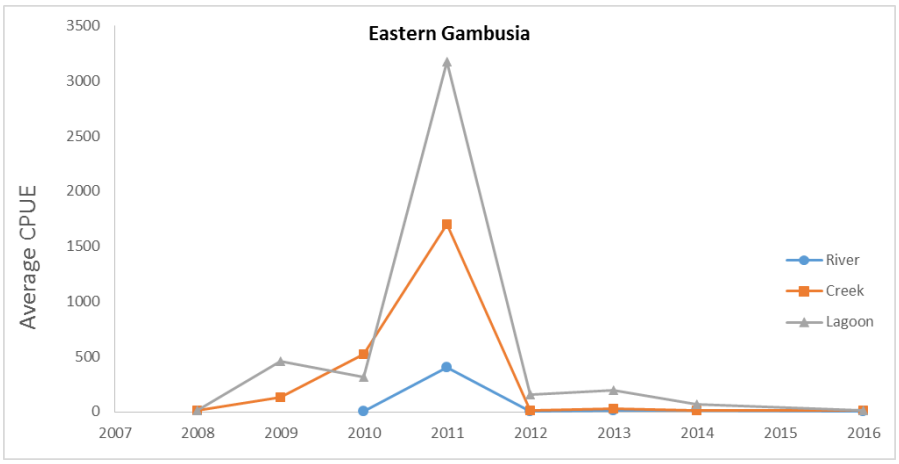

Figure 43 Average CPUE of Eastern Gambusia from River sites, Creek sites and four Lagoon sites (Cockatoo, Phyland, Turner and Gunbower). Note that Lagoon sampling effort was not standardised (i.e. did not include electrofishing) until 2012.

7 Discussion and Conclusion

7.1 2016 condition

In 2016, the Wetland and Lagoon sites were characterised by supporting very high abundances of some small-bodied native fish species such as Carp Gudgeon and Unspecked Hardyhead. The Creek and River sites differed in that they supported a higher proportion of native species. River sites supported the highest proportion of native species that are historically expected to have occurred, and the Wetland sites supported the lowest proportion of native species that are historically expected to have occurred. In particular, the River and Creek sites were the only sites to support 'Long-lived apex predators' (Baumgartner et al 2014) such as Murray Cod, and 'Flow dependent specialists' such as Golden Perch and Silver Perch (Baumgartner et al 2014), whereas, the Lagoon and Wetland sites generally supported small-bodied 'Foraging generalists' (Baumgartner et al 2014). None of the 'Floodplain specialists' species (Baumgartner et al 2014), such as Southern Pygmy Perch *Nannoperca australis* or Flatheaded Galaxias *Galaxias rostratus*, have been recorded during the monitoring program, indicating these species to be either locally extinct or present in exceptionally low abundance.

Recruitment is evident for most native species that are present in the Wetland sites, however the higher scores for the age class and recruitment indices are expected to be an artefact of the low number of native species recorded from this macrohabitat and the broader habitat and spawning requirements of the small-bodied foraging generalist species that predominantly occur. In contrast, some of the large-bodied native species occurring in the Creek and River macrohabitats, such as Golden Perch and Silver Perch, require specific spawning and recruitment conditions (i.e. a flow pulse) to generate a spawning response, and undertake large scale spawning and recolonization migrations that are often impeded by instream barriers. Silver Perch recruitment (one individual) was detected in the Murray River in 2016, the first time recruitment of this species has been detected during the monitoring program. Murray Cod recruitment occurred in both lotic macrohabitats (River and Creek) in 2016, the first time that this has occurred over the duration of the monitoring program.

Indices scores relating to threatened species are particularly low for the Wetland sites, because the sites support so few species and no longer support a range of threatened 'Floodplain specialist' species that are expected to have historically occurred. These include not only the Southern Pygmy Perch and Flatheaded Galaxias, but also the Southern Purple-spotted Gudgeon *Mogurnda adspersa* and the Olive Perchlet *Ambassis agassizii*. The 'River' sites support the highest proportion of historically expected threatened species (e.g. Murray Cod, Golden Perch, Silver Perch, Murray-Darling Rainbowfish and Unspecked Hardyhead), followed by the 'Creek' sites. Notable threatened species captures in 2016 include Freshwater Catfish at Turner Lagoon and Trout Cod from Gunbower Creek.

