



Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2013–2014)

Report to the Murray–Darling Basin Authority and the South Australian Department for Environment, Water and Natural Resources

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June 2014



This report may be cited as:

Wedderburn, S. and Barnes, T. (2014). Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2013–2014). The University of Adelaide, Adelaide, 71.

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Cover Image: Murray hardyhead, Dog Lake, retrieving fyke net, Yarra pygmy perch.

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Summary

Habitats fringing Lake Alexandrina and Lake Albert (the 'Lower Lakes'), at the terminus of the Murray–Darling Basin (MDB), harbour three threatened small-bodied fish species. Murray hardyhead *Craterocephalus fluviatilis* and Yarra pygmy perch *Nannoperca obscura* are 'Endangered' and 'Vulnerable', respectively, under the federal *Environment Protection and Biodiversity Conservation Act 1999*. Southern pygmy perch *N. australis* is 'Endangered' in South Australia. All were abundant in regions of the Lower Lakes, especially the Hindmarsh Island area, before their populations collapsed in the latter stages of the 1997–2010 drought.

Severe water level recession in the Lower Lakes during drought led to the desiccation of fringing habitats that were required for the threatened fishes. Consequently, Yarra pygmy perch and southern pygmy perch became regionally extinct. A population of Murray hardyhead persisted in a drought refuge on Hindmarsh Island because of environmental water allocations. The fish dispersed following the return of substantial river flows in 2010. Later, six fish were captured at a nearby location in November 2010, but then the species was undetected until 2012. In efforts to assist the population recovery of the threatened fishes, there were reintroductions to the Lower Lakes between 2011 and 2013 from captive stock.

The Murray–Darling Basin Authority has funded, through The Living Murray (TLM) program, the condition monitoring of the three threatened fish populations in the Lower Lakes since 2005. It is directed by the Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Target F2 of "improved spawning and recruitment success in the Lower Lakes for endangered fish species including Murray hardyheads (*Craterocephalus fluviatilis*) and pygmy perch (*Nannoperca* sp.)". This report presents the results of TLM condition monitoring in November 2013 and March 2014. The main objectives of this study were to re-examine or locate populations of the three threatened fish species at the Lower Lakes and establish if they successfully recruited over 2013–14.

In the 2013–14 TLM condition monitoring, all three threatened fish species were captured in the Lower Lakes. In regards to Yarra pygmy perch and southern pygmy perch, this was solely because of reintroductions. Murray hardyhead was the only threatened fish species to show substantial levels of recruitment in the Lower Lakes to meet the aims of the Target. The species appears to be naturally recolonising two areas of the Lower Lakes (Goolwa Channel and Dog Lake). There was limited evidence of localised recruitment for a precarious southern pygmy perch population on Mundoo Island. More critically, there was no evidence of recruitment for Yarra pygmy perch.

The return of a self-sustaining population of Murray hardyhead somewhat signifies ecological recovery in the Lower Lakes following the prolonged drought. The lack of captures and recruitment in the Yarra pygmy perch population indicate that reintroduction attempts have failed. Additional reintroductions are required to meet the Target. The remaining population of southern pygmy perch should be carefully monitored, and greater protection should be afforded. An increased understanding of the factors that drive and impact on recruitment and dispersal of the threatened fishes is required so that the Target, and objectives of national recovery plans for Murray hardyhead and Yarra pygmy perch, can be achieved through informed management.

Introduction

Lake Alexandrina and Lake Albert (the 'Lower Lakes') are shallow waterbodies covering over 75,000 hectares at the terminus of the Murray–Darling Basin (MDB) (Eastburn 1990). A range of habitats fringe the Lower Lakes, including stream, river, swamp, wetland, lake and brackish water areas (estuarine conditions). The broad characteristics of Lake Albert differ somewhat from Lake Alexandrian, because it is a terminal lake (e.g. higher salinity). The Lower Lakes harbour the most diverse fish community in the MDB, because they are inhabited by estuarine, diadromous and freshwater fishes. Of particular interest are three threatened small-bodied (<10 cm long), short-lived species that are ecological specialists, namely Murray hardyhead *Craterocephalus fluviatilis*, Yarra pygmy perch *Nannoperca obscura* and southern pygmy perch *N. australis* (Wedderburn and Hammer 2003; Wedderburn et al. 2012a).

The genetically distinct population of Yarra pygmy perch occurred nowhere else in the MDB (Hammer et al. 2010). Populations persist in other catchments, but the species became extinct in the MDB during the 1997–2010 drought (Wedderburn et al. 2012a; Wedderburn et al. 2014). It is 'Vulnerable' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and 'Critically Endangered' in South Australia (Hammer et al. 2009), due to population decline and regional extinctions (Wager and Jackson 1993; Saddler et al. 2013).

Southern pygmy perch is 'Endangered' in South Australia and 'Protected' under the *Fisheries Management Act 2007* (Hammer et al. 2009). Importantly, the southern pygmy perch population in the Lower Lakes is genetically unique from other populations in Australia (Unmack et al. 2013). The species became extinct in the Lower Lakes during the drought (Wedderburn et al. 2014). Populations persisted in adjoining tributaries of the Lower Lakes (Hammer et al. 2012), thereby providing the possibility of natural recovery.

Murray hardyhead is endemic to the MDB, occurring in fragments upstream from Kerang in Victoria to downstream approximately 2000 km in the Lower Lakes. The small population fragments in the lower River Murray, South Australia, include isolates near Berri and Murray Bridge (Wedderburn et al. 2007). Notably, the Lower Lakes population of Murray hardyhead is genetically distinct from populations upstream of Lock 1 in Blanchetown (Adams et al. 2011). It is 'Critically Endangered' in South Australia (Hammer et al. 2009) and 'Endangered' under the *EPBC Act* because of severe population decline and localised extinctions during the drought. Substantial effort was made during the drought to maintain each genetic management unit in a captive breeding program (Ellis et al. 2013; Bice et al. 2014). Likewise, a population of Murray hardyhead was conserved in a drought refuge of the Lower Lakes using environmental water allocations (Wedderburn et al. 2010; Wedderburn et al. 2013).

In an effort to assist the population recovery of four threatened small-bodied fish species following drought, there were reintroductions to the Lower Lakes from a captive maintenance program (see Bice et al. 2014). Several thousand Murray hardyhead, southern pygmy perch, Yarra pygmy perch and southern purple-spotted gudgeon (*Mogurnda adspersa*) were released into potentially suitable habitats between 2011 and 2013. The Critical Fish Habitat (CFH) project (previously the Drought Action Plan (DAP)) was part of the State Government's Murray Futures program, and was funded by the federal Department of Sustainability, Environment, Water, Populations and Communities' Water for the Future initiative. The main

objective of the CFH project was to support the establishment of self-sustaining populations of small-bodied threatened fishes in the Lower Lakes.

The Murray–Darling Basin Authority has funded, through The Living Murray (TLM) program, the condition monitoring of the three threatened fish species at the Lower Lakes since 2005 (Bice et al. 2008; Bice and Ye 2006; Bice and Ye 2007; Wedderburn and Barnes 2009; Wedderburn and Barnes 2011; Wedderburn and Barnes 2012; Wedderburn and Barnes 2013; Wedderburn and Hillyard 2010). It is directed by the Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Target F2 of “improved spawning and recruitment success in the Lower Lakes for endangered fish species including Murray hardyheads (*Craterocephalus fluviatilis*) and pygmy perch (*Nannoperca* sp.)” (Maunsell 2009). This report presents the results of TLM condition monitoring in November 2013 and March 2014. The main objectives of this study were to re-examine or locate populations of the three threatened fish species at the Lower Lakes and establish if they successfully recruited over 2013–14. The results are also compared with previous condition monitoring data to describe 6-year population and habitat trends at sites that hold, or previously held, the three threatened fish species. The study also examines general shifts in fish assemblages and habitat over the last several years.



Point Sturt in March 2010 (left) when water level in Lake Alexandrina was approximately -1 m AHD during the millennium drought, and in March 2013 (right) at approximately 0.75 m AHD.



Dunn Lagoon in March 2009 during the millennium drought (left) and re-established habitat in March 2014 (right).

Materials and methods

Sampling sites

Twenty-four sites were sampled in November 2013 and re-sampled in March 2014 (Figure 1; Table 1). Data for six additional locations (sites 3, 5, 14, 18, 37 and 38) were supplied by SARDI Aquatic Sciences and Aquasave (Bice et al. 2014). This is a continuation of data sharing between TLM condition monitoring and the CFH project, which increases the coverage of information regarding fish assemblages and habitat at the Lower Lakes. The reports by Bice et al. (2012), Bice et al. (2013) and Bice et al. (2014) include further information regarding fish releases, monitoring and habitat at CFH project sites (Table 2).

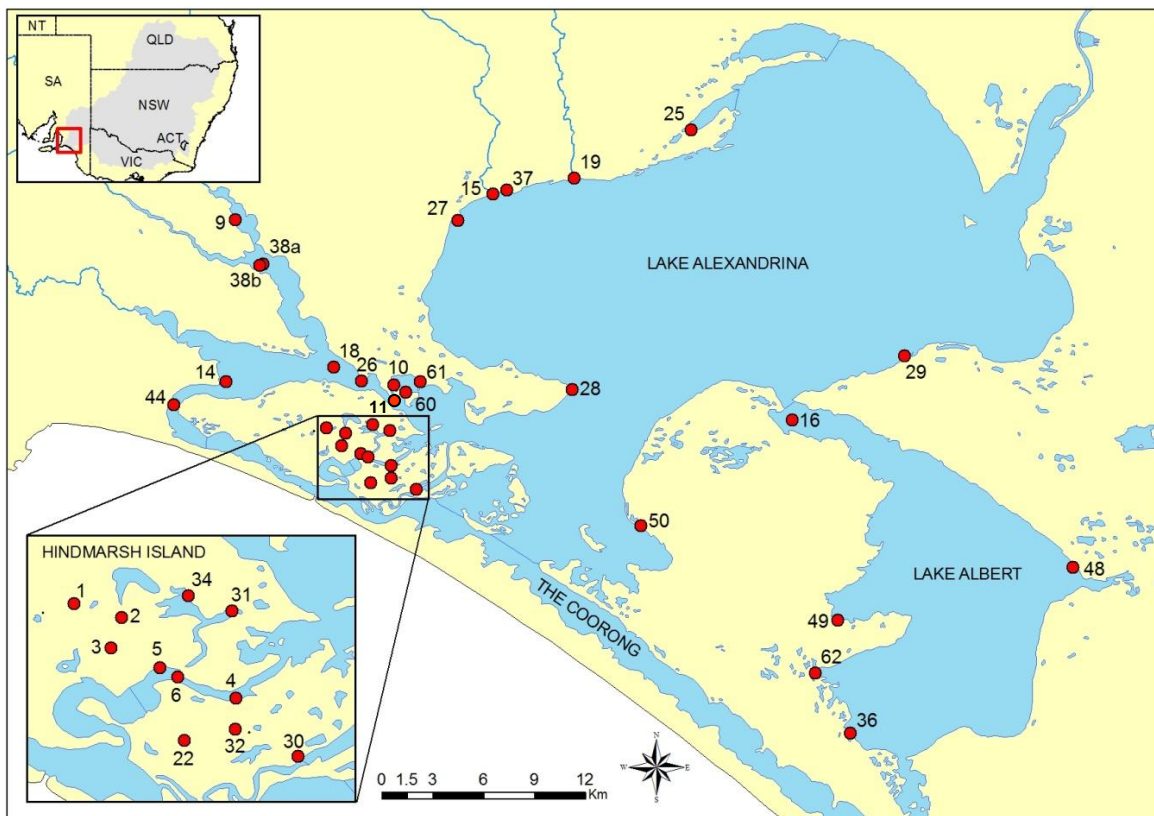


Figure 1. Current and former sampling sites at the Lower Lakes.

Table 1. Sampling sites in November 2013 and March 2014 (UTM zone 54H, WGS84).

Site	Site description	Easting	Northing	Habitat type
2	Wyndgate, Hindmarsh Island	309580	6067037	modified channel
3*	Hunter's Creek, Wyndgate	309336	6066321	natural channel
4	Holmes/Fish trap Ck channel	312489	6065025	modified channel
5*	Steamer Drain (Wyndgate)	310487	6065853	modified channel
6	Holmes Ck (Boggy Ck mouth)	310913	6065636	natural channel
9	Finniss River (Wally's Wharf)	303084	6079610	natural channel
10	Dunn Lagoon	312414	6069870	wetland
11	Dunn Lagoon	312421	6069267	wetland
14*	Goolwa Channel (Currency Ck)	302559	6070065	natural channel
15	Angas River mouth	318245	6081200	natural channel
16	Narrung (Lake Albert)	334667	6068532	wetland
18*	Goolwa Channel (Finniss River)	308882	6070934	natural channel
19	Bremer River mouth	323062	6082057	natural channel
22	Mundoo Island	311065	6064130	modified channel
25	Dog Lake	329963	6084901	wetland
26	Old Clayton	310519	6070104	lake edge
27	Milang	316188	6079597	lake edge
28	Point Sturt	322934	6069625	lake edge
29	Poltalloch	342532	6071580	lake edge
30	Mundoo Is (near Boundary Ck)	313752	6063750	modified channel
31	Boggy Creek	312194	6067197	modified channel
32	Mundoo Is (nearest Homestead)	312275	6064403	modified channel
34	Shadows Lagoon	311165	6067555	wetland
36	Campbell House (Lake Albert)	339327	6049381	lake edge
37*	Turvey's drain	319095	6081360	modified channel
38*	Black Swamp	304545	6076940	wetland
48	Waltowa (Lake Albert)	352454	6059134	lake edge
49	Nindethana (Lake Albert)	338591	6056042	lake edge
60	Dunn Lagoon	313141	6069457	wetland
62	Belcanoe	337274	6052900	wetland

*Site sampled by SARDI Aquatic Sciences & Aquasave (Bice et al. 2014).

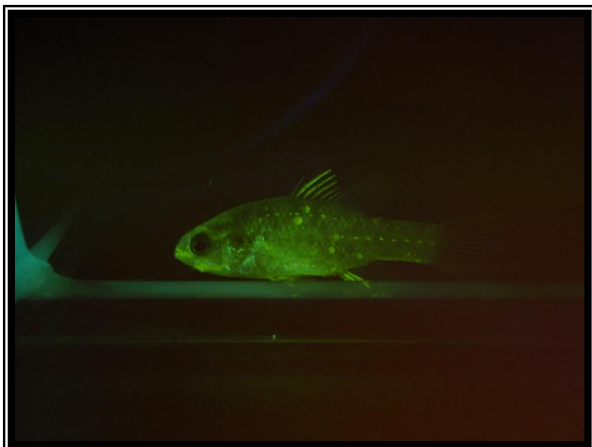
Table 2. Summary of fish reintroductions from 2011 to 2013 through the Critical Fish Habitat project.

Site	Species	Number	Release date
Wyndgate (site 2)	Southern pygmy perch	750	2/11/2011
Blue Lagoon (Finniss River confluence)	Yarra pygmy perch	400	8/11/2011
Finniss River junction (site 18)	Yarra pygmy perch	800	8/11/2011
Finniss River (Winery Road, near site 9)	Purple-spotted gudgeon	200	9/11/2011
Turvey's Drain (site 37)	Southern pygmy perch	400	9/11/2011
Steamer Drain (site 5)	Yarra pygmy perch	2200	27/03/2012
Shadows Lagoon (site 34)	Yarra pygmy perch	1500	29/03/2012
Mundoo Island (site 32)	Murray hardyhead	3500	28/03/2012
Mundoo Island (site 32)	Southern pygmy perch	280	29/03/2012
Finniss River (Winery Road, near site 9)	Purple-spotted gudgeon	400	29/03/2012
Finniss River (Winery Road, near site 9)	Purple-spotted gudgeon	320	3/12/2012
Mundoo Island (site 32)	Murray hardyhead	3500	4/12/2012
Wyndgate (Hunter's Creek, site 3)	Yarra pygmy perch	400	5/12/2012
Wyndgate (Hunter's Creek, site 3)	Murray hardyhead	520	5/12/2012
Shadows Lagoon (site 34)	Yarra pygmy perch	250	5/12/2012
Wyndgate (Hunter's Creek, site 3)	Yarra pygmy perch	300	31/02/2013
Finniss River (Winery Road, near site 9)	Purple-spotted gudgeon	200	20/03/2013

See details in Bice et al. (2012), Bice et al. (2013) and Bice et al. (2014).



Releasing Yarra pygmy perch into a soft release enclosure at Steamer Drain on Hindmarsh Island in March 2012 (photo: CFH project).



Southern pygmy perch stained with calcein glows green under ultraviolet light (Photo: CFH project).

Fish sampling

Fish sampling equipment and methods varied between sites depending on habitat conditions. Fyke nets were set at all sites, and seine shots, box trapping and dab netting supplemented some sampling. Total lengths (TL) were measured for all threatened fish, and for the first ten fish of all other species from each fyke net. Fin clips were taken from a sub-sample of captured pygmy perch by a PhD student, as part of an on-going genetics study (Chris Brauer, Flinders University).

Fish sampling equipment:

Three single-leader fyke nets (5-mm half mesh) set perpendicular to the bank or angled when in narrow channels or deep water. Grids (50-mm) at the entrances of nets excluded turtles and fish that might harm threatened fish, but are not expected to affect their ability to capture fish <250 mm long (cf. Fratto et al. 2008). Three nets were set overnight at each site.

Three seine net (7 m long × 1.5 m deep, 5-mm half mesh) shots for up to 10 m, where conditions allowed, within 10 m of the shoreline. The effectiveness of seine shots was variable due to differences in habitat. For example, muddy sediment prevented rapid hauls.

Six box traps unbaited for 1 hour during the day at some sites.

Dab net (1 mm square mesh) was used for 10 minutes near fringing macrophytes where threatened species were captured using other methods, with the aim of detecting larval or early-juvenile fish.



Seine net (left) and retrieving a fyke net (right).

Habitat measures

Water quality

Secchi depth (cm) was measured, and the following parameters were recorded using a TPS WP-81 meter:

- Salinity in grams per litre (g/L)
- Electrical Conductivity units (EC)
- pH
- Temperature (°C)

Physical habitat

- Average water depth: five measures 1 m apart, beginning 1 m from the bank, or five measures equally spaced if in a narrow channel
- Bank gradient: 0–90 degrees
- Riparian vegetation: estimated percentage covering ground
- Aquatic plant cover: estimated percentage covering sediment
- Habitat complexity score: five 10 m transects set 5 m apart. Objects in the water directly below each meter mark on the tape measure were recorded: rock (1 point), terrestrial grass (1 point), algae (1 point), emergent plant (2 points) and submerged plant (3 points). In channels <10 m wide, transects were run the full width and scores were weighted (total points × 50/number of tape measure readings).
- Habitat type: natural channel (usually >10 m wide), modified channel (<10 m wide; includes natural drainage lines that have been excavated), lake, wetland
- Site 'connected' to a lake or a main channel, or 'isolated'.

Data analyses and interpretation

To examine fish assemblages in November 2013 and March 2014, and to investigate their relationship to habitat characteristics, standardised raw data (number of fish captured/fyke net hour in the TLM condition monitoring) were analysed by Non-metric Multi-dimensional Scaling (NMS) ordination using the Relative Sørensen distance metric, in PC-ORD (ver. 6: McCune and Mefford 2011). The 2013–14 data was analysed against the 2008–09 TLM condition monitoring data (Wedderburn and Barnes 2009) to examine shifts in fish assemblages since the drought. Only fyke net data was used in the ordination, because it is the only consistent method for comparisons.

Total lengths of threatened fish were placed into 20 categories from 0–100 mm (i.e. 0–5, 6–10, 11–15, 16–20 etc.). Length frequency charts were prepared (using the same length categories) for threatened species to provide a comparison between the November 2013 and March 2014 samples.

Annual comparisons of fish assemblages

Shifts in broad fish groups (e.g. estuarine, diadromous, freshwater, alien) in the Lower Lakes were examined by combining the total numbers captured at all sites using only the March (to avoid seasonal variations) sampling data from 2009 to 2014. Shifts in fish assemblages at each significant site (i.e. sites that were inhabited by a threatened species) were compared using the total numbers for fish captured in broad fish groups (threatened species individually, 'other native fish' and 'alien fish') during each November and March sampling event from 2008 to 2014.

Results

Water quality

Salinity

In November 2013, salinities at sites fringing Lake Albert ranged from 1.42 g/L at Waltowa to 2.10 g/L at Narrung (Table 3). At the same time, salinities in Lake Alexandrina varied from 0.35 g/L at point Sturt to 1.50 g/L at Wyndgate. In March 2014, salinities in Lake Albert ranged from 1.34 g/L at Narrung to 1.82 g/L in a wetland at Belcanoe. At sites in Lake Alexandrina, salinities ranged from 0.35 g/L at Milang to 1.34 g/L at a site in the lower Finniss River. In November 2013 and March 2014, the mean salinity of sites in Lake Albert (1.69 and 1.53 g/L, respectively) were always higher than of sites in Lake Alexandrina (0.63 and 0.57 g/L, respectively). This also represents a continual post-drought reduction of salinity in Lake Albert, where mean salinity was 4.26 g/L in November 2010, 3.09 g/L in March 2011, 3.15 g/L in November 2011, 2.59 g/L in March 2012, 2.17 g/L in November 2012 and 1.86 g/L in March 2013 (Wedderburn and Barnes 2011; Wedderburn and Barnes 2012; Wedderburn and Barnes 2013).

Other variables

In November 2013, readings ranged from pH 7.12 at a site on Mundoo Island to pH 8.78 at the Finniss River junction of the Goolwa Channel. In March 2014, readings ranged from pH 6.73 at the Bremer River mouth to pH 8.24 at the Finniss River junction of the Goolwa Channel. In November 2013, Secchi depth varied substantially, ranging from 16 cm at Nindethana in Lake Albert to >140 cm in Turvey's Drain. Mean water temperature was 19.5°C in November 2013 and 19.0°C in March 2014.

Physical habitat

As reflected by the values for aquatic plant cover and habitat complexity score (Table 4), physical habitat varied widely between sites in November 2013. Habitat scores ranged from 14 points (16% aquatic plant cover) at the Angas River mouth to 126 points (80%) in Boggy Creek (site 2) where continuous beds of hornwort (*Ceratophyllum demersum*) dominated. In March 2014, habitat complexity scores ranged from 16 points (16%) at the edge of Lake Albert to 146 points (100%) in Boggy Creek. Several other sites also had high habitat complexity scores (i.e. >100 points). In most cases this was attributed to expansive, thick beds of hornwort, and smaller proportions of water milfoil (*Myriophyllum* spp.) and cumbungi (*Typha domingensis*). An exception is Point Sturt, where much of the high habitat complexity score is attributed to ribbon weed (*Vallisneria australis*).

Water levels were below a mean depth of 1 m in November 2013, with the exception of the sites in Turvey's Drain and Black Swamp. Water levels at sites generally were lower in March 2014. Notably, this relates to management of Lake Alexandrina water level, which ranged from 0.68–0.78 m and 0.55–0.63 m above sea level during sampling in November 2013 and March 2014, respectively (Department for Environment, Water and Natural Resources, unpublished data). The fringing sites were 'connected' to Lake Alexandrina and Lake Albert during the study period, with the exception of Steamer's Drain in November 2013 (see Bice et al. 2014).

Table 3. Water quality in November 2013 (N) and March 2014 (M).

Site	Salinity (g/L)		Conductivity (μ S/cm) EC		pH		Secchi depth (cm)		Water temperature ($^{\circ}$ C)	
	N	M	N	M	N	M	N	M	N	M
2	1.50	0.96	2800	1989	7.47	7.05	62	49	17.0	19.0
3	-	-	1230	1180	8.03	7.12	44	>90	19.5	20.4
4	0.44	0.43	873	927	7.59	7.21	33	41	19.9	17.3
5	-	-	899	879	7.41	7.39	26	>90	20.9	17.4
6	0.43	0.46	845	989	8.01	7.52	49	36	18.2	18.7
9	1.07	1.34	2029	2757	7.39	7.08	29	28	20.8	23.0
10	0.42	0.43	821	936	7.58	7.31	51	51	20.5	16.7
11	0.39	0.42	769	900	7.82	7.02	39	32	22.1	17.6
14	-	-	868	989	8.59	7.95	45	36	21.3	21.4
15	0.82	0.81	1570	1705	7.62	6.74	62	42	16.0	19.6
16	2.10	1.34	3860	2760	7.82	7.29	23	23	17.3	18.9
18	-	-	826	921	8.78	8.24	22	33	24.7	21.7
19	0.36	0.36	707	790	7.31	6.73	22	38	15.9	19.9
22	0.49	0.54	968	1145	7.12	6.83	31	38	20.5	17.2
25	0.43	0.44	840	954	7.46	7.15	34	21	16.2	17.4
26	0.40	0.44	780	954	8.14	7.53	42	24	18.6	19.0
27	0.45	0.35	690	765	7.61	7.69	27	27	15.0	19.6
28	0.35	0.36	689	796	7.80	7.63	22	26	17.3	19.2
29	0.38	0.39	746	847	7.37	6.97	25	24	17.9	19.7
30	0.54	0.50	1064	1068	7.99	7.42	44	33	21.5	16.9
31	0.76	0.62	1463	1314	7.49	7.04	49	115	20.4	17.9
32	1.50	0.80	2816	1677	7.93	6.97	48	49	20.5	15.6
34	0.86	0.84	1653	1767	7.78	7.09	37	61	19.9	19.5
36	1.44	1.44	2700	2970	8.27	7.56	26	23	15.8	19.9
37	-	-	4850	1060	7.31	7.13	54	>140	18.1	22.0
38	-	-	1230	1650	7.97	7.54	34	33	21.7	21.2
48	1.42	1.53	2660	3120	7.97	7.26	45	26	20.6	17.7
49	1.45	1.53	2760	3140	8.34	7.42	16	16	25.7	16.9
60	0.39	0.41	779	880	8.21	7.92	36	27	19.2	16.8
62	2.06	1.82	3810	3660	7.77	7.32	17	17	22.3	21.6

Table 4. Physical habitat in November 2013 (N) and March 2014 (M).

Site	Mean depth (cm)		Aquatic plants (%)		Riparian plants (%)		Habitat complexity (score)		Connected	
	N	M	N	M	N	M	N	M	N	M
2	53	43	66	100	100	100	98	139	yes	yes
3	51	51	35	50	-	-	-	-	yes	yes
4	54	57	58	95	100	100	76	128	yes	yes
5	70	70	80	90	-	-	-	-	no	yes
6	39	39	30	36	100	100	39	45	yes	yes
9	26	31	46	78	100	100	52	127	yes	yes
10	52	37	78	92	100	100	89	104	yes	yes
11	56	39	74	76	100	100	83	78	yes	yes
14	69	77	80	60	-	-	-	-	yes	yes
15	54	33	16	26	100	100	14	32	yes	yes
16	45	52	60	52	100	90	60	54	yes	yes
18	57	61	50	60	-	-	-	-	yes	yes
19	39	100	42	44	100	100	42	43	yes	yes
22	59	55	86	77	80	90	74	81	yes	yes
25	41	23	40	42	100	60	54	57	yes	yes
26	38	30	46	40	100	100	43	38	yes	yes
27	39	36	92	80	100	100	104	103	yes	yes
28	35	22	29	82	90	90	71	96	yes	yes
29	56	48	48	54	100	100	48	55	yes	yes
30	71	87	38	53	80	70	35	44	yes	yes
31	84	75	80	100	100	100	126	146	yes	yes
32	59	39	69	100	80	100	115	123	yes	yes
34	51	22	38	58	100	100	60	91	yes	yes
36	28	21	60	16	100	100	66	16	yes	yes
37	104	117	90	80	-	-	-	-	yes	yes
38	130	116	50	50	-	-	-	-	yes	yes
48	54	25	38	22	95	100	37	22	yes	yes
49	16	32	48	24	99	100	44	29	yes	yes
60	96	92	68	50	100	100	90	84	Yes	yes
62	34	25	54	60	100	100	49	62	yes	yes

Fish assemblages

In November 2013, TLM (24 sites) and CFH project (six sites only herein) monitoring recorded 4083 fish represented by 19 native and five alien species (Table 5). Flathead gudgeon (23% of total catch), common galaxias (18%) and Australian smelt (11%) were the most numerous native fishes. Notably, the diadromous congolli made up almost 5% of the total catch. Five alien fishes constituted 16% of the total catch (cf. 24% in November 2012), and consisted of redfin perch (5%), common carp (3%), goldfish (2%), eastern Gambusia (7%) and tench (<1%). A summary of the overall catches for each site sampled in TLM condition monitoring are presented in the Appendices.

In March 2014, TLM and CFH monitoring recorded 6125 fish represented by 19 native and four alien species. There were substantial increases in the relative abundances of unspotted hardyhead (13%) and bony herring (13%), which were the most common native fish species in March 2014 with flathead gudgeon (16%) and common galaxias (12%). Of the alien fishes, the relative abundances and proportions of redfin perch (1%), common carp (<1%) and goldfish (<1%) in the total catch were lower than in the November sampling. In contrast, the extremely high relative abundance of eastern Gambusia dominated the overall catch (33%). Tench was not captured in March.

The overall number of fish captured in March 2014 is comparable to other years, with the exception of an extreme abundance in March 2010 (Figure 2). The extremely high overall abundance in March 2010 is likely a result of drying and salinisation in the Lower Lakes, which promoted estuarine fishes, especially lagoon goby and smallmouth hardyhead. Additionally, the concentration of fish in shrinking habitats made them easier to catch in some cases. In 2013–14, their abundances and proportions in the catch were low (Figure 3). In March 2014, the composition of the fish assemblages in off-channel sites at the Lower Lakes were similar to March 2012 and March 2013, whereby they were largely dominated by alien fishes and common native freshwater generalists.

The total abundance of eastern Gambusia captured was high at the peak of drought in March 2009, where it constituted 89% of alien fish numbers (Figure 4). Its abundance and proportion (11% of alien fish and 6% overall fish) in fish assemblage was lowest in March 2011 immediately following high river inflows to the Lower Lakes. It was again the most numerous alien fish species in March 2013 (76%) and March 2014 (93%) when flows had stabilised. Redfin perch, common carp and goldfish were in relatively low abundances in March 2014, where they made up a small proportion of the alien fish numbers (4%, 2% and 1%, respectively). Notably, adult common carp were frequently observed at many sites, but they were too large to be captured in the gridded fyke nets.

During the last six March monitoring events, the overall numbers of freshwater fishes peaked in 2010 and was lowest in 2012 (Figure 5). Two ecological generalists, flathead gudgeon and Bony herring, were the most numerous species in catches, excluding in March 2009. Notably, unspotted hardyhead made up a substantial proportion (27%) of native freshwater fish captured in March 2014 after being extirpated from the Lower Lakes during the drought. In March 2013, the freshwater ecological specialists (including the threatened fishes) continued to constitute a minor proportion of the fish assemblages in the Lower Lakes. In March 2014, Murray hardyhead was notable when it made up 7% of the native freshwater fish captured.

Common galaxias and congolli were the only diadromous fishes captured in the last six TLM condition monitoring events. Common galaxias remained relatively abundant from March 2008 to March 2012, but its numbers were substantially higher in March 2013 and March 2014 (Figure 6). Congolli was notably absent during the peak of drought in March 2009 and March 2010, but relatively low to moderate numbers were captured thereafter.

Table 5. Number of sites recorded and total abundance of each fish species captured in November 2013 and March 2014 during TLM and CFH monitoring at 30 sites.

Common name	Scientific name	November 2013		March 2014	
		No. sites	Total abundance	No. sites	Total abundance
Freshwater species					
Southern pygmy perch	<i>Nannoperca australis</i>	1	1	1	14
Yarra pygmy perch	<i>Nannoperca obscura</i>	1	1	1	1
Murray hardyhead	<i>Craterocephalus fluviatilis</i>	2	49	6	206
Unspecked hardyhead	<i>Craterocephalus stercusmuscarum fulvus</i>	11	70	10	787
Golden perch	<i>Macquaria ambigua</i>	3	7	6	7
Bony herring	<i>Nematalosa erebi</i>	11	141	22	767
Flathead gudgeon	<i>Philypnodon grandiceps</i>	28	942	29	960
Dwarf flathead gudgeon	<i>Philypnodon macrostomus</i>	14	46	10	39
Carp gudgeon	<i>Hypseleotris</i> sp.	19	337	9	74
Australian smelt	<i>Retropinna semoni</i>	18	463	9	77
River Murray rainbowfish	<i>Melanotaenia fluviatilis</i>	1	3	1	1
Common carp*	<i>Cyprinus carpio</i>	18	122	12	51
Goldfish*	<i>Carassius auratus</i>	17	70	12	22
Redfin perch*	<i>Perca fluviatilis</i>	24	189	20	82
Eastern Gambusia*	<i>Gambusia holbrooki</i>	16	288	25	2062
Tench*	<i>Tinca tinca</i>	1	1	0	0
Diadromous species					
Congolli	<i>Pseudaphritis urvillii</i>	27	195	24	159
Common galaxias	<i>Galaxias maculatus</i>	22	744	24	720
Estuarine species					
Smallmouth hardyhead	<i>Atherinasoma microstoma</i>	5	124	20	23
Blue-spot goby	<i>Pseudogobius olorum</i>	9	108	10	46
Tamar River goby	<i>Afurcagobius tamarensis</i>	5	20	2	6
Lagoon goby	<i>Tasmanogobius lasti</i>	10	143	4	19
Sandy sprat	<i>Hyperlophus vittatus</i>	2	18	1	1
Greenback flounder	<i>Rhombosolea tapirina</i>	1	1	0	0
River garfish	<i>Hyporhamphus regularis</i>	0	0	1	1

*alien species

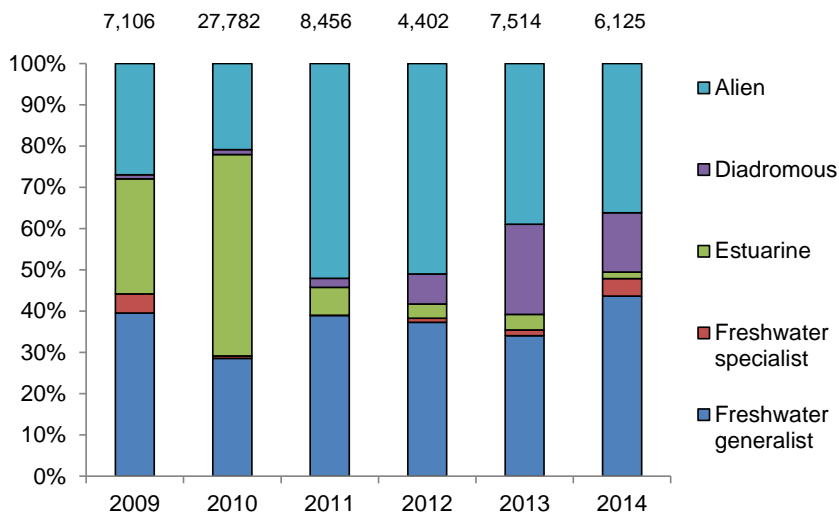


Figure 2. Proportion of each general group of fish and the total number of fish in catches (values above bars) in combined TLM and CFH/DAP March monitoring events from 2009 to 2014.

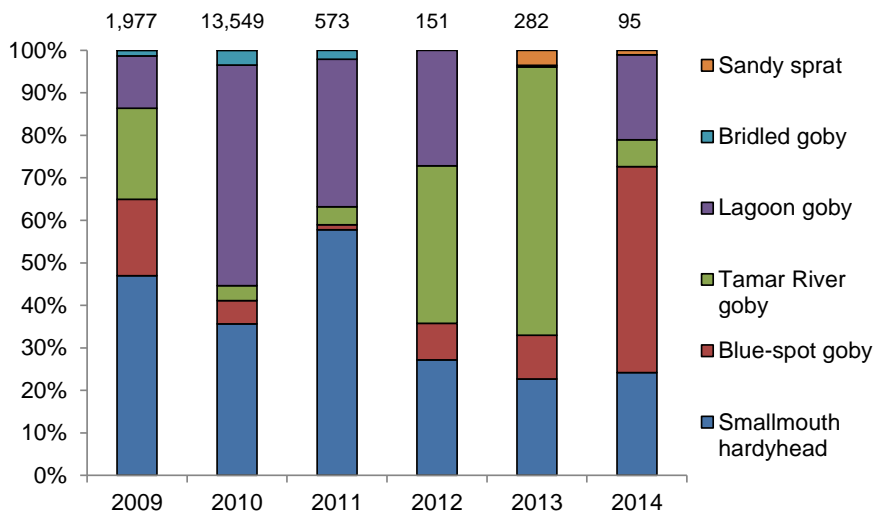


Figure 3. Proportion of each estuarine fish species and the total number of estuarine fish in catches (values above bars) in combined TLM and CFH/DAP March monitoring events from 2009 to 2014.

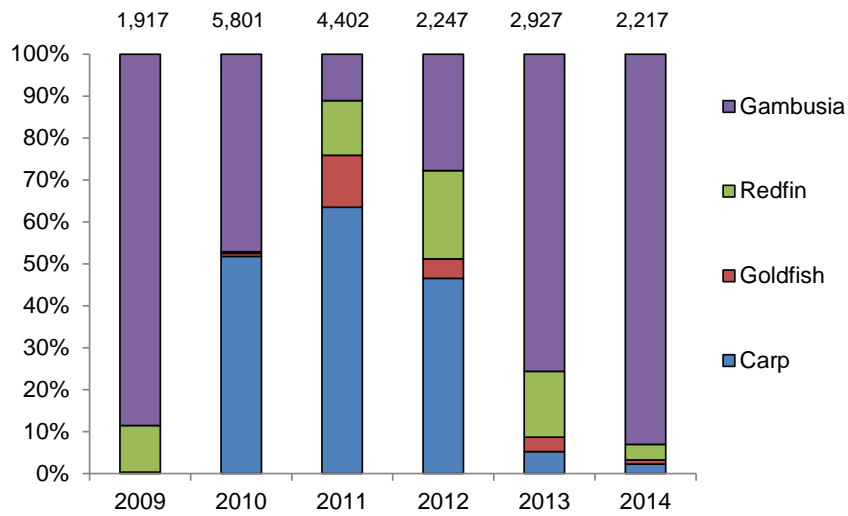


Figure 4. Proportion of each alien fish species and the total number of alien fish captured (values above bars) in combined TLM and CFH/DAP March monitoring events from 2009 to 2014 (tench excluded).

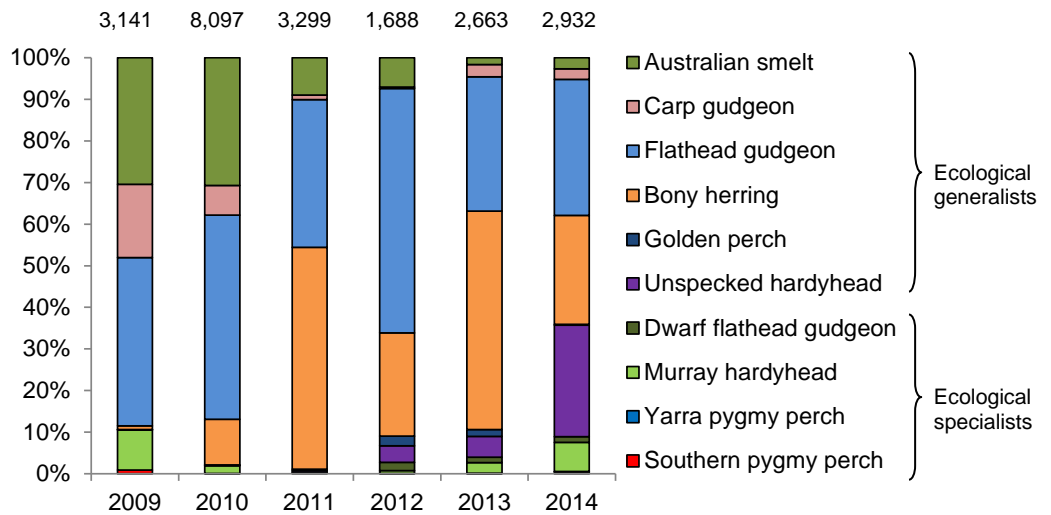


Figure 5. Proportion of each native freshwater fish species and total number of native fish captured (values above bars) in combined TLM and CFH/DAP March monitoring events from 2009 to 2014 (Murray rainbowfish excluded).

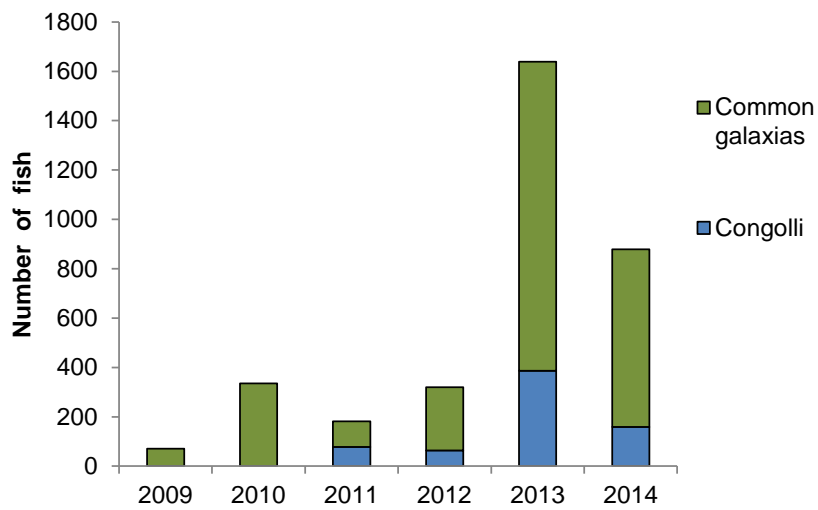


Figure 6. Total numbers of diadromous fishes captured in combined TLM and CFH/DAP March monitoring events from 2009 to 2014 (represented as total numbers because there are only two species).



A selection of non-threatened native fish species captured during the 2013–14 TLM condition monitoring: river garfish (top left), unspecked hardyhead (top right), golden perch (bottom left) and sandy sprat (bottom right).

The ordination shows a separation of sites based on the time of sampling. Sites sampled in 2008-09 are to the left-hand side of the plot (open dots), and sites sampled in 2013-14 are to the right-hand side of the plot (Figure 7). Multi-response Permutation Procedure confirmed that the fish assemblages recorded during the two sampling events are significantly different ($P < 0.001$).

Electrical conductivity (EC), and therefore salinity, is the variable most strongly associated with fish assemblages, on Axis 1 (correlation between EC and axis score: $r = -0.57$) and Axis 2 ($r = 0.16$), directed towards sites sampled in 2008-09. The correlation for pH shows a similar trend on Axis 1 ($r = -0.51$) and Axis 2 ($r = -0.37$). Conversely, the correlations for habitat complexity (Axis 1: $r = 0.38$; Axis 2: $r = 0.41$) are directed towards sites sampled in 2013-14. Similarly, water depth is positively associated on Axis 1 ($r = 0.43$) with fish assemblages sampled in 2013-14.