7.2 Change in condition over time

Over the 2008–2016 monitoring period, the condition of the Gunbower Icon site components (macrohabitats) as indicated by the various indices has fluctuated considerably.

For many of the objectives and indices, particularly those relating to native fish abundance and native fish species richness, there has been a steady improvement in condition over time in the Creek and River macrohabitats, particularly since 2011. Large bodied native fish recruitment in particular appears to have improved since 2013, particularly for Murray Cod. This has reportedly coincided with a concerted effort since 2013 to optimise flow delivery to match the spawning and recruitment requirements of the apex predator guild (Murray Cod and Trout Cod), particularly in mitigating daily flow variability over spring/summer (Sharpe et al 2014).

A fractured population structure for Gunbower Creek Murray Cod had previously been reported for the 2006–2013 monitoring period, with a consistent absence of size classes representative of fish less than 3 years of age (Sharpe et al 2014). The average abundance of Murray Cod was higher in 2016 that in any previous year of the monitoring period for both the River and Creek macrohabitats. Although capture rates remain below those required to reliably assess the population structure, the rates are now sufficient to more reliably estimate it. The Gunbower Creek Murray Cod population now appears well represented by juvenile and sub-adult size classes, and not notably dissimilar to the Murray River population where juvenile and sub-adult size classes clearly dominate.

The capture of Trout Cod in 2016 was only the second time that the species has been detected over the duration of the monitoring program, with the previous capture being from Gunbower Creek in 2008. These captures, together with angling captures reported in Sharpe (2014) indicate the likely persistence of a low-density population.

There has been a slight reduction in native fish abundance over time at the four Lagoon sites (Cockatoo, Phyland, Turner and Upper Gunbower) however the proportion of native fish in these habitats has increased substantially since 2011 due to a large coinciding drop in exotic species abundance (i.e. Carp, Goldfish and particularly Eastern Gambusia). Threatened species occurrence rates have remained comparable over the course of the monitoring period for the Lagoon sites. Although only one Freshwater Catfish was recorded in 2016, the monitoring dataset suggests that a low-density population persists in Turner and Phyland Lagoons, with relatively strong recruitment being evident from Phyland Lagoon in 2015, where five YOY were captured with fine meshed fyke nets. It should be noted that electrofishing capture rates vary between species and sizes (Lyon et al 2014) and that much lower capture efficiencies for some species (e.g. Silver Perch, Freshwater Catfish) are likely to result in the abundance of these species being underestimated.

The Gunbower Icon site supports a relatively diverse fish community. Although caution is advised in examining the dataset for any particular year in isolation, the 2013-2016 period indicates that progress is being made towards many of the objectives and associated targets and none appear to be in decline. The recruitment success of Murray Cod in recent years and likely re-establishment of a healthy population structure is a particular standout, as is the persistence of number of threatened species, albeit in low densities (e.g. Trout Cod in Gunbower Creek and Freshwater Catfish in Phyland Lagoon).