The relatively strong correlation for eastern Gambusia on Axis 2 ($r = 0.63$) suggests a positive association with habitat complexity. The species is split between sites sampled in 2008-09 and 2013-14. The correlation for southern pygmy perch on Axis 2 ($r = 0.24$) suggests a similar but weaker association. Golden perch, bony herring and congolli have a weak association on Axis 1 ($r = 0.33, 0.32, \text{ and } 0.27$, respectively) towards sites sampled in 2013-14, which are negatively associated with EC. Conversely, smallmouth hardyhead, blue-spot goby, and Murray hardyhead are associated with sites sampled in 2008-09 (Axis 1: $r = -0.68, -0.48 \text{ and } -0.27$, respectively), and show a positive relationship with EC. The correlations for flathead gudgeon, Australian smelt, and redfin perch on Axis 2 ($r = -0.41, -0.38 \text{ and } -0.33$, respectively) show they are associated with sites sampled in both sampling periods.

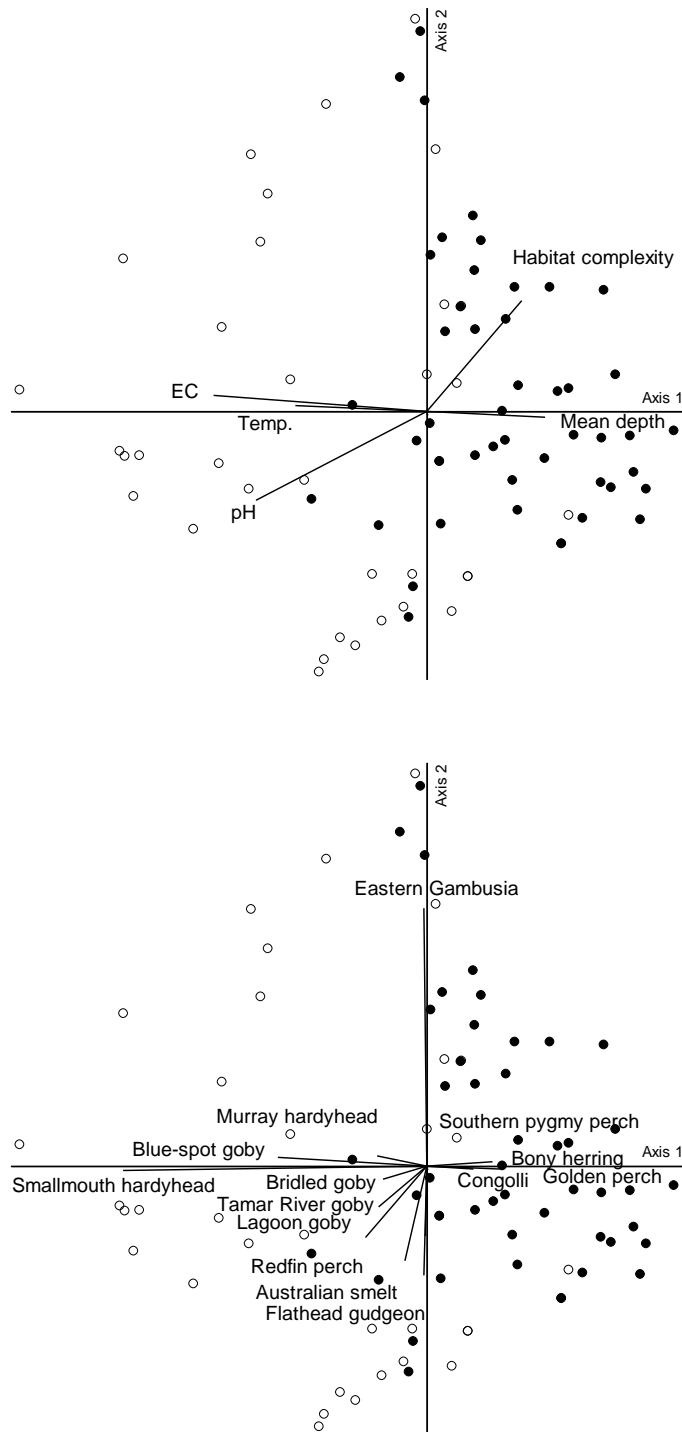


Figure 7. Three-dimensional NMS ordination (Stress = 0.13) of TLM condition monitoring sites based on similarities between fish species composition and abundance. Habitat (top plot) and fish species (bottom plot) are overlaid with the vector length proportional to, and directed towards, their correlation with sites. Open dots represent sites sampled in 2008-09, and solid dots represent sites sampled in 2013-14.

Threatened fishes

Summation

Southern pygmy perch and Yarra pygmy perch were captured in low numbers in November 2013 and March 2014 (Table 6). Only one Yarra pygmy perch was captured in November and another in March, at Shadows Lagoon (site 34), which suggests recruitment was lacking over the 2013–14 season. There is evidence of recruitment over 2013–14 for southern pygmy perch but the population is restricted to a small pool on Mundoo Island. The data suggests it represents a small but self-sustaining population.

Moderate numbers of Murray hardyhead were captured in November 2013, while relatively high numbers were recorded in March 2014. The data suggests Murray hardyhead has recovered to a self-sustaining population in the Goolwa Channel region, particularly near the junctions of the Finniss River and Currency Creek (Table 6). There is also evidence of a recovering Murray hardyhead population in Dog Lake (site 25). The species is yet to recover to its full range, which included habitats on Mundoo Island and Hindmarsh Island, and in Lake Albert (Hammer et al. 2002; Wedderburn and Hammer 2003; Higham et al. 2005).



Southern pygmy perch



Murray hardyhead



Yarra pygmy perch

Table 6. Numbers of each threatened fish species captured in the last two seasons by site, and a summary of their local (site) population status.

Site	Fish species	Number captured				Population status
		Nov. 2012	Mar. 2013	Nov. 2013	Mar. 2014	
2 Wyndgate	Southern pygmy perch	0	0	1	0	A single fish captured several hundred metres from the Wyndgate reintroduction site in November 2013. A self-sustaining population appears unlikely.
5 Steamer Drain	Yarra pygmy perch	2	0	0	0	Two adult fish captured in spring 2012 were from reintroduction, and absence of YOY fish suggests failed recruitment. A self-sustaining population appears unlikely.
10 Dunn Lagoon	Murray hardyhead	0	7	0	0	Seven fish captured in March 2013 were YOY, and likely recruited in the wild in or near the Goolwa Channel. Lack of fish captured during the 2013–14 sampling suggests habitat of Dunn Lagoon is lacking.
14 Goolwa Channel (Currency)	Murray hardyhead	0	0	0	2	First record of Murray hardyhead from the Currency Creek Game Reserve since sampling during the drought.
18 Goolwa Channel (Finniss)	Murray hardyhead	7	43	47	173	Conclusive signs of strong local recruitment at the Finniss River junction of the Goolwa Channel in 2012–13. A self-sustaining population is confirmed in the 2013–14 sampling.
22 Mundoo Island	Southern pygmy perch	0	1	0	14	A single fish was captured in March 2013 provided an indication of possible limited recruitment, but evidence of a self-sustaining population was lacking. Thirteen YOY fish and one 1+ fish captured in March 2014 confirmed successful recruitment in a precarious population.
25 Dog Lake	Murray hardyhead	0	0	2	7	Evidence of recruitment in 2013–14 suggests early stage natural population recovery in Dog Lake.
26 Old Clayton	Murray hardyhead	0	7	0	22	Seven fish captured at in March 2013 were late stage YOY. A similar finding in 2013–14 confirms the fish are recruited in the wild, and indicates they are part of a self-sustaining population in or near the Goolwa Channel.
32 Mundoo Island	Murray hardyhead	4	9	0	1	Small numbers captured in November 2012 and March 2013 were re-stocked fish, and absence of YOY fish over 2013–14 suggests a lack of recruitment at the site.
32 Mundoo Island	Southern pygmy perch	2	0	0	0	Two adult fish captured in November were re-stocked fish, and absence of YOY fish suggests a lack of recruitment.
34 Shadows Lagoon	Yarra pygmy perch	7	2	1	1	Small numbers of adults captured in November 2012 were re-stocked fish, but two fish captured in March 2013 were YOY likely recruited in the wild. The small number of 1+ fish in 2013–14 suggests a self-sustaining population is lacking.

Murray hardyhead

Relatively low numbers of Murray hardyhead were recorded during TLM condition monitoring in 2007–08 (Figure 8). The subsequent increase in relative abundance in 2008–09 is likely a reflection of the concentration of the species in off-channel sites during the drought (i.e. easier to catch), which was followed by a substantial decline as sites dried over 2009–10. In November 2009, relatively low numbers of Murray hardyhead were captured at lake edges, natural channels and modified channels (connected and isolated sites), and a relatively high number was recorded in a drainage channel on Mundoo Island (site 32) (Wedderburn and Hillyard 2010). In March 2010, a moderate number of Murray hardyhead was recorded in channels at Dog Lake (site 25) and Boggy Creek (site 31) (Wedderburn and Hillyard 2010).

Murray hardyhead was undetected at the Lower Lakes in the 2011–12 TLM condition monitoring. At the same time, 13 individuals were captured at the Finniss River junction of the Goolwa Channel during monitoring through the CFH project (Bice et al. 2012). During the 2012–13 TLM condition monitoring, Murray hardyhead was mostly associated with the Finniss River and Goolwa Channel area, apart from a few individuals captured at the CFH project’s reintroduction site on Mundoo Island (near site 32). Overall, recruitment was apparent for the Murray hardyhead population in the Lower Lakes over 2012–13 (Wedderburn and Barnes 2013).

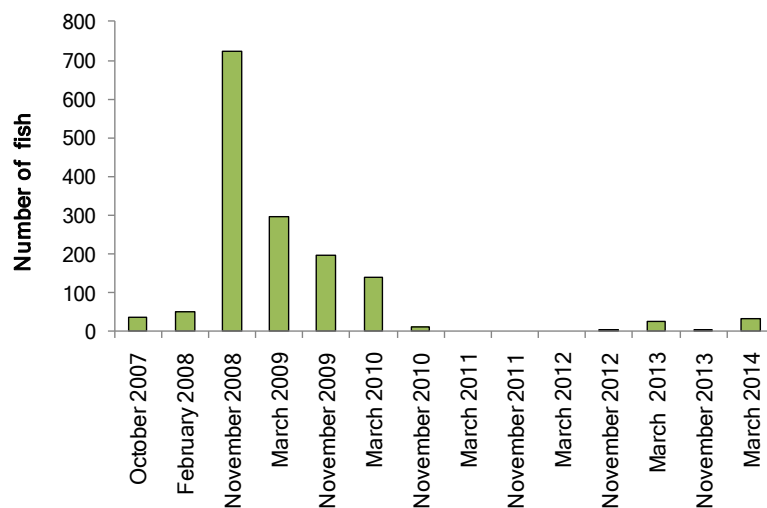


Figure 8. Total numbers of Murray hardyhead captured during TLM condition monitoring in the Lower Lakes (CFH data excluded).

Length frequency distributions for all Murray hardyhead captured in TLM and CFH project monitoring indicate a single cohort of adult fish in November 2013 (Figure 9). A distinct cohort is also apparent for March 2014, and represent young-of-the-year fish. Therefore, recruitment is confirmed for the Murray hardyhead population in the Lower Lakes in 2013–14.

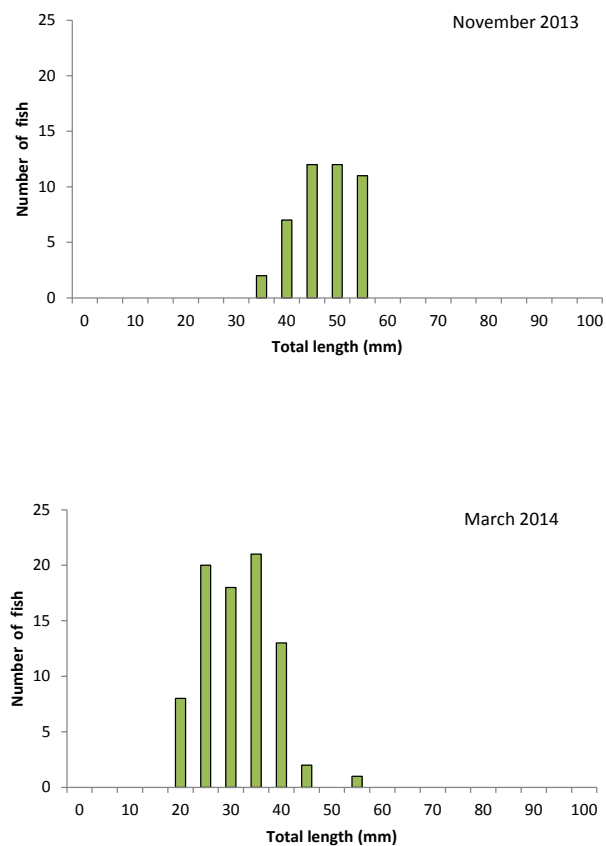


Figure 9. Length frequency distributions of Murray hardyhead captured in the Lower Lakes during TLM and CFH sampling in November 2013 ($n = 49$) and March 2014 ($n = 83$).

Southern pygmy perch

Relatively high numbers of southern pygmy perch were captured in the Lower Lakes between 2002 and 2005 (Hammer et al. 2002; Wedderburn and Hammer 2003; Higham et al. 2005). The species still inhabited the Lower Lakes when TLM condition monitoring began in 2007 (Figure 10). Condition monitoring recorded southern pygmy perch at four sites in November 2008 (Wedderburn and Barnes 2009), including in a modified natural drainage line on Mundoo Island (site 22). Southern pygmy perch was not recorded at the site again until March 2014. The young-of-the-year fish recorded in 2014 are obviously recruits from the southern pygmy perch that were reintroduced nearby (approx. 500 m) between 2011 and 2013 (see details for site 22 later in this document).

Monitoring recorded low numbers of southern pygmy perch at Turvey's Drain (site 37) near Milang in 2009–10 (Bice et al. 2010), where the habitat was conserved using an environmental water allocation. Further, seven southern pygmy perch were recorded at Black Swamp (site 38) during spring 2009, but the species was not detected at the site in autumn 2010 (Bice et al. 2010). Two southern pygmy perch were captured in the nearby channel in autumn 2010. In 2011–12, two southern pygmy perch were recaptured at Wyndgate following their release a few weeks earlier. A single southern pygmy perch was recorded at Wyndgate in November 2013, but the species was undetected at the site in March 2014.

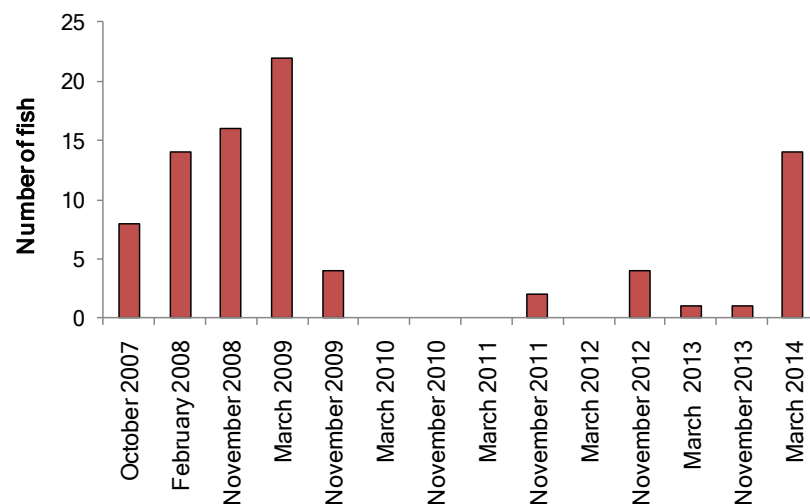


Figure 10. Total number of southern pygmy perch captured during TLM condition monitoring in the Lower Lakes (CFH data excluded).

Length frequency distributions for the small number of southern pygmy perch captured at the Lower Lakes in TLM and CFH project monitoring indicate recruitment success over 2013–14 (Figure 11). Notably, all fish captured in March 2014 were from a single site on Mundoo Island (site 22).

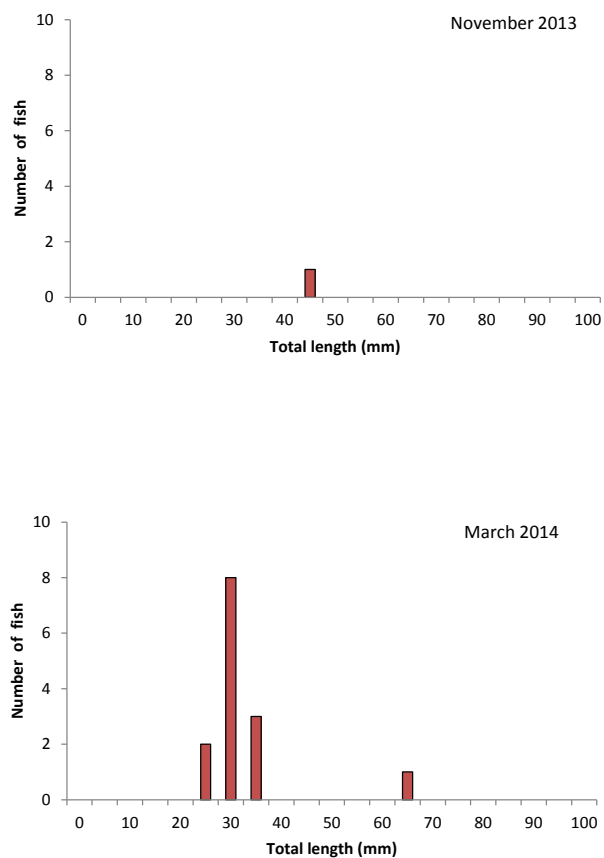


Figure 11. Length frequency distributions of all southern pygmy perch captured in the Lower Lakes during TLM and CFH sampling in November 2013 ($n = 1$) and March 2014 ($n = 14$).

Yarra pygmy perch

Records for Yarra pygmy perch in the Lower Lakes region date back to 1915 (Hammer et al. 2009). The species was more recently rediscovered (Hammer et al. 2002). It was relatively abundant at sites on Hindmarsh Island from 2002 to 2005 (Hammer et al. 2002; Wedderburn and Hammer 2003; Higham et al. 2005). Moderate numbers of Yarra pygmy perch were recorded in the 2007–08 TLM condition monitoring (Figure 12). The beginning of rapid water level recession in the Lower Lakes in 2007 led to the elimination of its required habitat. The species was extinct in the MDB by 2009 (Wedderburn et al. 2014). More detailed discussions regarding the causes of decline and extinction are presented in Hammer et al. (2009).

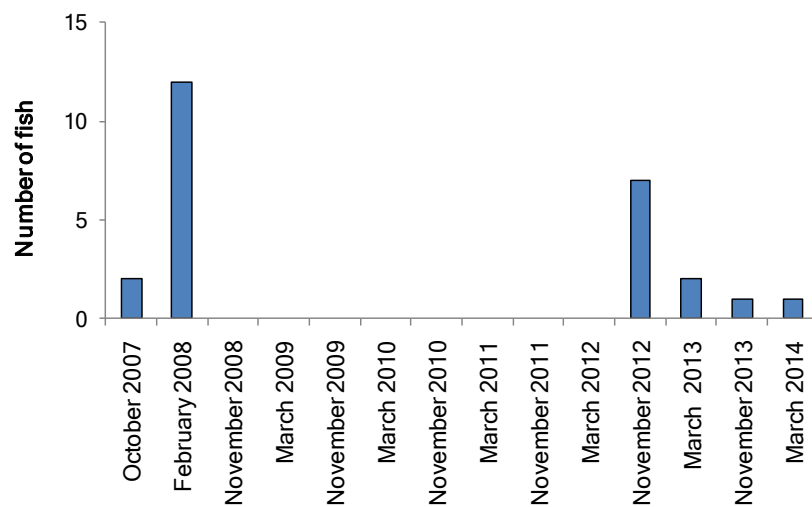


Figure 12. Total number of Yarra pygmy perch captured during TLM condition monitoring in the Lower Lakes (CFH data excluded).

The length frequency distributions for only two Yarra pygmy perch captured at the Lower Lakes during the 2013–14 monitoring event provide no evidence of recruitment (Figure 13).

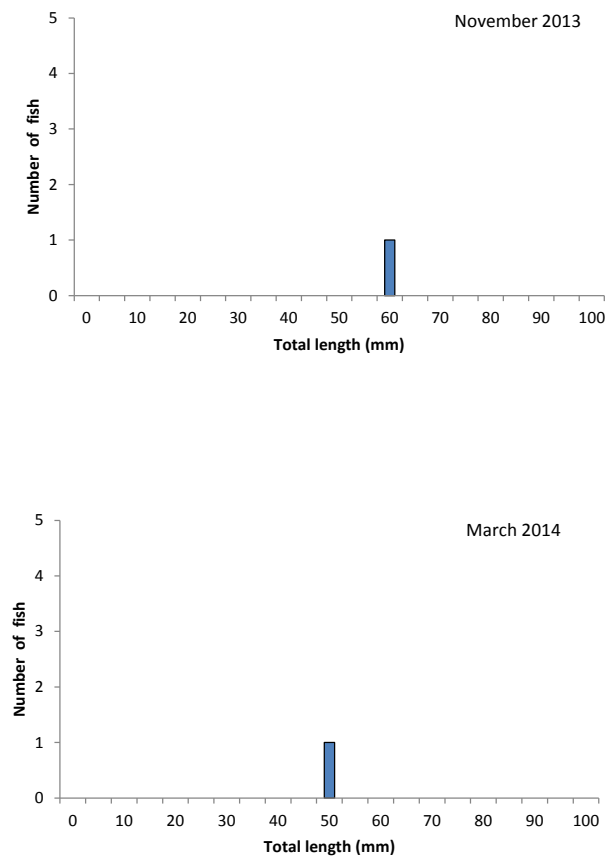


Figure 13. Length frequency distributions of all Yarra pygmy perch captured at the Lower Lakes during TLM and CFH sampling in November 2013 ($n = 1$) and March 2014 ($n = 1$).