7.3 Objective and target attainment summary

Table 19 Objective attainment summary

Detailed objectives (adapted from DELWP & NCCMA 2015)	Relevant Indices (this report)	Objective attainment
• An increase in the abundance of native fish – using the 2009 abundance as a baseline for Lagoons and the 2010 abundance for the River Murray	• $I_{\text{Native abundance}}$ • $I_{\text{Native species}}$ • $I_{\text{Native expected}}$ • I_{SA}	• River – attained • Creek – attained • Lagoon – partially attained (attained using relative abundance indices) • Wetland – long-term data cannot be assessed
• A range of age/size classes present for each native fish species – evidence of recruitment as indicated by Young of Year (YOY) native fish using the species-specific thresholds identified in Sharpe and Villizi 2014)	• $I_{\text{Age ategory}}$ • $I_{\text{Recruitment}}$ • I_{LBAC} • I_{LBYOY}	• River – attained • Creek – attained • Lagoon – attained (small-bodied fish) • Wetland – attained (small-bodied fish)
• A contribution to population recovery of threatened fish species – recovery inferred by an increase in the abundance of each threatened species from 2009 levels	• $I_{\text{Threatened species compliant}}$ • $I_{\text{Threatened species occurrence}}$	• River – attained • Creek – attained • Lagoon – not attained • Wetland – not attained although long-term data cannot be assessed

Table 20 Target attainment summary

Descriptive targets (adapted from DELWP & NCCMA 2015)	Objective attainment
• At least 4 of the 5 commonly occurring native species (i.e. Carp Gudgeon, Flat-headed Gudgeon, Australian Smelt, Dwarf Flat-headed Gudgeon and Golden Perch) occur in any year.	• Attained (all but Dwarf Flatheaded Gudgeon recorded in 2016)
• At least 3 of the 7 less commonly occurring (i.e. Bony Herring) and/or threatened native species (i.e. Murray-Darling Rainbowfish, Silver Perch, Murray Cod, Trout Cod, Un-specked Hardyhead, Freshwater Catfish) occur in any year.	• Attained (all seven species recorded in 2016)
• A decrease in the abundance of alien fish (i.e. non indigenous to Gunbower Island) since 2009 (Gunbower Creek and Lagoons) and since 2010 (Murray River)	• River – not attained • Creek – attained • Lagoon – attained

7.4 Data analyses issues

Analyses of recruitment and size class related indices could not be included for the Lagoon macrohabitat because of a relative lack of large-bodied species. The other five Lagoon sites could not be included in the analyses due to the lack of temporal continuity, in that they were not sampled in 2015 and were only sampled with fyke nets until 2011 (the other four sites were electrofished).

Similarly, the condition of the Wetland macrohabitats cannot be compared over time because only a proportion of the Wetlands have been sampled in any given year, and the discretionary selection approach is problematic for statistical analysis. This is because it is unclear what the selected wetlands represent with regard to the pool of available wetlands in any given year. For example, it is likely that in some years, the sampled wetlands represent all available wetlands (i.e. the other wetland sites may have been dry), whereas in other years the sampled wetlands may represent the best available wetlands, or a mix of both. Additionally there may be a number of wetlands that are regarded as a lower priority for monitoring, with these wetlands being added or withdrawn from the annual sampling mix on an ad hoc basis. This inconsistency precludes any meaningful comparison between years at the macrohabitat scale, because with sites having unequal and unknown 'weights' in the analyses, it is not possible to calculate any totals or averages or proportions. The condition of individual wetlands can however, be examined over time, although they are not capable of providing data that can be used for Icon site scale reporting purposes.

Inconsistencies in the small-bodied fish length dataset were problematic for efficient analyses of recruitment and size class indices for the long-term dataset. Total Length (TL) and Standard Length (SL) were used up until 2014, however Total Length and Caudal Fork Length (LCF) were used from 2015 onwards (C Sharpe pers. comm. 2016). Conversions factors therefore need to be applied to parts of the dataset in order to achieve consistency and enable valid comparison against relevant size thresholds (Table 5). Additionally, there are a hundreds of erroneous length measurements, on the basis that the Fork Length/Standard Length values for individual fish are larger than the Total length values. Analysis of this component of the dataset therefore requires a significant amount of data conversion and additional cleaning, that should be included in subsequent years of reporting. Thus, in the current report, we only look at large-bodied species for long-term recruitment, but all species for current recruitment indices.

The use of 2008 data as a point of reference for Lagoon and Creek sites as stipulated in the Condition Monitoring Plan (DELWP & NCCMA 2015) was problematic due to this being the only year that sampling occurred in December, rather than autumn. Any differences observed between 2008 data and other data would therefore be confounded by seasonal differences including implications for YOY detection, and potential implications in terms of capture efficiency (typically reduced under high turbidity and water levels)(Lyon et al 2014), fish abundance and distribution. Rehwinkle and Sharpe (2009) demonstrated considerable differences in Gunbower Creek large-bodied species abundance between spring 2008 and autumn 2009. For condition reporting purposes, it is therefore more appropriate to treat 2008 as pilot study data and exclude it from analyses, using 2009 as the point of reference year.

8 Recommendations

The following recommendations are made:

- Manage data quality and streamline the calculation of indices with the use of the database management system developed as part of this project;
- Include long-term analyses of recruitment and age class indices for small-bodied species in future reports, and increase consistency between the Objective 2 indices calculations for the current year and the long-term indices calculations;
- Include long-term analyses of 2015 Lagoon data in future reports;
- Revise the PERCH list derived for the Koondrook Perricoota Forest by NSW Fisheries (Hohnberg et al 2015). At a minimum, Dwarf Flatheaded Gudgeon should be assigned a rarity score of 1 for 'semi-permanent' habitats;
- Develop a consistent and statistically sound approach to the selection of Wetland sites for sampling in any given year;
- For condition monitoring purposes, continue to exclude the 2008 seasonally confounded data from analyses and use 2009 as the alternative point of reference;
- Ensure that a consistent approach is used for fish measurements. It is suggested that Total Length (TL) be used for round-tailed species and Caudal Fork Length (LCF) be used for fork-tailed species (for individuals with damaged tails, measure Standard Length and estimate TL or LCF and flag as an estimate). These can be clearly identified in the database;
- Ensure that a consistent approach is used for labelling of 'observed' individuals. It is suggested that this be used for individuals that were observed but not captured, either missed or not netted for other reasons (e.g. animal ethics considerations when encountering a large school of Australian Smelt). That is, fish collected in a shot or a net but not measured should be counted as caught;
- Consider limiting the length or area of the sampling reach (e.g. 500 m), particularly for River and Creek habitats; and
- Several of the indices included in this report have been used for the first time, and would benefit from review of their statistical properties (e.g. an evaluation of sensitivity and power).

9 References

Baumgartner L, Conallin J, Wooden I, Campbell B, Gee R, Robinson W, Mallen-Cooper M (2014). Using flow guilds of freshwater fish in an adaptive management framework to simplify environmental flow delivery for semi-arid riverine systems. Fish and Fisheries, 2014, 15, 410–427.

DELWP and NCCMA (2015). The Living Murray Condition Monitoring Plan: Gunbower Icon Site. Document prepared for the Murray-Darling Basin Authority Department of Environment, Land, Water

Hale, J. and Butcher, R., (2011). Ecological Character Description for the Gunbower Forest Ramsar Site. Report to the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), Canberra.

Lyon J., Bird, T., Nicol S., Kearns J., Mahony J., Todd C., Cowx I., Bradshaw C. (2014). Efficiency of electrofishing in turbid lowland rivers: implications for measuring temporal change in fish populations. Can. J. Fish. Aquat. Sci. 71: 878–886 (2014)

Mallen-Cooper M, Stuart I G, Sharpe C (2014). The Native Fish Recovery Plan - Gunbower & Lower Loddon. Report prepared for the North Central Catchment Management Authority. 156p.

PIRVic (2007). Report of a Fish Survey of the Gunbower Creek. Undertaken for North Central CMA by Primary Industries Research Victroria 30/6/2007

Raadik, T., Lieschke, J., (2010). PERCH lists (pre european reference condition of fish), working document. ARI Freshwater Ecology. Heidelburg, Arthur Rylah Institute for Envirnomental Research

Rehwinkel, R. and Sharpe, C (2009). *Gunbower Forest Fish Monitoring Surveys 2008/2009*. Report prepared for The North Central Catchment Management Authority by The Murray-Darling Freshwater Research Centre. June 2009. 57pp

Richardson A, Meredith S, Conallin A, Sharpe C (2005). Status of the Gunbower Island Fish Community, June 2005 Including recommendations for future monitoring. An MDFRC Consultancy Report for the North Central Catchment Management Authority

Robinson WA (2012) Calculating statistics, metrics, sub-indicators and the SRA Fish theme index: A Sustainable Rivers Audit Technical report. Report to the Murray-Darling Basin Authority, 4th April 2012.