The only Yarra pygmy perch captured at the Lower Lakes in March 2014.

Significant sites

Wyndgate Conservation Park (site 2)

Fish were first sampled on Hindmarsh Island as part of the Biological Survey of the Murray Mouth reserves just prior to its proclamation as Wyndgate Conservation Park (Hammer et al. 2002). The survey and a subsequent inventory of the Lower Lakes in the following year highlighted that three threatened fish species thrived in the well-vegetated, freshwater habitats in a diverse fish community (Wedderburn and Hammer 2003). In 2005, during the middle stage of drought, Yarra pygmy perch, southern pygmy perch and Murray hardyhead were still abundant at Wyndgate Conservation Park (Bice and Ye 2006). Most habitats, including Hunters Creek and a series of interconnected drainage lines, dried during the summer of 2007–08.

In November 2010, after inundation of habitat following drought, the catches from Wyndgate Conservation Park were overwhelmingly alien fish (Figure 14). They were mostly young-of-the-year carp and goldfish (cyprinids). In November 2011, cyprinids still dominated fish assemblages at the site. At the same time, a low number of southern pygmy perch were recaptured after the CFH project's reintroductions (Bice et al. 2012). Cyprinids again dominated the fish assemblage in November 2012, when two Yarra pygmy perch were the only threatened fish captured (i.e. at the nearby Steamer drain (site 5): Bice et al. 2013). Threatened fish species were not recorded at Wyndgate Conservation Park in March 2013. A single southern pygmy perch was captured in November 2013.

In March 2014, the habitat at Wyndgate was a continuous expanse of hornwort, which appeared to fill most of the volume of water at the site. Indeed, it was the site with the second highest habitat complexity score (see Table 4). Possibly, prolific hornwort is deleterious for most fish species (e.g. oxygen depletion at night time, inhibits fish movement), but this area of research is lacking. Compared to the current study, the habitats at Wyndgate in 2003 often consisted of lower proportions of submerged plant cover (Wedderburn and Hammer 2003). Further, the submerged plants were mostly water milfoil, which has a different habit to hornwort. For example, there is space in the water column below its semi-floating leaves (see photograph below). In 2003, southern pygmy perch was more abundant ($n = 120, 9$ and 3) at sites in Wyndgate with a low proportion of submerged aquatic vegetation cover (10, 80 and 90%, respectively). The pattern for Yarra pygmy perch was unclear, but 201 fish were captured at a site that had only 10% submerged aquatic plant cover. In 2003, Murray hardyhead was relatively abundant ($n = 2-61$ fish captured) at sites with 5–80% submerged aquatic plants, but no relationship was apparent (Wedderburn and Hammer 2003).

Fish provided one of the highest conservation values of any biological group in Wyndgate Conservation Park when it was first proclaimed (Brandle 2002). It is important to track changes in fish assemblages at Wyndgate over coming years to determine if populations of the three threatened fish species re-establish.

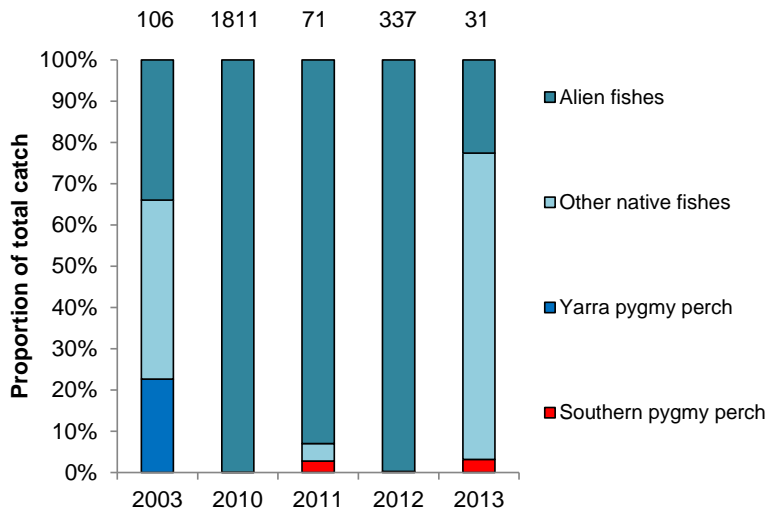


Figure 14. Comparison of fish community composition and total abundance (value above bar) in Wyndgate (site 2) in 2003 (site D2 in Wedderburn and Hammer 2003) and in the last four November TLM condition monitoring events (site dry from 2007–09).



Habitat at Wyndgate Conservation Park in 2003 (left) consisted predominantly of water milfoil, whereas hornwort congested the channel system in March 2014 (right).

Dunn Lagoon (sites 10 and 11)

In November 2008, as salinisation continued during drought, common native fish species dominated the catch at Dunn Lagoon (Figure 15). It mostly consisted of the estuarine smallmouth hardyhead, which constituted approximately two-thirds of the catch. The fish assemblage was more diverse following re-inundation of the lagoon in mid-2010, but the proportion of alien fish increased substantially. During that time, six adult Murray hardyhead were captured at Dunn Lagoon. Possibly, the fish had migrated from the nearby Boggy Creek drought refuge (see Wedderburn et al. 2013), but will remain unconfirmed. In November 2011, the overall catch was the lowest in any of the last six condition monitoring events. In November 2012, the high proportion of alien fish was mostly attributed to redfin perch. Several young-of-the-year Murray hardyhead were captured at Dunn Lagoon in March 2013 (Wedderburn and Barnes 2013). Murray hardyhead was undetected at Dunn Lagoon during the 2013–14 TLM condition monitoring, when the fish assemblage was dominated by other native fish.



Well-vegetated habitats at Dunn Lagoon site 10 (left) and site 60 (right) in March 2014.

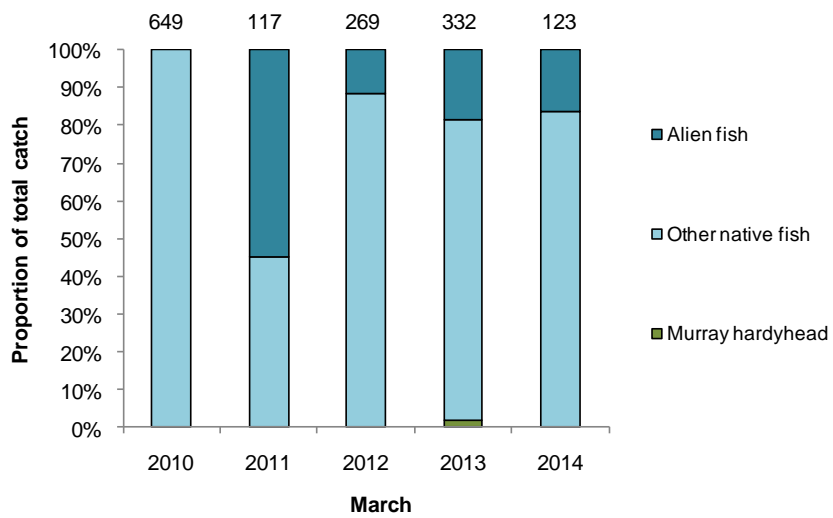
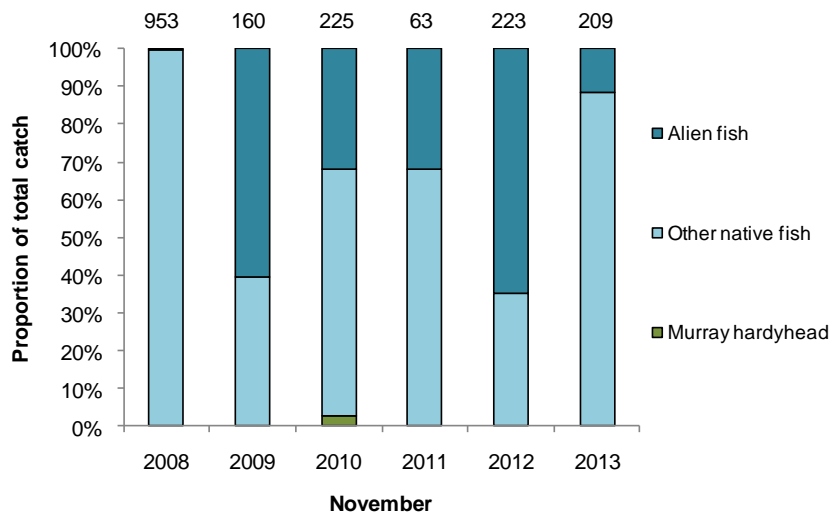


Figure 15. Comparison of fish community composition and total abundance (value above bar) in Dunn Lagoon for the last six November (top) and March (bottom) TLM condition monitoring events (site was dry in March 2009).

Moderate numbers of Murray hardyhead were recorded in the early stages of monitoring at Dunn Lagoon (Figure 16). Murray hardyhead was undetected during the 2011–12 TLM condition monitoring, despite the additional effort of sampling two new sites (sites 60 and 61: see Wedderburn and Barnes 2012). There was an apparent recovery of aquatic habitat in Dunn Lagoon when water levels returned in 2010–11 (Figure 17). Given the capture of several Murray hardyhead at site 10 in March 2013, there is a suggestion that suitable habitat has re-established. Specifically, the habitat includes submerged macrophytes (e.g. water milfoil) and slightly elevated salinity, which are preferred by Murray hardyhead.

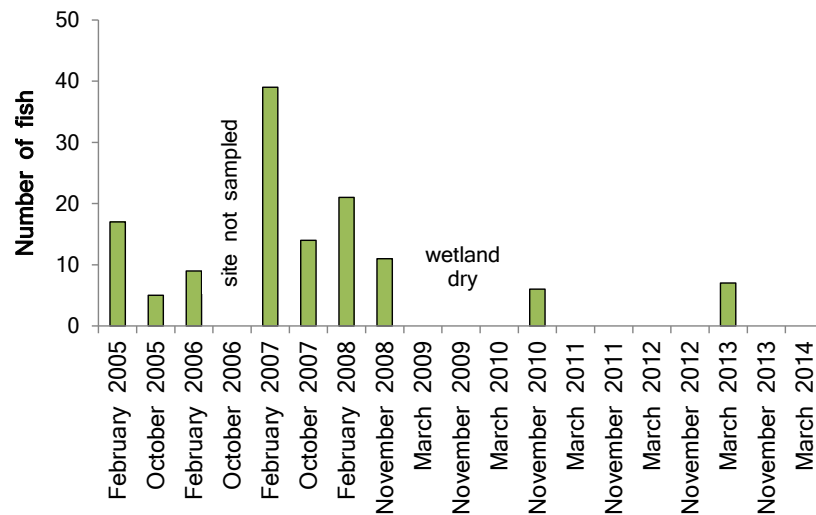


Figure 16. Numbers of Murray hardyhead captured at Dunn Lagoon over the entire TLM condition monitoring program.

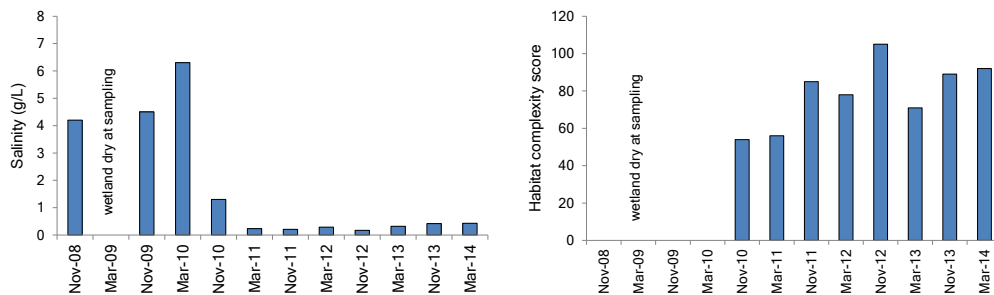


Figure 17. Corresponding changes in salinity and habitat complexity score at Dunn Lagoon from November 2008 to March 2014.

Currency Creek (site 14)

This site is at the junction of Currency Creek and the Goolwa Channel. Moderate numbers of adult Murray hardyhead were captured in November 2010 (~5% of the catch), but the species was not detected in March 2011 (Figure 18). Therefore, it was unconfirmed whether Murray hardyhead bred and recruited at the site over that period. In 2011–12, monitoring through the CFH project captured a single adult Murray hardyhead in November 2011 (Bice et al. 2012). Murray hardyhead was not recorded at the site in 2012–13 or 2013–14. Over time, native fish have dominated the site, with the exception of the high numbers of alien fish (predominantly eastern Gambusia) in March 2013. The total number of fish captured at the site has fluctuated widely between seasons and years. Notably, the extremely high number of native fish captured in November 2008 was predominantly smallmouth hardyhead.

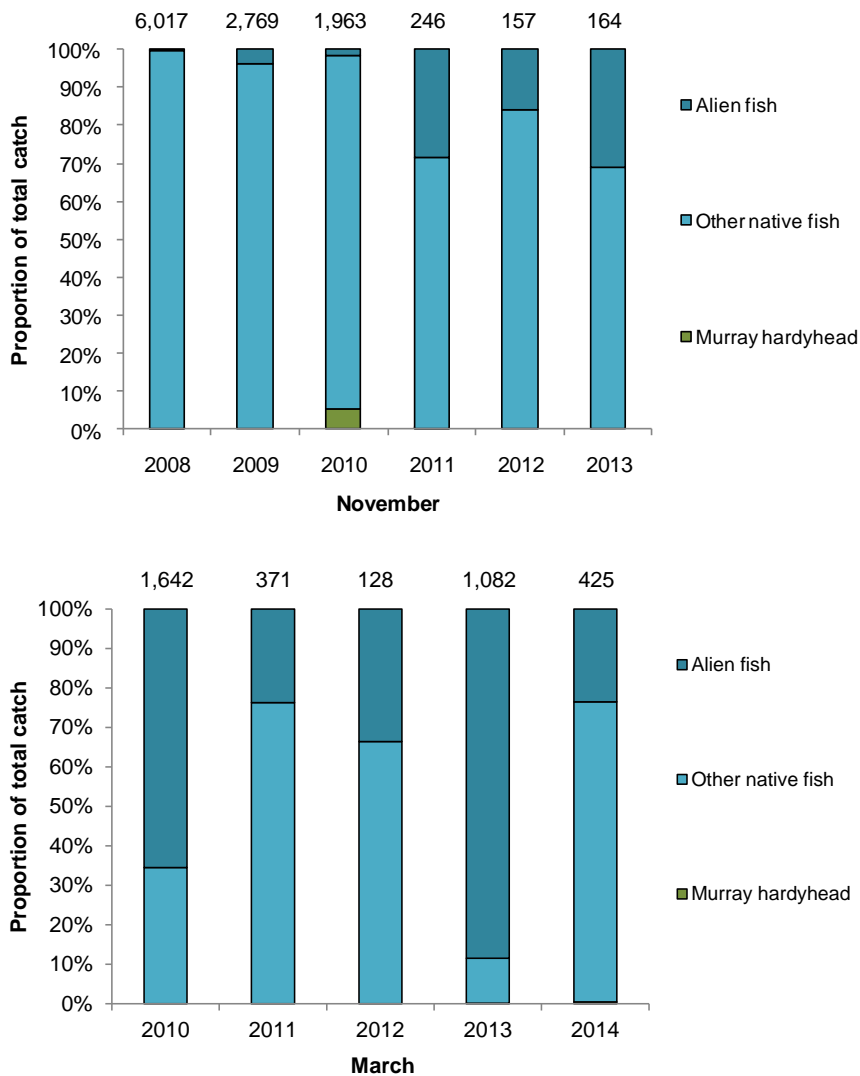


Figure 18. Comparison of composition and total abundance (value above bar) in fish assemblages at Currency Creek for the last six November (top) and five March CFH/DAP sampling events (site not sampled in March 2009).

Finniss River junction (site 18)

The overall number of fish captured was highest in November 2010, immediately after the return of substantial river flows following drought (Figure 19). At the time, the fish assemblage was dominated by non-threatened native fish species. In 2012–13, the fish assemblage at the site was dominated by a few native fishes and the alien eastern Gambusia. In 2013–14, the fish assemblage included relatively high numbers of Murray hardyhead, but was dominated by several other native fish species and eastern Gambusia (see Appendices).

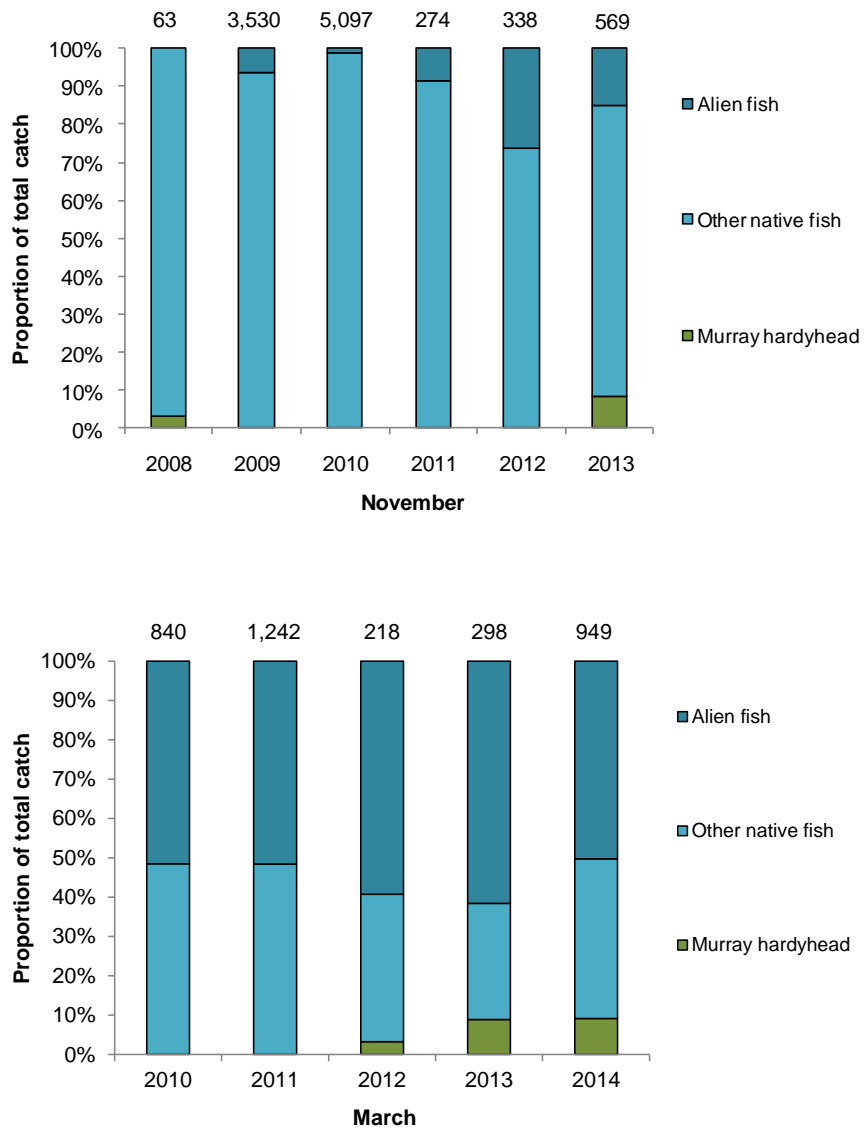


Figure 19. Comparison of composition and total abundance (value above bar) in fish assemblages at the Finniss River junction for the last five November (top) and March (bottom) CFH/DAP sampling events (site not sampled in March 2009).

Forty-seven adult Murray hardyhead were captured at the Finnis River junction of the Goolwa Channel in November 2013 during monitoring under the CFH project (Bice et al. 2014). The length frequency chart representing the 173 Murray hardyhead captured in March 2014 displays a young-of-the-year cohort for 50 representative fish (Figure 20). Therefore, it can be concluded that Murray hardyhead successfully recruited at or near the site in 2013–14.

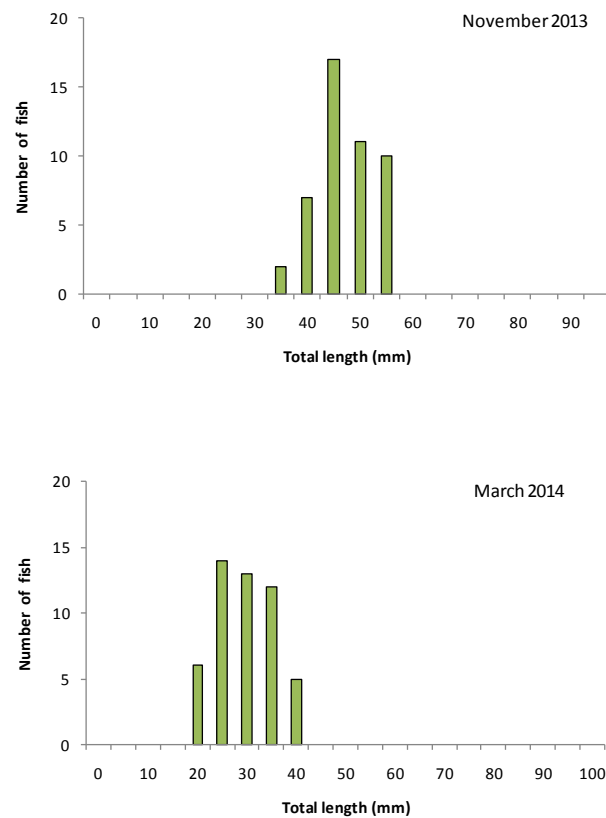


Figure 20. Length frequency distributions of Murray hardyhead measured from the Finnis River junction of Goolwa Channel in November 2013 ($n = 47$) and March 2014 ($n = 50$).