Robinson W A (2014) The Living Murray Condition Monitoring Plan Refinement Project: Summary Report. Technical Report to the MDBA, March 2015. 95 pp.

Robinson (2015). Summary of mechanisms for reporting against objectives. November 2015. Technical note to NCCCMA. Wayne Robinson November 2015.19 pp.

Hohnberg et al (2015) Koondrook-Perricoota Forest Icon Site: Fish Condition Monitoring 2015 Annual Report. David Hohnberg, Peter Graham, Martin Asmus and Wayne Robinson.Prepared by: David Hohnberg, Peter Graham, Martin Asmus and Wayne Robinson. Reviewed by:

Dean Gilligan. Department of Primary Industries. Fisheries Research. Port Stephens Fisheries Institute. Date: July 2015. 44 p.

Sharpe, C, Vilizzi, L, and Campbell-Brown, S (2014). Gunbower Island Annual Fish Surveys: 2014. Report for the North Central Catchment Management Authority by CPS Enviro. 72pp

Sharpe and Vilizzi (2014). Development of Ecological Indices for Gunbower Icon Site Fish Component TLM Monitoring Plan Refinement Project. CPS Environmental Research.

Young W J, Scott A C, Cuddy S M and Rennie B A (2003). Murray Flow Assessment Tool – a technical description. Client Report, 2003. CSIRO Land and Water, Canberra

Appendix 1 Index calculation examples

2016 Calculations:

Consider the following raw data extract from Cockatoo Lagoon in 2008 (there were 659 fish recorded):

Site Name	Year	Method	Name Common	Length mm
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	42
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	43
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	47
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	45
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	40
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	40
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	47
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	45
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	51
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	44
Cockatoo Lagoon	2008	SMFYKE	Un-specked Hardyhead	33
…				
Cockatoo Lagoon	2008	SMFYKE	Flathead Gudgeon	50
Cockatoo Lagoon	2008	SMFYKE	Flathead Gudgeon	54
Cockatoo Lagoon	2008	LGFYKE	Murray-Darling Rainbowfish	.

These data can be summarized to catch records per species:

Common name	Status	not measured	measured	Total
AUSTRALIAN SMELT	Native	0	3	3
CARP GUDGEON	Native	465	100	565
DWARF FLATHEAD GUDGEON	Native	0	11	11
EASTERN MOSQUITOFISH	Alien	0	30	30
EUROPEAN PERCH	Alien	0	2	2
FLATHEAD GUDGEON	Native	0	12	12
MURRAY-DARLING RAINBOWFISH	Native	1	0	1
UN-SPECKED HARDYHEAD	Native	0	35	35
Total Fish		466	193	659

Objective 1: Abundance of native fish species

- $I_{native\ abundance}$ = the proportion of fish abundance in each site that are native

  All data are used. In the above example there are 32 alien fish (30 mosquito fish + 2 European perch) out of a total of 659 fish.

  $I_{native\ abundance}$ = 627/659 = 0.95

- $I_{native\ species}$ = the proportion of fish species in each site that are native

  In Cockatoo Lagoon in 2008 there were 8 species collected in total and 6 of these were native

  $I_{native\ species}$ = 6/8 = 0.75

- $I_{expected\ species}$ = the proportion of historically expected native species present in each site.

  This is a lagoon site, which is classified as a semi-permanent habitat, and so we would expect an average of 7.15 of the species listed in Table 5 to be present in sites in these habitats (see last row of table 5 for the reference value of 7.15).

  Of the 6 native species collected in this site in 2008, 5 of them are in the list (Table 5).

  $I_{expected\ species}$ = 5/7.15 = 0.70

  Note that a native species, Dwarf Flathead Gudgeon, was collected in this site but is not included in the calculation for this index as it is not on the expected list.

Objective 2: Size classes of native species

$I_{age\ category}$ = the proportion of native fish species age categories present compared to the reference value for that macrohabitat.

Using the above Cockatoo Lagoon data in 2008 as an example, there were 193 measured fish (note that the one Murray Rainbow fish collected but not measured is not used in the calculations).

A summary of the number of measured native fish in each age class;

Common name	YOY	Adult	Total
AUSTRALIAN SMELT	3	0	3
CARP GUDGEON	52	48	100
DWARF FLATHEAD GUDGEON	0	11	11
FLATHEAD GUDGEON	1	11	12
UN-SPECKED HARDYHEAD	8	27	35
Total	64	97	161

And there are 8 native fish age categories present (Smelt and Dwarf Flatheaded Gudgeons only have 1 age class present, the rest have 2). This is compared to the reference number of native species age categories present for Lagoon habitats (Table 6) of 9.

$I_{age\ category} = 8/9 = 0.889$

$I_{recruitment}$ = the proportion of native fish species present that had YOY × (the number of native species collected ÷ the best achievable number of species collected for that macrohabitat).

In this example, 3/5 native species measured had YOY, there were 5 native species measured, and the best achievable number of native species collected for this habitat is 6 (Table 6).

$I_{recruitment} = 3/5 \times 5/6 = 0.500$

Objective 3: Threatened native fish species

$I_{\text{Threatened species present}}$ = The number of threatened species present ÷ expected number present for each site.

For the current example, only Un-specked Hardyhead and Murray Darling Rainbow fish are on the recorded and predicted threatened species list (Table 7). The expected number of threatened species present for 'semi-permanent habitat' site (using only extant species) is 3.25 (Table 7).

$I_{\text{Threatened species present}} = 2/3.25 = 0.615$

$I_{\text{Threatened species occurrence}}$ = The average proportion of sites that the threatened species occur in for that habitat

Note that this Index is calculated for the entire habitat. All other indices are calculated at the individual sampling site scale.

In 2008 there were 9 lagoon sites sampled, with three threatened species collected (Table below). The number of lagoons that all extant species (those collected since 2008 TLM monitoring began) are counted and the proportion of lagoons containing the species is the raw score. These scores are then adjusted for the rarity of each species based on the PERCH scores (Table 7).

Threatened Species	Lagoons occurred in	Lagoons sampled	Lagoon raw score	Adjusted Lagoon Score
FRESHWATER CATFISH	2	9	0.222	0.494
GOLDEN PERCH	0	9	0.000	0.000
MURRAY COD	0	9	0.000	0.000
MURRAY-DARLING RAINBOWFISH	1	9	0.111	0.131
SILVER PERCH	0	9	0.000	0.000
TROUT COD	0	9	0.000	0.000
UN-SPECKED HARDYHEAD	8	9	0.889	1.000
Average score				**0.233**

The lagoon habitat assessment score is then calculated as the average of the adjusted habitat scores for the year. In this case, the average lagoon score in 2008 was 0.233.

$I_{\text{Threatened species occurrence}} = \{0.494 + 0.000 + 0.000 + 0.131 + 0.000 + 0.000 + 1.000]/6 = 0.233$

This habitat wide index is in development and there are three potential ways to calculate the habitat score, depending on which species are included in the calculations. Note that only Method 2 has been used for this report.

Method 1. Only include threatened species that occurred in the year. That is the index can be interpreted as "how well are those that are present doing?". (For above data = 0.406)

Method 2. Include only threatened species that have occurred since TLM monitoring began. This index can be interpreted as “how well are extant threatened species doing?”. For above data, $I_{\text{Threatened species occurrence}} = 0.233$

Method 3. Include all threatened species in the list (Table 7). That is the index can be interpreted as “how well are threatened species doing compared to historical predictions?”. (For above data = 0.125)

Long-Term Indices calculations:

To demonstrate these indices, the data from Gunbower Creek in 2011 has been used.