Mundoo Island (site 22)

This site is in a natural drainage system on Mundoo Island, which has been deepened by excavation. Although southern pygmy perch was recorded at the site in November 2009, it was undetected thereafter until reintroductions under the CFH project (Figure 21). During the drought, there was habitat deterioration that included salinisation (e.g. from 4.6 g/L in November 2009 to 10.3 g/L in March 2010) and a corresponding decrease in habitat complexity (Figure 22). Following re-inundation of the habitat with the return of river flows in 2010, salinity reduced to pre-drought levels and freshwater aquatic plants re-colonised. Notably, heavy stands of cumbungi now occupy the site.

In 2013–14, cumbungi dominated the site to the point that very little open water remained. Therefore, the fyke nets were set adjacent to the original site in the only remaining open water area (as in 2012–13: Wedderburn and Barnes 2013). No southern pygmy perch were captured in November 2013. Fourteen southern pygmy perch were captured at the site in March 2014. One fish is apparently age 1+, while the remaining fish are young-of-the-year (see photograph below). The proposition is supported by the length frequency distribution for the southern pygmy perch captured in March 2014 (Figure 23).



The only remaining open water at site 22 on Mundoo Island, and the only southern pygmy perch captured in March 2014.

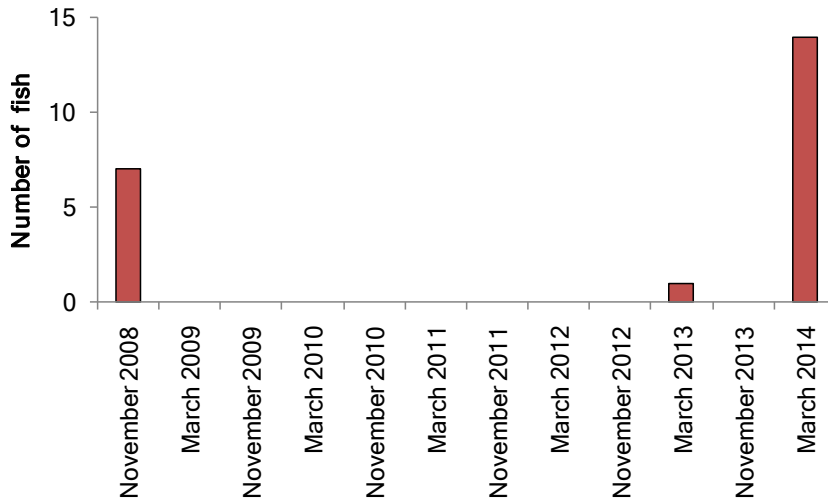


Figure 21. Numbers of southern pygmy perch captured at Mundoo Island (site 22) in the last six TLM condition monitoring events.

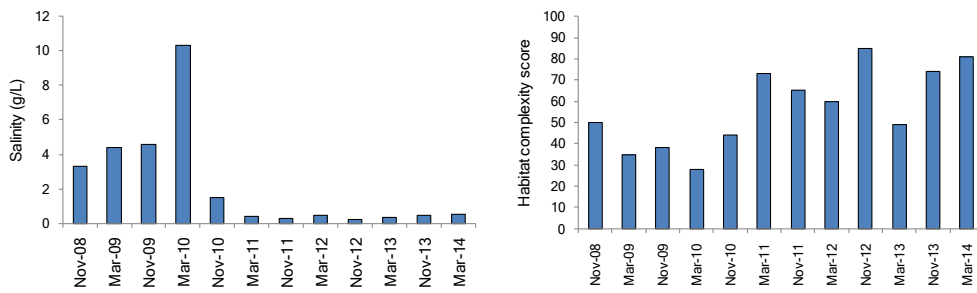


Figure 22. Corresponding changes in salinity and habitat complexity score at Mundoo Island (site 22) from November 2008 to March 2014.

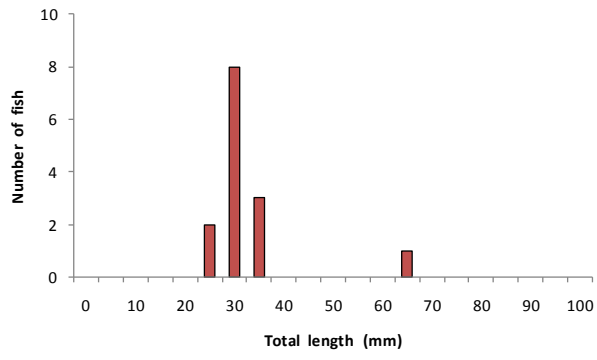


Figure 23. Length frequency distribution of southern pygmy perch from site 22 on Mundoo Island in March 2014 ($n = 14$).

Most native fish species declined at site 22 during the latter stages of the drought (2008 to 2010), but non-threatened native fish made up the highest proportion of the catches (mostly carp gudgeon) (Figure 24). Following the re-inundation of the site in mid-2010, the fish community consisted largely of alien fish (mostly young-of-the-year common carp and goldfish) in November 2010. Alien fish have continued to make up the vast majority of the catches since 2010. The total numbers of fish captured at the site have been low in recent years. The alien eastern Gambusia was by far the most abundant species in March 2014 ($n = 177$), when southern pygmy perch was captured (see appendix 2).

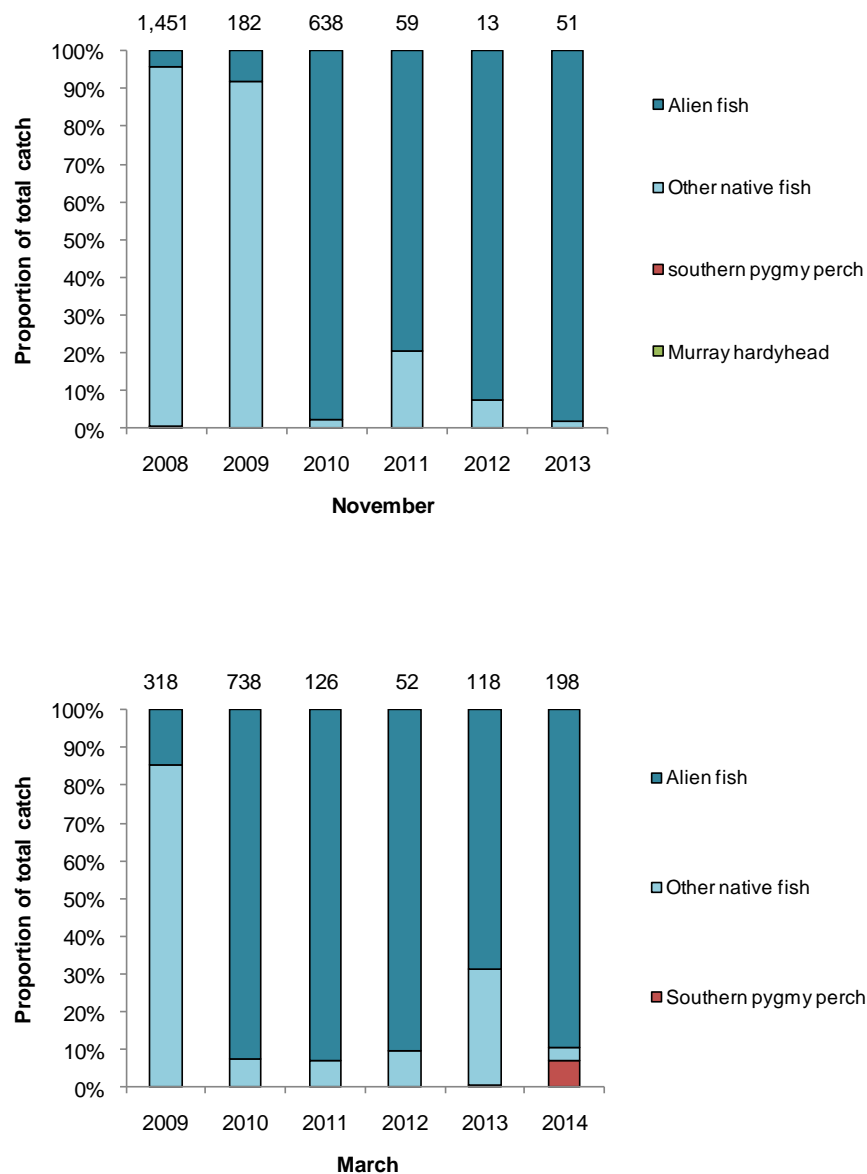


Figure 24. Comparison of composition and total abundance (value above bar) in fish assemblages at Mundoo Island (site 22) for the last six November (top) and March (bottom) TLM condition monitoring events (one Murray hardyhead and seven southern pygmy perch not discernable in chart for November 2008).

Dog Lake (site 25)

The site was originally in an irrigation channel fringing Dog Lake (now too deep to sample at >3 m). Currently, the site is within 20 m of the original sampling location, on the edge of Dog Lake. Murray hardyhead was recorded at the site in 2008–09 and 2009–10 (Figure 25), when there was evidence of local recruitment (Wedderburn and Barnes 2009; Wedderburn and Hillyard 2010). The length frequency distributions for Murray hardyhead indicate recruitment occurred over 2013–14 (Figure 26). This is the first evidence of recruitment in four seasons. Salinity had returned to normal levels following inundation in 2010 (Figure 27). Consequently, habitat complexity scores have remained relatively high over the last three condition monitoring events (November 2011 to March 2014). Aquatic plants in Dog Lake include water milfoil, ribbon weed (*Vallisneria spiralis* Var. *americana*), cumbungi, water primrose (*Ludwigia peploides*), duckweed (*Lemna* sp.) and small spike rush (*Eleocharis acuta*).



Dog Lake sampling site and a young-of-the-year Murray hardyhead captured in March 2014.

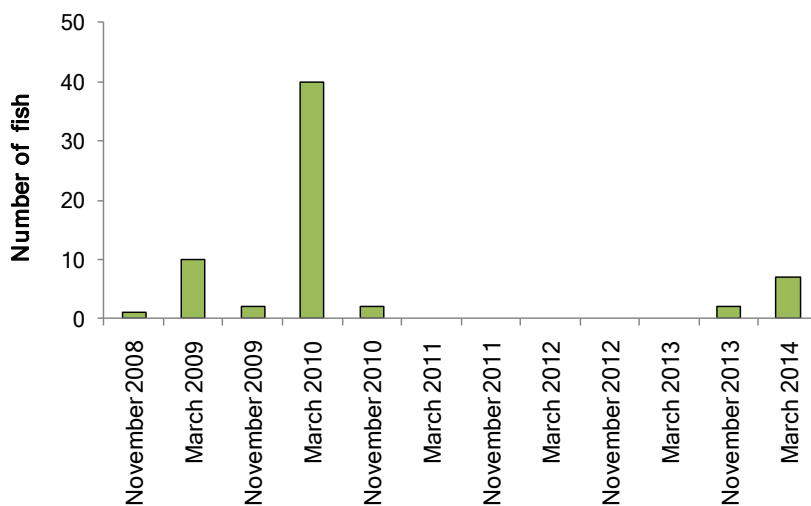


Figure 25. Numbers of Murray hardyhead captured at Dog Lake since its inclusion in the TLM condition monitoring program.

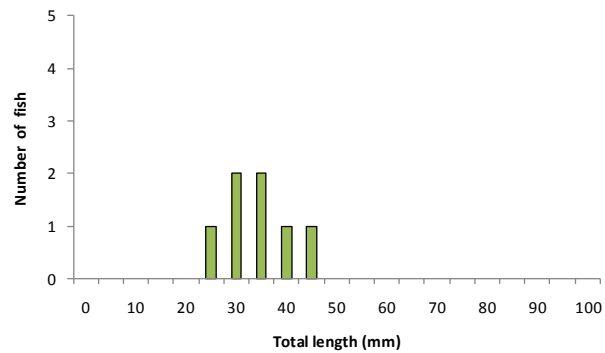
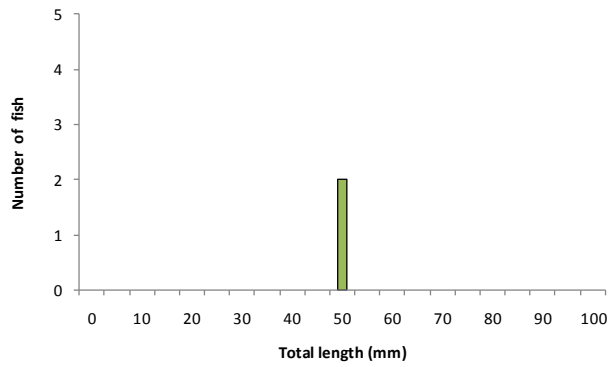


Figure 26. Length frequency distributions of Murray hardyhead measured from Dog Lake in November 2013 ($n = 2$) and March 2014 ($n = 7$).

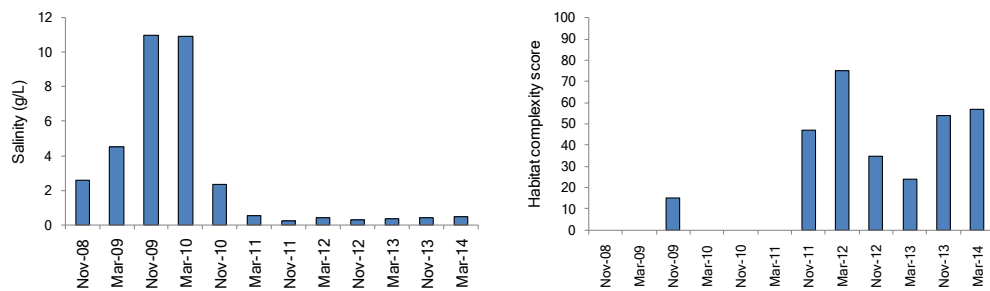


Figure 27. Corresponding changes in salinity and habitat complexity score at Dog Lake from November 2008 to March 2014.

The fish assemblage at Dog Lake consisted predominantly of non-threatened native fish in November 2008, March 2009 and November 2009 (mostly flathead gudgeon, smallmouth hardyhead and Australian smelt) (Figure 28). Murray hardyhead made up

almost 20% of the catch in March 2010. Following drought, there was an extremely high overall number of fish captured in November 2010, and more than half were young-of-the-year cyprinids. The catch was relatively low in November 2011 but more diverse than the previous year when more than half of the catch consisted of alien fish. During this time, Australian smelt and the estuarine lagoon goby were the most common native fish species. In November 2012 and March 2013, moderate numbers of fish were captured, and the relatively diverse fish assemblage was dominated by lagoon goby and redfin perch, and congolli was notable. In 2013–14, Murray hardyhead was captured for the first time in four years. During this time, the fish assemblage was dominated by other native fish (predominantly Australian smelt in November 2013) and alien fish (predominantly eastern Gambusia in March 2014).



Figure 28. Comparison of composition and total abundance (value above bar) in fish assemblages at Dog Lake for the last six November (top) and March (bottom) TLM sampling events.

Mundoo Island (site 30)

This site is in a natural drainage line on Mundoo Island that runs off Boundary Creek approximately 20 m above the barrage. Moderate numbers of adult Murray hardyhead were captured in November 2008 (Figure 29), and one young-of-the-year fish was captured in March 2009 (Wedderburn and Barnes 2009). Murray hardyhead has not been captured at this site in the last five TLM condition monitoring events. Salinity was elevated to over 18 g/L at the height of drought in November 2009 (Figure 30). Since inundation of the site in 2010, salinity has returned to pre-drought levels and freshwater aquatic plants are re-colonising, mostly cumbungi and water milfoil.



The channel off Boundary Creek on Mundoo Island in March 2009 (left) just prior to the extirpation of Murray hardyhead, and the site in March 2014 (right).



Figure 29. Numbers of Murray hardyhead captured at Mundoo Island (site 30) since the site's inclusion in the TLM condition monitoring program.

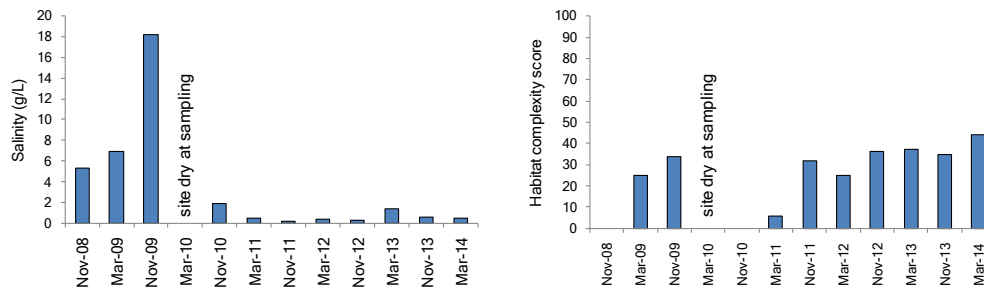


Figure 30. Corresponding changes in salinity and habitat complexity score at site 30 on Mundoo Island from November 2008 to March 2014.

The fish assemblage at site 30 on Mundoo Island included a relatively high proportion of Murray hardyhead in November 2008 (Figure 31). Alien eastern Gambusia made up almost all of the catch in November 2009. The highest number of fish recorded was in November 2010, when alien fish comprised more than 90% of the catch (predominantly redfin perch). The low numbers of fish captured in the 2013–14 TLM condition monitoring event consisted of non-threatened native fish and alien fish. In November 2013, flathead gudgeon and redfin perch were predominant in the fish assemblage. In March 2014, bony herring and redfin perch were predominant in the fish assemblage (see appendices).



Murray hardyhead captured at site 30 Mundoo Island in November 2008.

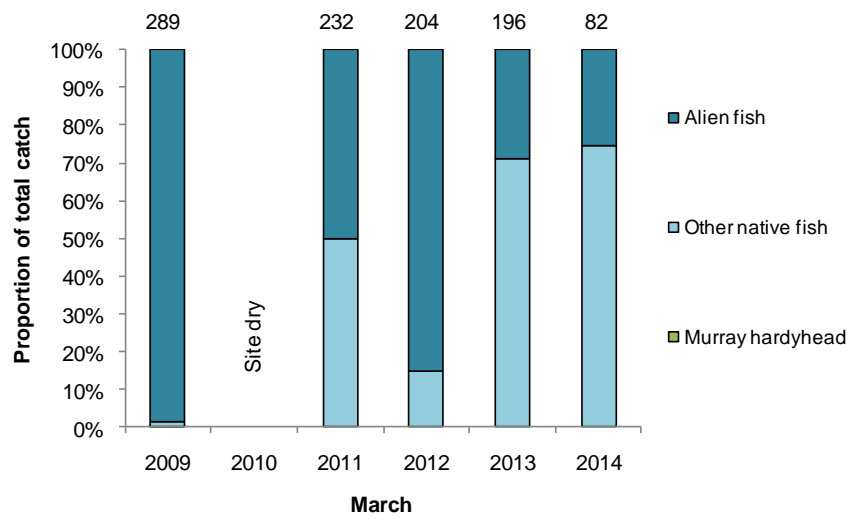
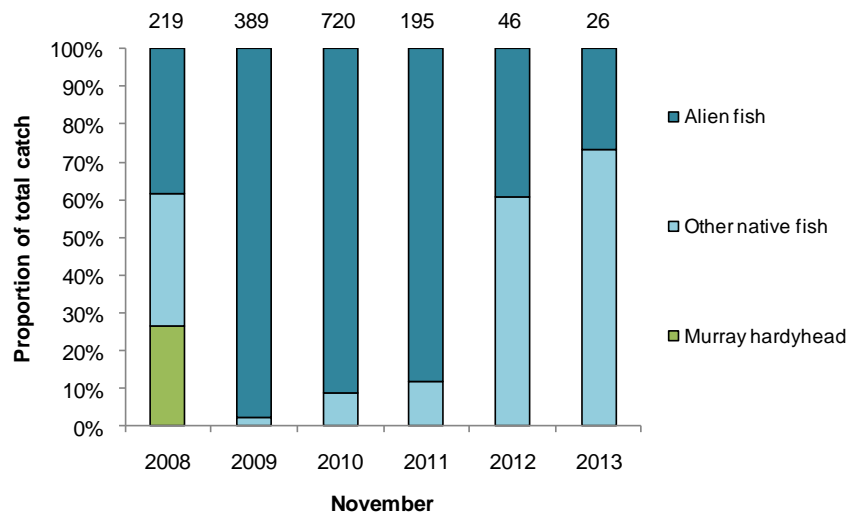


Figure 31. Comparison of composition and total abundance (value above bar) in fish assemblages at site 30 Mundoo Island for the last six November (top) and March (bottom) TLM condition monitoring events (one Murray hardyhead not discernable in March 2009).

Boggy Creek (site 31)

Using environmental water sourced through The Living Murray program and from Healthy Rivers Australia, the drought refuge at Boggy Creek received environmental water allocations between October 2009 and March 2010 as part of a State Government management strategy to conserve Murray hardyhead (Wedderburn et al. 2010; Wedderburn et al. 2013). In November 2009, Murray hardyhead was captured in relatively low numbers (Figure 32). In March 2010, the species was moderately abundant. Mostly young-of-the-year Murray hardyhead were captured in November 2009, and only an abundant adult cohort was sampled in March 2010 (Wedderburn and Hillyard 2010). The species was not captured at Boggy Creek in the 2010–11, 2011–12, 2012–13 and 2013–14 TLM condition monitoring events.



The drying Boggy Creek in November 2008 (left) when Murray hardyhead was abundant in the drought refuge, and the site in March 2014 (right).