Objective 1: Abundance of native fish species

Note that for this index, only averages are used. In 2011, there were the usual 7 Creek sites sampled and the average abundance for each species as well as the baseline (2008 used in this example, however 2009 should be used in all future calculations) average abundances are first compared. Abundances greater than the 2008 score 1, and abundances less than 2008 score -1.

The first step is to calculate the reference scores for each species. The example here shows how the reference for Australian Smelt was calculated. Note that sites where the species were not collected in either the current year of in the reference year must be given an abundance of zero before calculating the average.

	REACH	REACH	REACH	REACH	REACH	REACH	REACH	Creek Average
AUSTRALIAN_SMELT	1	2	3	4	5	6	7	CPUE
2008	30	5	9	2	32	2	0	11.43
2011	6	14	9	2	0	0	5	5.14

The 2008 example reference points (note 2009 should be used) for all Gunbower Creek species, as well as the average abundances in 2011 are given in table below, and separate indices can be calculated as the averages for aliens and for natives. Note that there are no new native species from 2008, but that a new alien species, contributes to the alien index.

species	type	2011	2008	Difference	2011 Species ISA
COMMON CARP	Alien	16.29	8.57	7.71	1
EASTERN MOSQUITOFISH	Alien	1705.86	9.14	1696.71	1
EUROPEAN PERCH	Alien	0.29	0.00	0.29	1
GOLDFISH	Alien	37.14	0.29	36.86	1
ORIENTAL WEATHERLOACH	Alien	0.71	7.14	-6.43	-1
AUSTRALIAN SMELT	Native	5.14	11.43	-6.29	-1
BONY HERRING	Native	0.00	0.14	-0.14	-1
CARP GUDGEON	Native	399.00	1133.14	-734.14	-1
DWARF FLATHEAD GUDGEON	Native	0.29	0.43	-0.14	-1
FLATHEAD GUDGEON	Native	2.71	117.71	-115.00	-1
GOLDEN PERCH	Native	0.43	1.00	-0.57	-1
MURRAY COD	Native	0.14	3.00	-2.86	-1
MURRAY DARLING RAINBOWFISH	Native	1.71	0.14	1.57	1
SILVER PERCH	Native	0.00	0.43	-0.43	-1
TROUT COD	Native	0.00	0.14	-0.14	-1
UN SPECKED HARDYHEAD	Native	50.43	13.29	37.14	1

$I_{SA\ native}$	-0.636
$I_{SA\ alien}$	0.600

I_{NSA} = Average status of native species CPUE for native fish species present in 2011 = -0.636

I_{ASA} = Average status of alien species CPUE for native fish species present in 2011 = 0.600

Objective 2: Size classes of large-bodied native species

I_{LBAC} = Average number of Murray Cod and Golden Perch YOY, Sub-adult, and adult age categories present ÷ 5

For every Murray Cod or Golden Perch in the data set that has a total length measurement, determine which age category they are in according to the lengths provided by Sharpe and Villizi (2014) and listed in Table 5.

Murray Cod YOY is <= 115mm, Sub adult is <= 425, Adults are > 425 mm

Golden Perch YOY is <= 118mm, Sub adult is <= 268, Adults are > 268 mm.

The value of 5 is used because even though it is possible (and has occurred in the data) for all 6 age categories to be present, it is unlikely to always be detected. That is, the sampling protocol is not perfect, not all fish are collected, not all those collected are measured, and thus even if a site has all 6 age categories present, it may not return a count of 6. Thus, a conservative reference value of 5 is chosen to account for sampling inefficiencies. This index is still subject to review and refinement.

There were only two adult Golden Perch and Murray Cod collected across all Creek sites in 2011.

	Golden Perch				**Murray Cod**				
	YOY	**Sub Adults**	**Adults**	**Not measured**	**YOY**	**Sub Adults**	**Adults**	**#Age categories present**	**Site sub index (# ÷ 5)**
REACH 1			1					1	0.2
REACH 2								0	0
REACH 3								0	0
REACH 4				(2)			1	1	0.2
REACH 5								0	0
REACH 6								0	0
REACH 7								0	0
GPYOY subindex	**0.00**			**MC YOY sub index**	**0.00**			**Site LBAC index**	**0.057**

From these results, it can be seed that in 2011, five of the sites scored 0, and the other two sites had only 1 age category present, scoring 0.2 when compared to the reference of 5. Note that even though the unmeasured fish in Reach 4 must have fit into one of the three age categories, they are not included in the calculations.

I_{LBAC} = Average of [0.2, 0.0, 0.0, 0.2, 0.0, 0.0, 0.0] = 0.057

I_{LBYOY} = average proportion of (creek or river) sites containing Murray cod and Golden Perch YOY

From the above data it is clear that there were no sites that had YOY for either of Golden Perch or Murray Cod in 2011, hence the respective sub-indices are 0/7 and 0/7 = 0.00.

I_{LBYOY} = average of (0.00, 0.00) = 0.00

Objective 3: A contribution to population recovery of threatened fish species

The threatened species occurrence is the same as the one calculated for the 2016 data, provided 'Method 2' is used. This means that species not recorded since TLM condition monitoring began are not included. For example, there have been no catfish recorded in Creek habitats, so they are not included in the creek assessments.

The Index of Threatened Species Compliance simply determines how many of the threatened species occur in the desired number of sites and includes all seven species in Table 7.

These indices are both easily calculated after counting how many sites each species occurs in within the macrohabitat. The complete dataset for Creek habitats are summarised in the following table.

Sites Occurred in	PERCH	2008	2009	2010	2011	2012	2013	2014	2016
GOLDEN PERCH	0.45	4	2	1	2	5	4	4	4
MURRAY COD	0.45	5	2	2	1	0	4	5	6
MURRAY-DARLING RAINBOWFISH	0.85	1	0	5	3	4	6	7	3
SILVER PERCH	0.1	2	0	1	0	3	3	1	1
TROUT COD	0.1	1	0	0	0	0	0	0	1
UN-SPECKED HARDYHEAD	0.85	6	7	7	5	6	6	5	6
FRESHWATER CATFISH	0.45								

So, in 2008 (included here as an example only - 2008 data has been excluded from analysis) Golden Perch occurred in 4 Creek sites, and they are expected to occur in 0.45 of semi-permanent habitat sites. Given that there were 7 Creek sites sampled in 2008, the score is:

Sub Index = sites ÷ expected sites. For Golden Perch in 2008 = 4 ÷ (7 × 0.45) = 1.27.

Note that this sub-index score is ceiled at 1.00.

So, for all the data in the above table we get the following table of species sub-indices. These are then summarised into the two indices at the bottom of the table.

Subindex	2008	2009	2010	2011	2012	2013	2014	2016
GOLDEN PERCH	1.00	0.63	0.32	0.63	1.00	1.00	1.00	1.00
MURRAY COD	1.00	0.63	0.63	0.32	0.00	1.00	1.00	1.00
MURRAY-DARLING RAINBOWFISH	0.17	0.00	0.84	0.50	0.67	1.00	1.00	0.50
SILVER PERCH	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00
TROUT COD	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
UN-SPECKED HARDYHEAD	1.00	1.00	1.00	0.84	1.00	1.00	0.84	1.00
FRESHWATER CATFISH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average score = Index of Threatened species occurrence	**0.861**	**0.378**	**0.632**	**0.383**	**0.612**	**0.833**	**0.807**	**0.917**
Index of Threatened species compliance	**0.714**	**0.143**	**0.286**	**0.000**	**0.429**	**0.714**	**0.571**	**0.714**