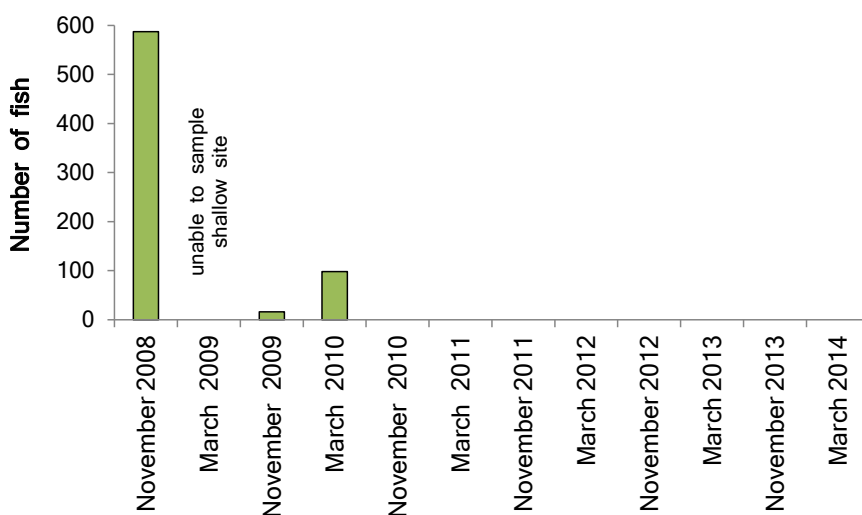


Figure 32. Numbers of Murray hardyhead captured at Boggy Creek since the site's inclusion in the TLM condition monitoring program.

Salinity at Boggy Creek was high (8.6–17.4 g/L) during the drought from November 2008 to March 2010 (Figure 33), but was prevented from becoming extreme using the environmental water allocations. Following re-connection with Lake Alexandrina in 2010, salinity reduced to normal levels. Habitat complexity scores have remained at moderate to high levels. In 2012–13, aquatic plants included an abundance of hornwort, cumbungi and water fern (*Azolla* sp.), which resulted in the highest habitat complexity score since monitoring commenced at the site (Wedderburn and Barnes 2013). Aquatic plants had expanded even more in 2013–14, to the extent that hornwort was so expansive that it occupied most of the volume of water at the site.

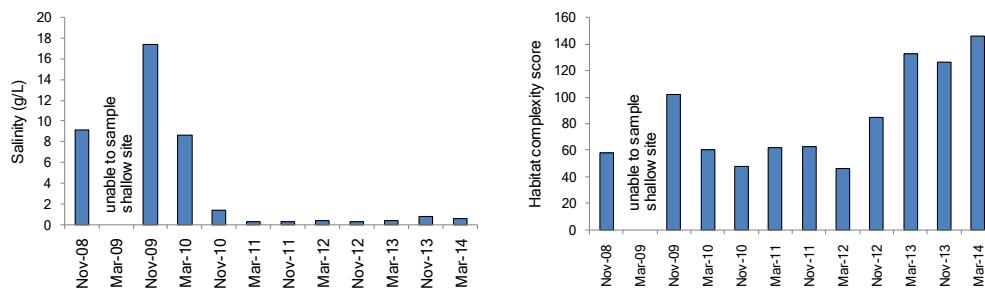


Figure 33. Corresponding changes in salinity and habitat complexity score at Boggy Creek from November 2008 to March 2014.

The fish assemblage at Boggy Creek was dominated by high numbers of Murray hardyhead and other native fish (high numbers of carp gudgeon and western blue-spot goby) in November 2008 (Figure 34). The low number of fish captured in November 2009 consisted only of Murray hardyhead, western blue-spot goby and eastern Gambusia. The higher numbers of fish captured in March 2010 consisted solely of Murray hardyhead ($n = 98$) and eastern Gambusia ($n = 334$). The successful recruitment of Murray hardyhead over 2009–10 was attributed to the influences (e.g. zooplankton blooms) of environmental water allocations (Wedderburn and Hillyard 2010; Wedderburn et al. 2010; Wedderburn et al. 2013).

Murray hardyhead dispersed from the Boggy Creek drought refuge when flows returned in mid-2010 and habitat connectivity was re-established. It has not been recorded at the site since 2010. The habitat at Boggy Creek in 2013–14 appeared suitable for Murray hardyhead, but obviously other factors are responsible for its absence. For example, the suitability of the habitat for Murray hardyhead is largely determined by salinity (positive association with salinity: Wedderburn et al. 2007), and predatory redfin perch might be a factor warranting consideration (Wedderburn et al. 2012b).

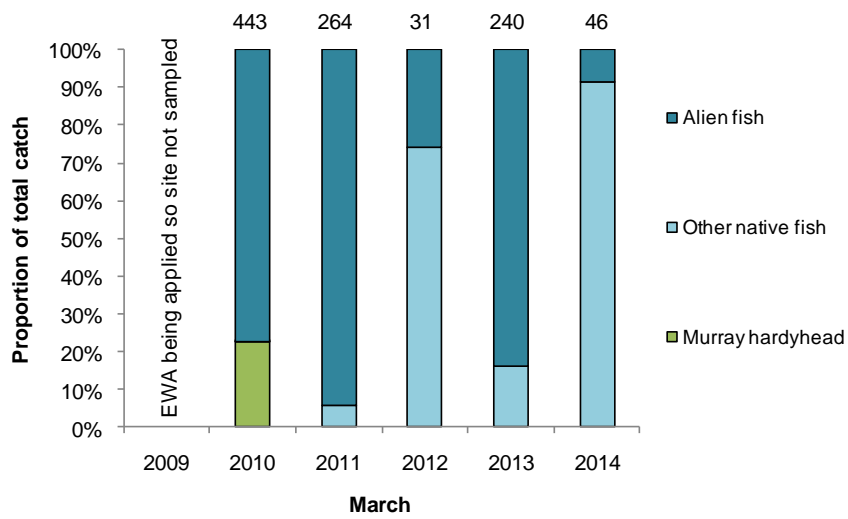
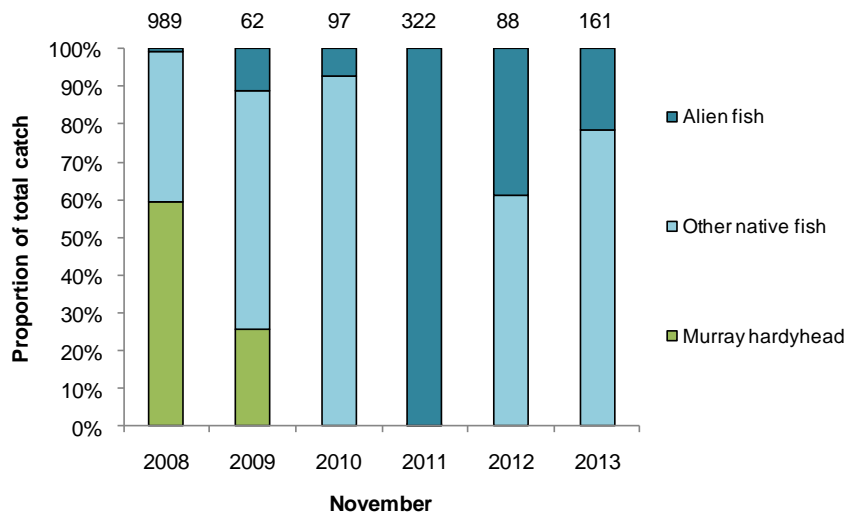


Figure 34. Comparison of composition and total abundance (value above bar) in fish assemblages at Boggy Creek for the last six November (top) and March (bottom) TLM condition monitoring events.

Mundoo Island (site 32)

This site is in a section of water that is part of a natural drainage system on Mundoo Island, which has been deepened by excavation. It is situated approximately 1 km east of site 22. Murray hardyhead was first recorded at the site in November 2008 (Figure 35). The high numbers captured in 2009 relate to a successful recruitment event (Wedderburn and Barnes 2009). There was an abundant adult cohort of Murray hardyhead captured at the site in November 2009. Despite this, there was no evidence of recruitment over 2009–10. Indeed, all fish species were extirpated at the site by January 2010 (Wedderburn and Hillyard 2010). The reasons might be related to the extremely high salinity (Figure 36: 63.3 g/L) or other disruptions to the food web (Wedderburn et al. 2010; Wedderburn et al. 2013). Habitat complexity score has remained consistently high at the site over the last six years, but with exceptional lows in March 2009 (drought) and November 2010 (recently inundated habitat). In 2013–14, the habitat consisted of relatively abundant hornwort, water milfoil, cumbungi and fennel pondweed (*Potamogeton pectinatus*).

In March 2012, approximately 3500 Murray hardyhead were released near site 32 through the CFH project (Bice et al. 2012). Sampling in November 2012 re-captured only four adult Murray hardyhead at the site. Another 3500 Murray hardyhead were released near the site in December 2012 (Bice et al. 2013). Sampling in March 2013 re-captured nine Murray hardyhead. A single adult Murray hardyhead (57 mm TL) was captured during the 2013–14 condition monitoring (in March 2014). Therefore, there is no evidence that the species recruited at the site in 2013–14, and the presence of a self-sustaining population is unlikely.

In March 2012, approximately 280 southern pygmy perch were released near site 32 through the CFH project (Bice et al. 2012). Only two adult southern pygmy perch (52 and 56 mm TL) were re-captured (calcién detected) in November 2012. Subsequently, the species has not been recorded at the site. Therefore, there is no evidence of recruitment by southern pygmy perch at site 32 over 2013–14. The presence of a self-sustaining population at the site is unlikely.

It is apparent that Murray hardyhead and southern pygmy perch have been unable to establish self-sustaining populations at the site. The physical habitat (abundant aquatic plants) appears ideal for the threatened fishes, so the reasons for their lack of breeding and recruitment since re-stocking are unclear. Possibly the naïve re-stocked fish were highly vulnerable to predation. In this instance, redfin perch presents a significant threat to Murray hardyhead and southern pygmy perch, because it is a highly efficient, opportunistic predator in the Lower Lakes from approximately 80 mm TL upwards (Wedderburn et al. 2012b). Further with regards to southern pygmy perch, the elevated salinity levels are likely to be unsuitable at times (e.g. 1.5 g/L or 2,816 EC in November 2013).



Mundoo Island site 32 in November 2012 (left) and the same site with abundant hornwort in March 2014 (right).

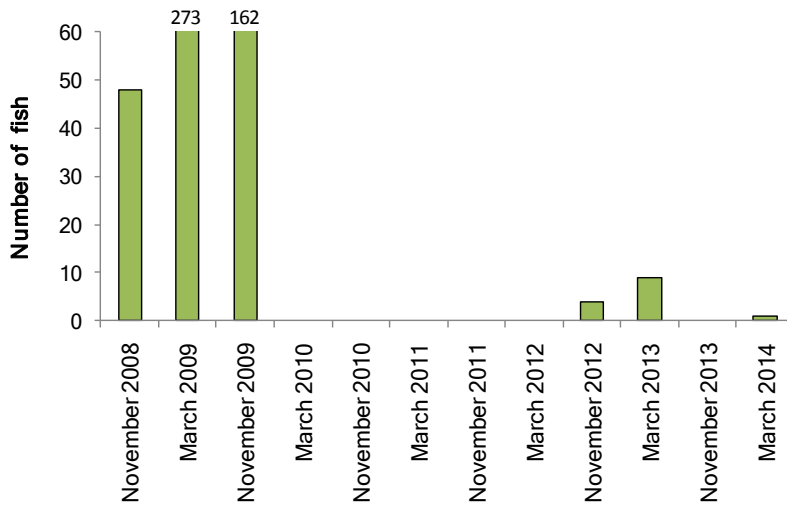


Figure 35. Numbers of Murray hardyhead captured at Mundoo Island (site 32) in the last six TLM condition monitoring events (total numbers of fish above bars for March and November 2009).

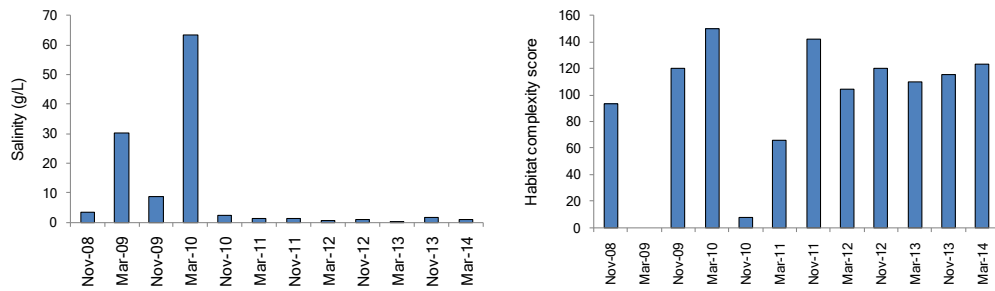


Figure 36. Corresponding changes in salinity and habitat complexity score at Mundoo Island (site 32) from November 2008 to March 2014.

The fish assemblage at site 32 on Mundoo Island has varied widely over the last six November TLM condition monitoring events (Figure 37). Murray hardyhead was one of the most abundant species from November 2008 to November 2009. Since the site’s re-connectivity with Lake Alexandrina after drought, the fish assemblage has consisted of non-threatened native fish species and alien fishes. The low numbers of Murray hardyhead and southern pygmy perch recorded in 2012–13 were re-captured from earlier CFH reintroductions. In 2013–14, the fish assemblage at site 32 consisted of ecological generalists, predominantly flathead gudgeon, carp gudgeon and eastern Gambusia. This might suggest that the habitat is yet to develop into a state that is suitable for the threatened fish species, which are ecological specialists. Interestingly, the habitat superficially appears suitable for Murray hardyhead. The underlying factors will remain unknown until targeted investigations reveal the determinants of distribution and abundance for the threatened fishes in the Lower Lakes.



The only Murray hardyhead captured at site 32 Mundoo Island in March 2014.

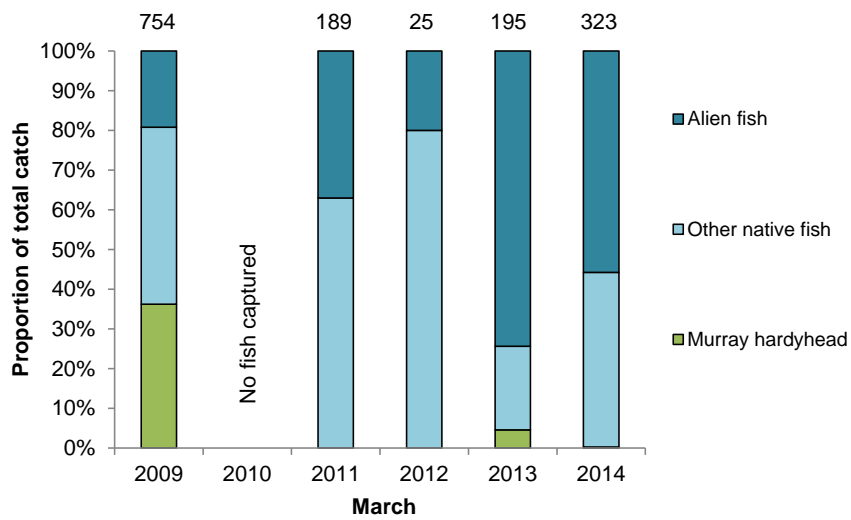
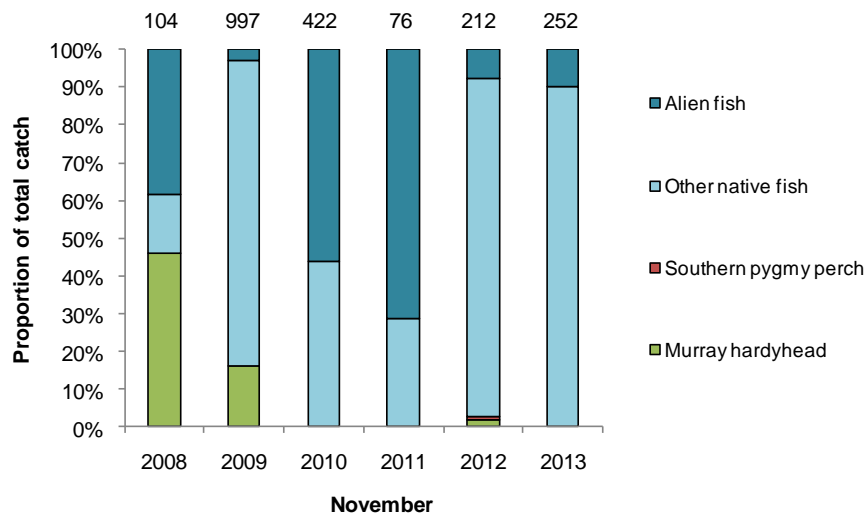


Figure 37. Comparison of composition and total abundance (value above bar) in fish assemblages at Mundoo Island (site 32) for the last six November (top) and March (bottom) TLM condition monitoring events (Murray hardyhead recorded in November 2012 and March 2013 were reintroduced through the CFH project).

Shadows Lagoon (site 34)

This site is located in the north-east of Shadows Lagoon on Hindmarsh Island (also known as 'The Shadows'). The site was initially sampled in 2008–09 TLM condition monitoring, when southern pygmy perch was recorded (Wedderburn and Barnes 2009). However, the species remained undetected at the site from 2009 to 2012. Approximately 1500 and 250 Yarra pygmy perch were re-stocked at the site in March 2012 and December 2012, respectively, through the CFH project (Bice et al. 2012). Salinity has remained relatively low at the site (Figure 38); even during the drought when possibly groundwater influenced the remaining waterhole. Habitat complexity score has always been relatively high, due to a constant abundance of aquatic plants. During the drought, habitat consisted of stoneworts (*Chara sp.*), but in 2012–13 and 2013–14 ribbon weed and water fern were the major components of aquatic habitat.

Seven adult Yarra pygmy perch were captured at site 34 in November 2012, of which some were obviously recaptures (calcein marking detected) from the CFH reintroduction program (Wedderburn and Barnes 2013). Several of those, and the two small Yarra pygmy perch captured in March 2013, failed to give substantial calcein readings (Bice et al. 2013). Initial findings suggest they were recruited in the wild (Bice et al. 2014). Only a single Yarra pygmy perch was captured in November 2013 and another in March 2014. Their sizes are consistent with fish >1-year old (Figure 39). Therefore, there is no evidence of recruitment in the Yarra pygmy perch population at site 34 in 2013–14.



Shadows Lagoon in November 2012 (left) and March 2014 (right).

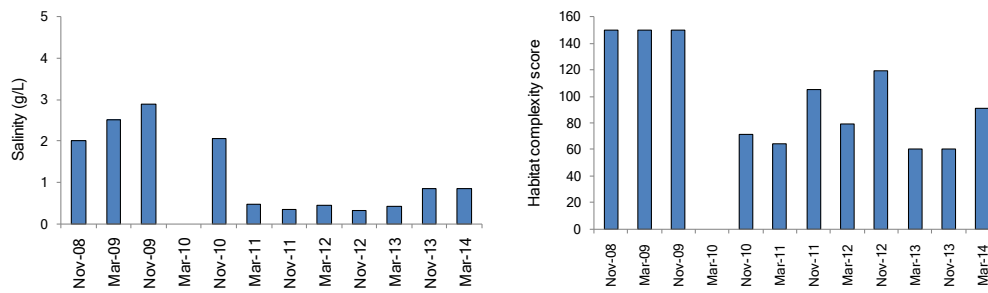


Figure 38. Corresponding changes in salinity and habitat complexity score at Shadows Lagoon from November 2008 to March 2014.

The fish assemblage was relatively diverse in November 2008, and included southern pygmy perch (Figure 40). Near the height of drought in November 2009, the alien eastern Gambusia was the only fish species captured. Immediately following the return of river flows that inundated and re-connected the site in 2010–11, the fish assemblage consisted only of extreme numbers of alien fish (predominantly young-of-the-year common carp and goldfish). The overall numbers of fish were very low in 2011–12. The fish assemblage included the native flathead gudgeon, but common carp dominated the catch. There was an increase in species diversity in 2012–13, as a result of the inclusion of low numbers of congolli and re-stocked Yarra pygmy perch. The fish assemblage was dominated by native and alien ecological generalists over 2013–14, when flathead gudgeon and eastern Gambusia predominated.



Shadows Lagoon viewed from the north-eastern shore.

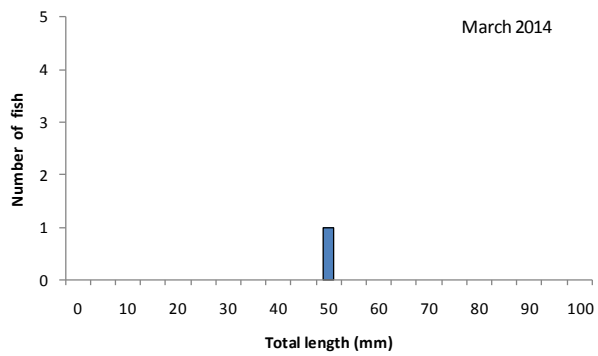
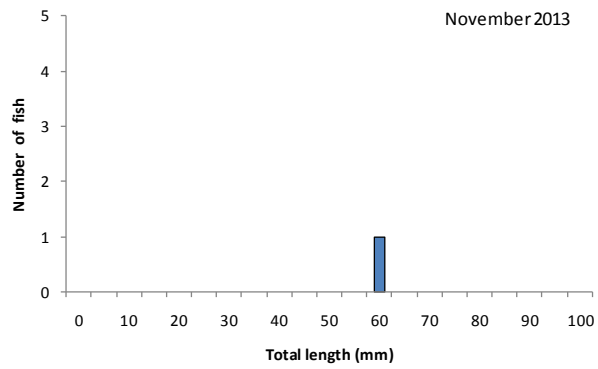


Figure 39. Length frequency distributions of Yarra pygmy perch captured at Shadow's Lagoon in November 2013 ($n = 1$) and March 2014 ($n = 1$).



The only Yarra pygmy perch captured during TLM and CFH project monitoring in November 2013 (left) and March 2014 (right).

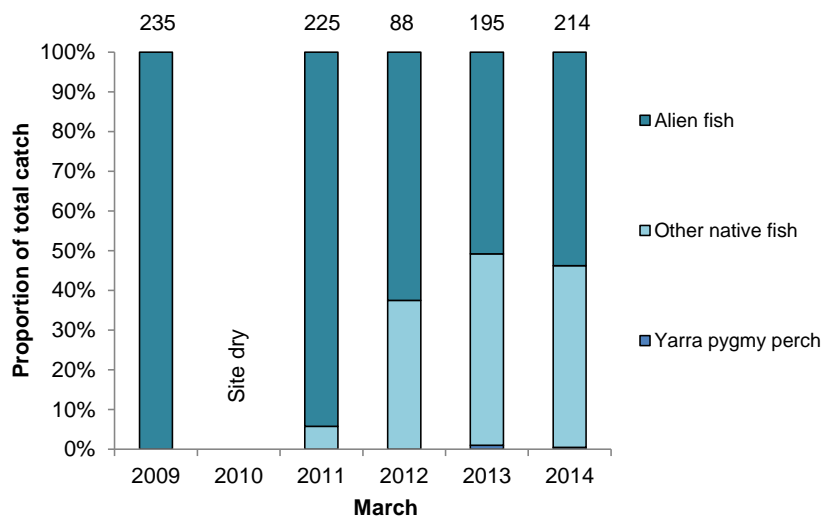
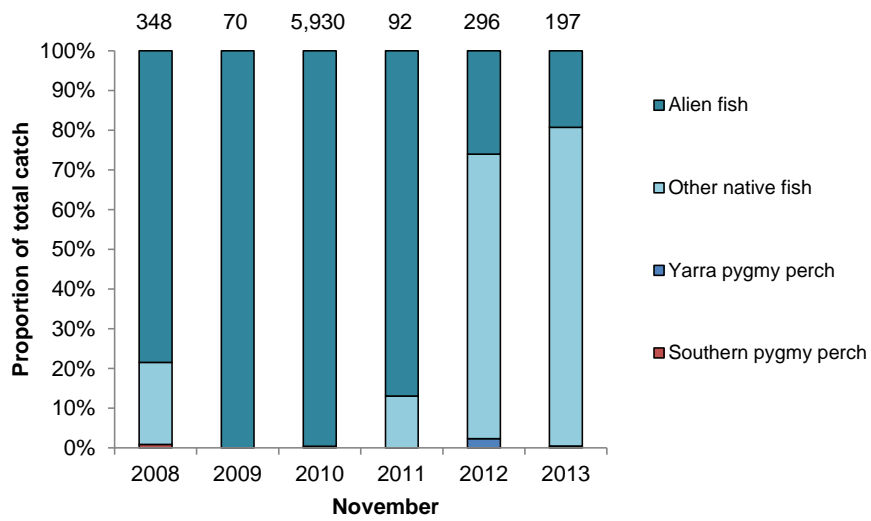


Figure 40. Comparison of composition and total abundance (value above bar) in fish assemblages at Shadow's Lagoon for the last six November (top) and March (bottom) TLM condition monitoring events.

Campbell House (site 36)

This lake-fringing site is adjacent to a modified channel near Campbell House, Lake Albert. There was evidence of recruitment in the Murray hardyhead population in 2008–09, during the drought (Wedderburn and Barnes 2009). Murray hardyhead has not been captured at this site since 2009 (Figure 41). Indeed, no fish were captured at this site in March 2010, when salinity was extremely high (49.1 g/L). Since the high freshwater inflows to Lake Albert in 2010, salinity at this site has been lower, which corresponds to an increase in freshwater aquatic plant cover (Figure 42).

The fish assemblage at the site was dominated by the estuarine western blue-spot goby from November 2009 to March 2010, when low numbers of Murray hardyhead were recorded (Figure 43). The fish assemblage was more diverse from November 2010, following the freshwater inflows. The fish assemblage included a number of estuarine (e.g. lagoon goby) and non-threatened freshwater (e.g. Australian smelt) species. The overall numbers of fish captured from March 2011 were substantially lower than during the same time in the previous two years. Overall fish numbers were again low in 2013–14, when estuarine and diadromous (e.g. common galaxias) fish species predominated (see appendices).



Habitat fringing Lake Albert at Campbell House in November 2009 at the height of drought (left), and in March 2014 (right).

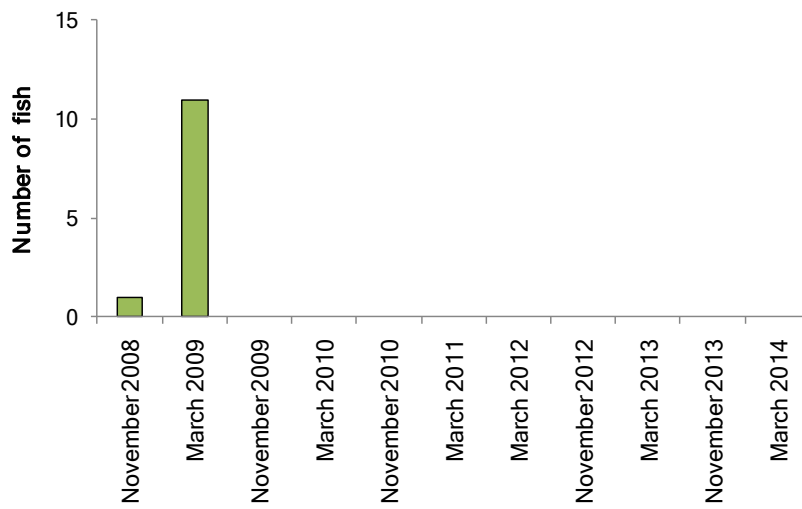


Figure 41. Numbers of Murray hardyhead captured from the edge of Lake Albert at Campbell House (site 30) since the site's inclusion in the TLM condition monitoring program.

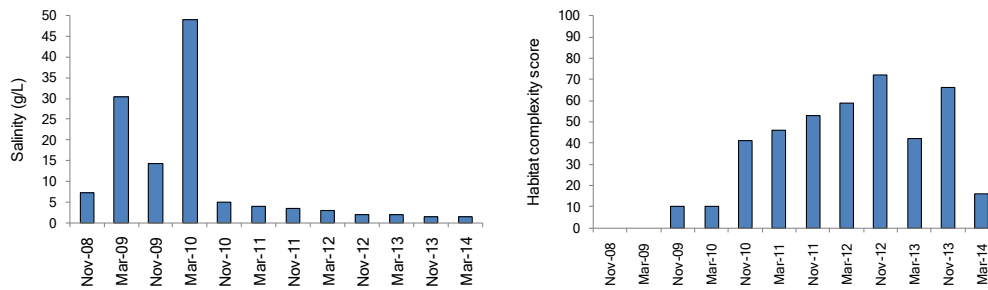


Figure 42. Corresponding changes in salinity and habitat complexity score in Lake Albert at Campbell House from November 2008 to March 2014.

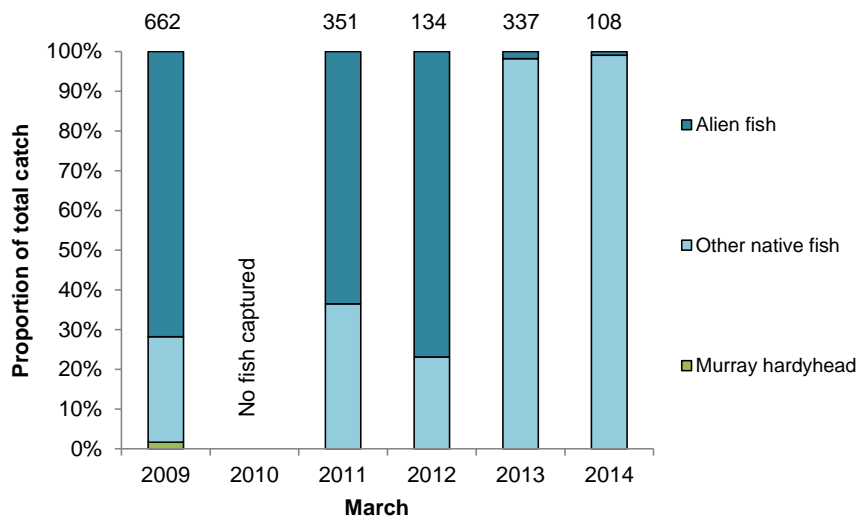
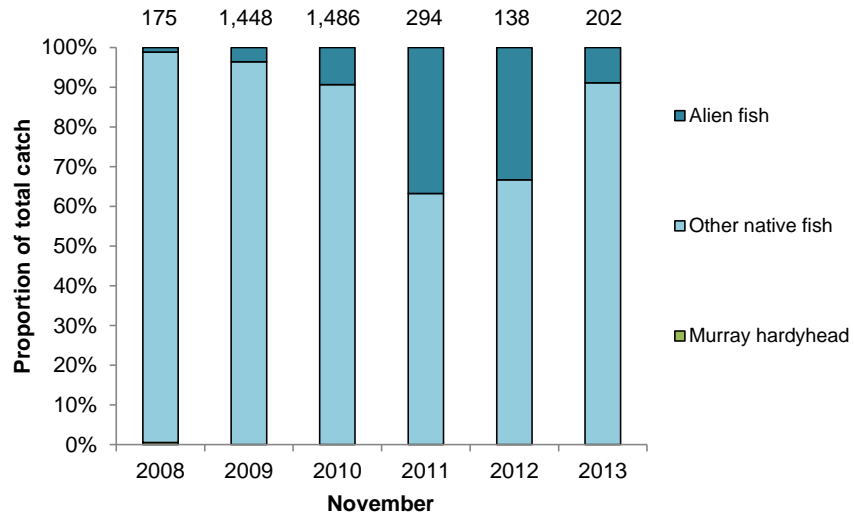


Figure 43. Comparison of composition and total abundance (value above bar) in fish assemblages at Campbell House for the last six November (top) and March (bottom) TLM condition monitoring events.

Turvey's Drain (site 37)

This site is in an irrigation channel that feeds directly off the northern shore of Lake Alexandrina. A relatively high number of southern pygmy perch was first recorded in November 2008 (Figure 44). There were indications that the species had undergone limited recruitment over the 2008–09 season (Bice et al. 2009), but only a single adult fish was capture in March 2010 (Bice et al. 2010). Two adult southern pygmy perch were captured in November 2010, but the species was undetected in March 2011 (Bice et al. 2011).

Under the CFH project, 400 southern pygmy perch were released into Turvey's Drain in November 2011 (Bice et al. 2012). One southern pygmy perch was recaptured a few weeks later and another in March 2012 (Bice et al. 2012). Southern pygmy perch was not recorded at the site in 2012–13 or 2013–14. The reintroduction attempt appears to have failed in Turvey's Drain.



Turvey's Drain in November 2008 when southern pygmy perch was abundant.
(photo: Michael Hammer)

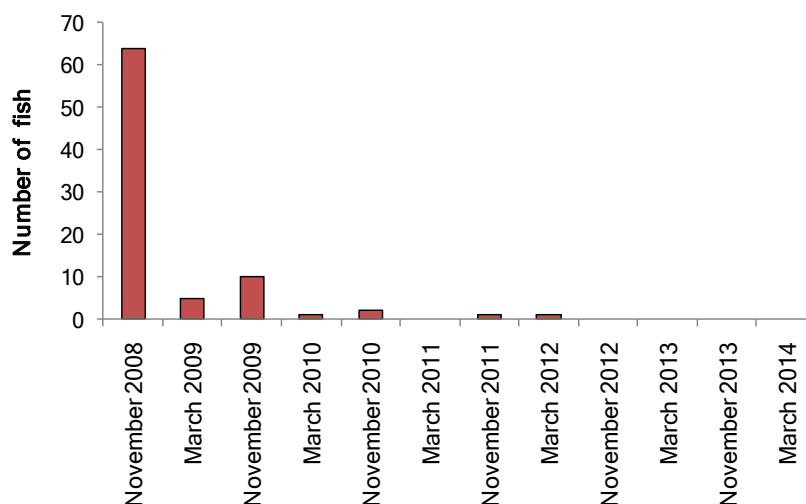


Figure 44. Numbers of southern pygmy perch captured at Turvey's Drain in DAP/CFH project monitoring in the last six seasons.

Murray hardyhead was also captured in Turvey’s Drain from November 2008 to November 2009, during drought (Figure 45). The species has not been captured at the site since the drought. Turvey’s Drain appears no longer suitable habitat for Murray hardyhead.

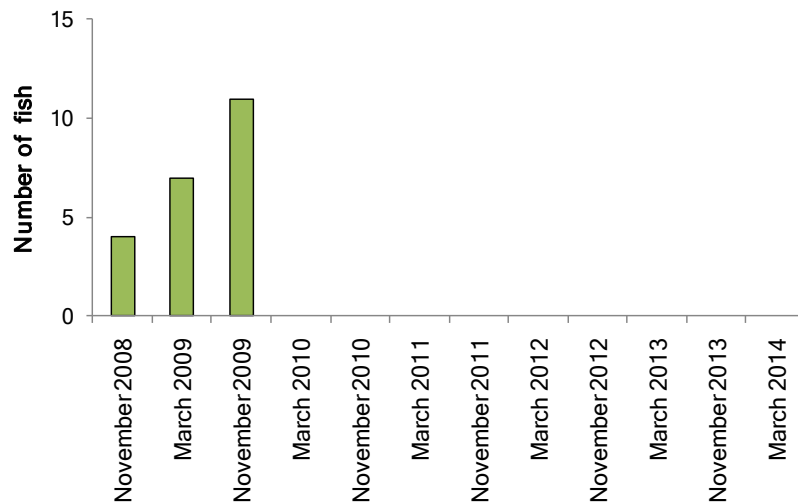


Figure 45. Numbers of Murray hardyhead captured at Turvey’s Drain in DAP/CFH project monitoring in the last six seasons.

Southern pygmy perch, other native fish (predominantly flathead gudgeon) and alien fish (predominantly eastern Gambusia) dominated the fish assemblage at Turvey’s Drain in November 2008 (Figure 46). The rise in overall numbers of fish captured in November 2009 is largely attributed to eastern Gambusia. Non-threatened native fish species dominated the catch in November 2010, but alien fish (predominantly common carp and goldfish) constituted more than half of the catch in November 2011. Very small numbers of fish were captured in November 2012 and November 2013. Alien fish dominated catches during all March sampling events, largely consisting of eastern Gambusia.

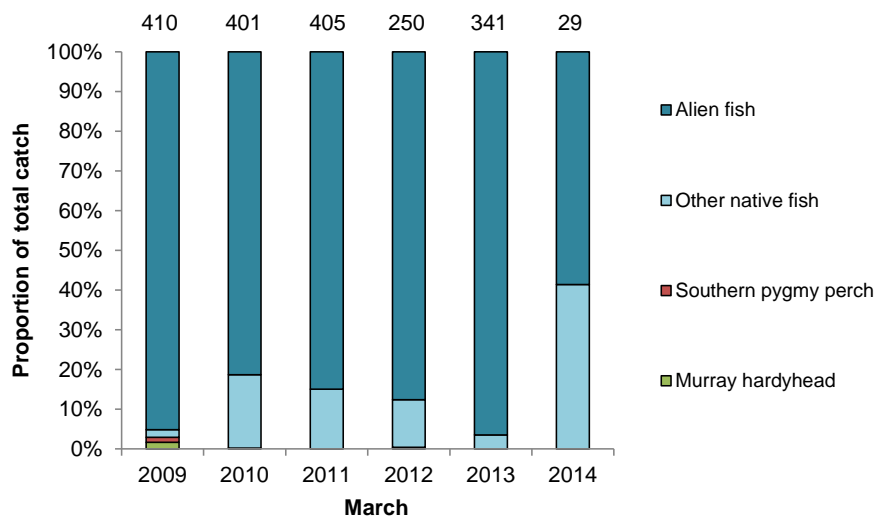
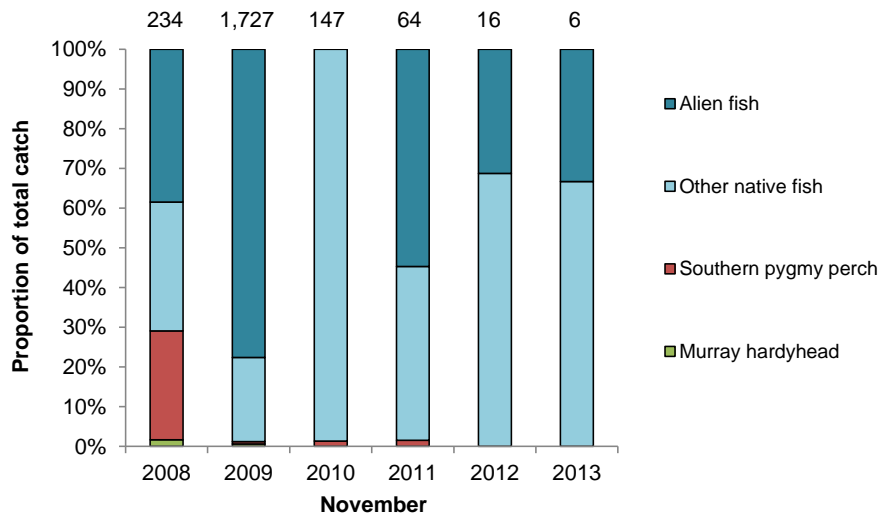


Figure 46. Comparison of composition and total abundance (value above bar) in fish assemblages at Turvey’s drain for the last six November (top) and March (bottom) DAP/CFH project sampling events.

Black Swamp (site 38)

This site is near the Tookayerta Creek junction on the Finnis River. Southern pygmy perch and Yarra pygmy perch were first recorded at the site in 2003 (Wedderburn and Hammer 2003). Only southern pygmy perch has been captured since. Black Swamp was dry by March 2009, but was inundated in September 2009 after installation of the Clayton regulator (see Bice and Zampatti 2011). Adult southern pygmy perch were then captured in low numbers from November 2009 to November 2010 (Figure 47). The species was not captured at Black Swamp in March 2011. Similarly, southern pygmy perch was not captured in the CFH project monitoring in 2011–12, 2012–13 and 2013–14 (Bice et al. 2012; Bice et al. 2013; Bice et al. 2014). It is unlikely that breeding and recruitment has occurred at Black Swamp since the drought.

As the site was drying in November 2008, a single carp gudgeon was the only fish captured (Figure 48). Southern pygmy perch dominated the fish assemblage in November 2009, with smaller proportions of alien fish and other native fish. A substantially higher number and greater diversity of fish was recorded in November 2010, which included a small proportion of southern pygmy perch. Thereafter, other non-threatened native fish species dominated the catches. The extremely low numbers of fish captured over 2013–14 did not include threatened species.

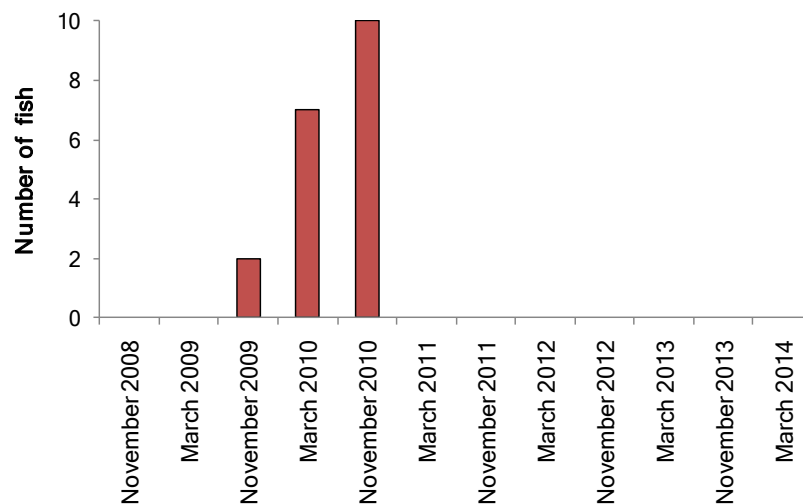


Figure 47. Numbers of southern pygmy perch captured at Black Swamp in DAP/CFH monitoring in the last six seasons.

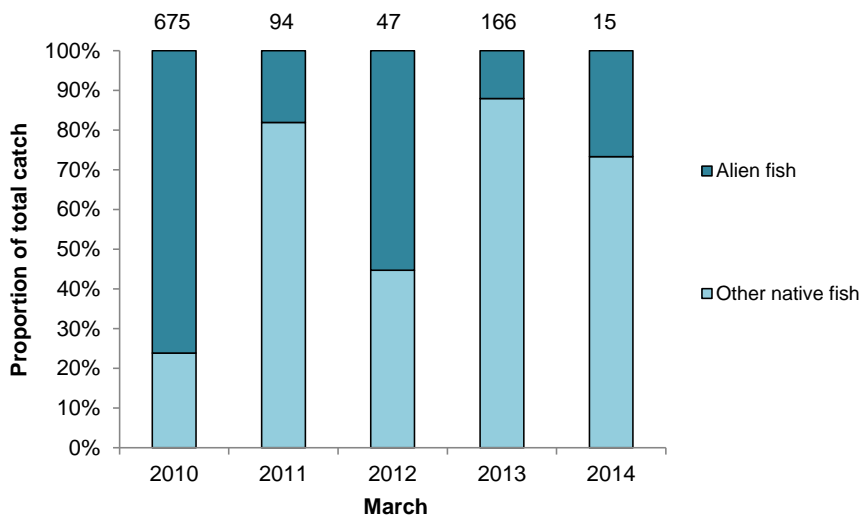
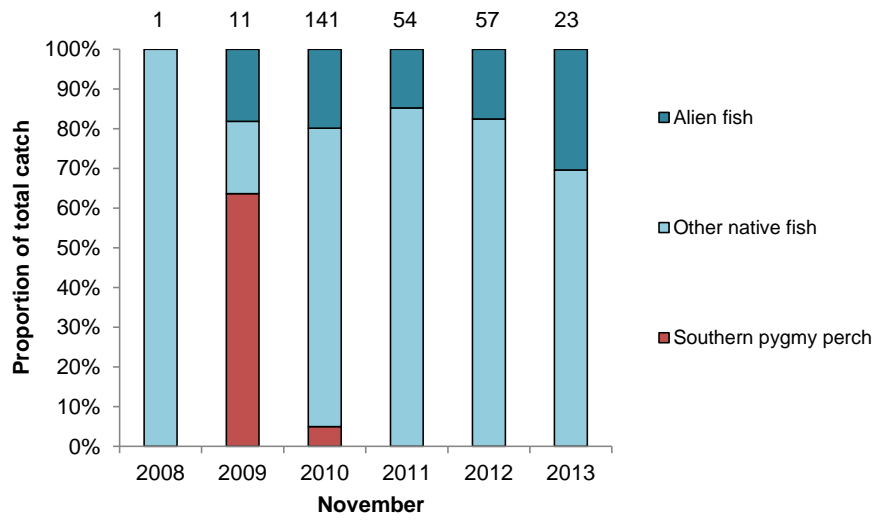


Figure 48. Comparison of composition and total abundance (value above bar) in fish assemblages at Black Swamp for the last six November (top) and March (bottom) sampling events (site not sampled in March 2009).

Discussion

The main objective of this study is to determine if recruitment was successful over the 2013–14 breeding-recruitment period for the three threatened fish species stated in The Living Murray's (TLM) Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Target F2 (Maunsell 2009). In the 2013–14 TLM condition monitoring, all three threatened fish species were captured in the Lower Lakes. In regards to Yarra pygmy perch and southern pygmy perch, this was solely because of reintroductions through the Critical Fish Habitat (CFH) project. Murray hardyhead was the only threatened fish species to show substantial levels of recruitment in the Lower Lakes in 2013–14, which meets the aims of the TLM Condition Monitoring Target. The species appears to be naturally recolonising two areas of the Lower Lakes. There was evidence of localised recruitment for southern pygmy perch on Mundoo Island, but the precarious nature of the small population means the Target was not achieved more widely for the Lower Lakes. More critically, there was no evidence of recruitment for Yarra pygmy perch. Its population recovery via the reintroductions was hindered by unknown factors. In this regard, the TLM Condition Monitoring Target F2 has failed for Yarra pygmy perch.

Self-sustaining populations of Murray hardyhead persisted in drought refugia from 2008 to 2010 (Wedderburn and Barnes 2009; Wedderburn and Hillyard 2010). There was no evidence of recruitment in 2010–11 (Bice et al. 2011; Wedderburn and Barnes 2011). In 2011–12, low numbers of Murray hardyhead were captured only at two sites (Wedderburn and Barnes 2012). The length frequency of Murray hardyhead captured in the Goolwa Channel area suggested low levels of recruitment in 2011–12 and 2012–13 (Bice et al. 2012; Bice et al. 2013; Wedderburn and Barnes 2012; Wedderburn and Barnes 2013). At the same time, there was no evidence of recruitment by the reintroduced Murray hardyhead in sites on Mundoo Island and Hindmarsh Island (Bice et al. 2013; Wedderburn and Barnes 2013), as was the case in 2013–14. Instead, the current study, and that of Bice et al. (2014), identified two self-sustaining populations of Murray hardyhead in 2013–14: in habitats associated with Goolwa Channel, and in Dog Lake. Notably, the Murray hardyhead population is yet to recover to its full natural range in the Lower Lakes, which included shallow, well-vegetated sites of elevated salinity in Lake Albert (see Wedderburn 2014).

Southern pygmy perch was abundant in the Hindmarsh Island region of the Lower Lakes in early 2003 (Wedderburn and Hammer 2003). A population collapse during the recent prolonged drought led to its local extinction by 2010 (Wedderburn et al. 2014). Through the CFH project, and based on habitat suitability, several hundred southern pygmy perch were released at Turvey's Drain, and sites on Hindmarsh Island and Mundoo Island from November 2011 to December 2012 (Bice et al. 2012; Bice et al. 2013). The species was undetected in Turvey's Drain in 2013–14 (Bice et al. 2014). The small, isolated southern pygmy perch population recorded on Mundoo Island in 2013–14 suggests that suitable habitats are yet to re-establish more broadly in the Lower Lakes. Alternatively, other factors have hindered recruitment and survival (e.g. predation by redfin perch on naïve re-stocked fish: Wedderburn et al. 2012b). In an extension of the current study, Wedderburn (2014) sampled a site connected to site 22 (i.e. approx. 400 m from the remaining southern pygmy perch population on Mundoo Island where redfin perch was absent). Southern pygmy perch was undetected, but several juvenile redfin perch were captured (Wedderburn 2014). There is a need to investigate possible relationships between the distribution and

abundance of the pygmy perch and redfin perch (Hammer et al. 2009; Wedderburn et al. 2012b). If borne out, the success of reintroductions could be established or improved by pre-removal of redfin perch from reintroduction sites.

Since preparation of the Yarra pygmy perch national recovery plan, the species' risk of extinction has increased throughout its range and few recovery actions have been completed (Saddler and Hammer 2010; Saddler et al. 2013). The genetically distinct MDB population of Yarra pygmy perch formerly inhabited the Finniss River confluence and the drainage systems on Hindmarsh Island (Hammer et al. 2010; Wedderburn and Hammer 2003). The species was extirpated from the Lower Lakes, and therefore the MDB, soon after it was last recorded in 2008 (Wedderburn et al. 2014). Almost 7000 Yarra pygmy perch were re-stocked in the Lower Lakes between 2011 and 2013 (Bice et al. 2014). The re-establishment of a self-sustaining Yarra pygmy perch population in the MDB relied solely on the success of the CFH project (Bice et al. 2012). Monitoring over 2012–13 captured nine Yarra pygmy perch after several thousand were released, and limited evidence of recruitment was observed. The absence of young-of-the-year Yarra pygmy perch in 2013–14 suggests the species is again on the verge of extinction in the MDB (see Wedderburn 2014).

Several non-threatened native fish species continue to show signs of population recovery since the drought. The re-connection of the Lower Lakes with the estuary obviously has benefitted catadromous fishes, such as congolli and common galaxias (see Zampatti et al. 2011). Dwarf flathead gudgeon, a freshwater ecological specialist, has returned to being captured in relatively high abundances at numerous sites. Similarly, unspotted hardyhead showed signs of returning to the Lower Lakes in high numbers at several sites in 2013–14. Therefore, despite the state of pygmy perch populations, there are other positive signs of recovery in the Lower Lakes fish assemblage.

During the 2010–11 high flow period following drought, fish assemblages in the Lower Lakes were dominated by alien species, namely young-of-the-year common carp, goldfish and redfin perch (Wedderburn and Barnes 2011). Overall abundances of most fish species decreased at the majority of sites between November 2010 and March 2011, but the species compositions were similar. In 2011–12, overall numbers of fish captured at most study sites declined since peaking in 2010–11. This is largely because lower numbers of common carp and goldfish were captured in 2011–12. Notably, the overall relative abundances of common carp and goldfish were substantially lower in 2012–13, and even more so in 2013–14. The relative abundance of redfin perch was the lowest in 2013–14 since the return of normal lake levels in 2010. Importantly, the decline of redfin perch might reduce the impacts of predation on the ability of pygmy perch to establish self-sustaining population through any future reintroduction attempts (see Wedderburn et al. 2012b).

Contrary to the other alien fish species, there was a substantial increase in the relative abundance of eastern *Gambusia* in 2013–14. Its abundance has increased substantially since declining during the high flow conditions of 2010–11. Indeed, eastern *Gambusia* constituted approximately a third of the overall catch in March 2014. The species is a potential threat to Murray hardyhead and the pygmy perch populations because of competition for resources and predation (Ellis et al. 2013; Saddler et al. 2013). Therefore, its interactions with the threatened fishes require examination to determine if it hinders recruitment and population recovery.

Recommendations

The Lower Lakes populations of the three threatened fishes represent distinct genetic management units within the MDB and Australia (Adams et al. 2011; Hammer et al. 2010; Unmack et al. 2013). Their conservation is critical from an ecological and evolutionary perspective. Wedderburn and Hammer (2003) first highlighted that specific information regarding the requirements for conservation of the threatened fishes was lacking. This is still the case in 2014, as highlighted by a secondary population crash in the pygmy perch populations (Wedderburn 2014). An increased understanding of the factors that drive and impact on recruitment and dispersal in the threatened fishes is required to address the downfalls of meeting the Condition Monitoring Target F2. Further, the key objective of the national recovery plans to 'prevent the extinction of Yarra pygmy perch and Murray hardyhead in the wild' (Saddler and Hammer 2010; Stoessel et al. 2014) will be addressed. Understanding these issues will assist management of their natural populations or future reintroduction attempts. The following are deemed priority themes for investigations, but the list is not exhaustive:

- (1) Monitor the impacts of redfin perch and eastern Gambusia on the three threatened species, particularly with regards to inhibition of recruitment and population recovery.
- (2) Examine the diet of, and food availability for, the three threatened species to determine if starvation is impacting on early life survivorship (e.g. in relation to flow regime, competition with eastern Gambusia).
- (3) Explore the dispersal ability of the three threatened species to gauge their capacity to naturally re-colonise suitable habitat.

Habitat will strongly influence the factors that drive and impact on recruitment of threatened fishes in the Lower Lakes (e.g. 1–3 above). Anecdotally, water level fluctuations in fringing habitats appear to substantially benefit threatened fish populations (Wedderburn and Hammer 2003; Wedderburn et al. 2010). Obviously, they are intrinsically linked to Lake Alexandrina water levels. Correct hydrological regimes (water levels, and timing and duration of inundation) in lake-fringing sites will establish aquatic plant assemblages and prey communities necessary for the threatened fishes. Although the fish populations are positively associated with some macrophyte species (e.g. water milfoil), our results anecdotally suggest that extreme high abundances of other plant species are deleterious (e.g. prolific cumbungi and hornwort). If borne out, hydrological regimes could be managed at individual sites to establish appropriate macrophyte assemblages, food resources and habitat connectivity for fish (1–3 above). In this regard, for example, managing flow regimes to enhance zooplankton prey for reproducing adult and young-of-the-year fish is beneficial for recruitment (cf. Wedderburn et al. 2010). In this case, Dog Lake provides an ideal site for the study of an isolated Murray hardyhead population. Alternatively, aquatic macrophyte control could be necessary where hydrological management is unfeasible. In this regard, sites on Hindmarsh Island and Mundoo Island, where threatened fish occur or occurred, are applicable for trials and investigations. This includes fish reintroduction sites. Notably, aquatic plant control is considered a viable option in the MDBA's Icon Site Plan.

Conclusions

The return of a self-sustaining population of Murray hardyhead somewhat signifies ecological recovery in the Lower Lakes following the prolonged drought. The recruitment of Murray hardyhead successfully addresses the Lower Lakes, Coorong and Murray Mouth Icon Site Condition Monitoring Target. The lack of recruitment in the Yarra pygmy perch population suggests a failed population recovery. Additional reintroductions of Yarra pygmy perch are required to meet the TLM Condition Monitoring Target. Fortunately, there are captive populations of Yarra pygmy perch that can be utilised. There was limited evidence of recruitment in southern pygmy perch, but the precarious nature of the population suggests the Target was not achieved for the Lower Lakes. The remaining population of southern pygmy perch should be carefully monitored, and greater protection should be afforded.

Acknowledgements

This project was funded by The Living Murray initiative of the Murray–Darling Basin Authority. The project has been managed by the Department of Environment, Water and Natural Resources, through the Lower Lakes, Coorong and Murray Mouth Icon Site staff (Adrienne Frears, Kirsty Wedge and Claire Sims). We acknowledge the people of the Ngarrindjeri Nation as the traditional custodians of the land on which this study was undertaken. Thanks to Owen Love, Tom Trevorow Jr, Cyril Trevorow and Russell Rigney from the Ngarrindjeri Regional Authority for their valued field assistance. Thank you to the landholders who allowed access to sites, including Colin and Sally Grundy (Mundoo Island), Phil and Yvonne Giles (Nindethana), Lesley and Mick Fischer (Campbell House), Nigel Treloar (Belcanoe), Kevin and Benita Wells (Shadows Lagoon), Ack and Jenny Vercoe (Dog Lake), Chris and Beth Cowan (Poltalloch) and Amanda Burger (Boggy Creek). Thank you to Stuart Hicks (DEWNR) for allowing access to sites in Wyndgate Conservation Park on Hindmarsh Island. Thanks to Chris Bice and Nick Whiterod for use of their data in this report. Sampling was conducted in accordance with the University of Adelaide’s Animal Ethics Policy (approval number S-2012-167) and the *Fisheries Management Act 2007* Section 115 (exemption numbers 9902595 and 9902676).

References

- Adams, M., S. D. Wedderburn, P. J. Unmack, M. P. Hammer and J. B. Johnson (2011). Use of congeneric assessment to reveal the linked genetic histories of two threatened fishes in the Murray–Darling Basin, Australia. *Conservation Biology* **25**: 767–776.
- Bice, C., M. Hammer, S. Leigh and B. Zampatti (2010). Fish monitoring for the ‘Drought Action Plan for South Australian Murray–Darling Basin threatened freshwater fish populations’: Summary for 2009/10. SARDI Aquatic Sciences, Adelaide, 156.
- Bice, C., M. Hammer, P. Wilson and B. Zampatti (2009). Fish monitoring for the ‘Drought Action Plan for South Australian Murray–Darling Basin threatened freshwater fish populations’: Summary for 2008/09. SARDI Aquatic Sciences, Adelaide, 110.
- Bice, C., M. Hammer, P. Wilson and B. Zampatti (2011). Fish monitoring for the ‘Drought Action Plan for South Australian Murray–Darling Basin threatened freshwater fish populations’: summary for 2010/11. SARDI Aquatic Sciences, Adelaide, 214.

- Bice, C., N. Whiterod, P. Wilson, B. Zampatti and M. Hammer (2012). The Critical Fish Habitat Project: Reintroductions of Threatened Fish Species in the Coorong, Lower Lakes and Murray Mouth region in 2011/12. SARDI Aquatic Sciences, Adelaide, 43.
- Bice, C., N. Whiterod, P. Wilson, B. Zampatti and M. Hammer (2013). The Critical Fish Habitat Project: Reintroductions of Threatened Fish Species in the Coorong, Lower Lakes and Murray Mouth region in 2012–13. SARDI Aquatic Sciences, Adelaide, 67.
- Bice, C., N. Whiterod, B. Zampatti and M. Hammer (2014). The Critical Fish Habitat Project: Assessment of reintroduction success of threatened species in the Coorong, Lower Lakes and Murray Mouth region 2011–2014. SARDI Aquatic Sciences, Adelaide, 39.
- Bice, C., P. Wilson and Q. Ye (2008). Threatened fish populations in the Lower Lakes of the River Murray in spring 2007 and summer 2008. SARDI Aquatic Sciences, Adelaide, 31.
- Bice, C. M. and Q. Ye (2006). Monitoring threatened fish communities on Hindmarsh Island, in the Lower Lakes of the River Murray, South Australia in 2005. SARDI Aquatic Sciences, Adelaide.
- Bice, C. M. and Q. Ye (2007). Monitoring threatened fish communities on Hindmarsh Island, in the Lower Lakes of the River Murray, South Australia, in the summers of 2006 and 2007 with reference to baseline data from 2005. SARDI Aquatic Sciences, Adelaide, 47.
- Bice, C. M. and B. P. Zampatti (2011). Engineered water level management facilitates recruitment of non-native common carp, *Cyprinus carpio*, in a regulated lowland river. *Ecological Engineering* **37**: 1901–1904.
- Brandle, R. (2002). A Biological Survey of the Murray Mouth Reserves, South Australia March 2002. Department for Environment and Heritage.
- Eastburn, D. (1990). The river. In Mackay, N. & D. Eastburn (eds) The Murray. Murray–Darling Basin Commission, Canberra, 3–15.
- Ellis, I. M., D. Stoessel, M. P. Hammer, S. D. Wedderburn, L. Suitor and A. Hall (2013). Conservation of an inauspicious endangered freshwater fish, Murray hardyhead (*Craterocephalus fluviatilis*), during drought and competing water demands in the Murray–Darling Basin, Australia. *Marine and Freshwater Research* **64**: 792–806.
- Fratto, Z. W., V. A. Barko and J. S. Scheibe (2008). Development and efficacy of a bycatch reduction device for Wisconsin-type fyke nets deployed in freshwater systems. *Chelonian Conservation and Biology* **7**: 205–212.
- Hammer, M., S. Wedderburn and J. van Weenan (2009). Action Plan for South Australian Freshwater Fishes. Native Fish Australia (SA), Adelaide.
- Hammer, M., S. Wedderburn and S. Westergaard (2002). Freshwater fishes. In Brandle, R. (ed) A Biological Survey of the Murray Mouth Reserves, South Australia. Department for Environment and Heritage, Adelaide, 54–61.
- Hammer, M. P., M. Adams and R. Foster (2012). Update to the catalogue of South Australian freshwater fishes (Petromyzontida & Actinopterygii). *Zootaxa* **3593**: 59–74.
- Hammer, M. P., P. J. Unmack, M. Adams, J. B. Johnson and K. F. Walker (2010). Phylogeographic structure in the threatened Yarra pygmy perch *Nannoperca obscura* (Teleostei: Percichthyidae) has major implications for declining populations. *Conservation Genetics* **11**: 213–223.

- Higham, J., Q. Ye and B. Smith (2005). Murray–Darling Basin drought monitoring: monitoring small bodied fish in the Lower Murray during and after drought conditions in 2003–2004. SARDI Aquatic Sciences, Adelaide, 40.
- Maunsell (2009). Lower Lakes, Coorong and Murray Mouth Condition Monitoring Plan. Report prepared for the South Australian Murray–Darling Basin Natural Resources Management Board. Adelaide.
- McCune, B. and M. J. Mefford (2011). PC-ORD. Multivariate Analysis of Ecological Data. Version 6. MjM Software, Gleneden Beach, Oregon, U.S.A.
- Saddler, S. and M. Hammer (2010). National recovery plan for the Yarry Pygmy Perch *Nannoperca obscura*. Department of Sustainability and Environment, Melbourne, 20.
- Saddler, S., J. Koehn and M. Hammer (2013). Let's not forget the small fishes: conservation of two threatened species of pygmy perch in south-eastern Australia. *Marine and Freshwater Research* **64**: 874–886.
- Stoessel D., I. Ellis and M. Riedere (2014). Revised National Recovery Plan for the Murray hardyhead *Craterocephalus fluviatilis*. Department of Environment and Primary Industries, Melbourne.
- Unmack, P. J., M. P. Hammer, M. Adams, J. B. Johnson and T. E. Dowling (2013). The role of continental shelf width in determining freshwater phylogeographic patterns in south-eastern Australian pygmy perches (Teleostei: Percichthyidae). *Molecular Ecology* **22**: 1683–1699.
- Wager, R. and P. Jackson (1993). The Action Plan for Australian Freshwater Fishes. Australian Nature Conservation Agency, Canberra.
- Wedderburn, S. (2014). An Assessment of Threatened Fish Populations in Lake Alexandrina and Lake Albert, South Australia. The University of Adelaide, Adelaide.
- Wedderburn, S. and T. Barnes (2009). Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2008–2009). The University of Adelaide, Adelaide, 40.
- Wedderburn, S. and T. Barnes (2011). Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2010–2011). The University of Adelaide, Adelaide, 41.
- Wedderburn, S. and T. Barnes (2012). Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2011–2012). The University of Adelaide, Adelaide, 62.
- Wedderburn, S. and T. Barnes (2013). Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2012–2013). The University of Adelaide, Adelaide, 64.
- Wedderburn, S., T. Barnes and M. Geddes (2012b). Intervention monitoring of redfin in regards to diet overlap with golden perch and its potential to prey on threatened native fishes in the Lower Lakes. The University of Adelaide, 27.
- Wedderburn, S. and M. Hammer (2003). The Lower Lakes Fish Inventory: Distribution and Conservation of Freshwater Fishes of the Ramsar Convention Wetland at the Terminus of the Murray Darling Basin, South Australia. Native Fish Australia (SA), Adelaide, 38.
- Wedderburn, S. and K. Hillyard (2010). Condition Monitoring of Threatened Fish Species at Lake Alexandrina and Lake Albert (2009–2010). The University of Adelaide, Adelaide, 42.
- Wedderburn, S., R. Shiel, K. Hillyard and J. Brookes (2010). Zooplankton response to watering of an off-channel site at the Lower Lakes and implications for Murray hardyhead recruitment. The University of Adelaide, Adelaide, 52.

- Wedderburn, S. D., T. C. Barnes and K. A. Hillyard (2014). Shifts in fish assemblages indicate failed recovery of threatened species following prolonged drought in terminating lakes of the Murray–Darling Basin, Australia. *Hydrobiologia* **730**: 179–190.
- Wedderburn, S. D., M. P. Hammer and C. M. Bice (2012a). Shifts in small-bodied fish assemblages resulting from drought-induced water level recession in terminating lakes of the Murray–Darling Basin, Australia. *Hydrobiologia* **691**: 35–46.
- Wedderburn, S. D., K. A. Hillyard and R. J. Shiel (2013). Zooplankton response to flooding of a drought refuge and implications for the endangered fish species *Craterocephalus fluviatilis* cohabiting with alien *Gambusia holbrooki*. *Aquatic Ecology* **47**: 263–275.
- Wedderburn, S. D., K. F. Walker and B. P. Zampatti (2007). Habitat separation of *Craterocephalus* (Atherinidae) species and populations in off-channel areas of the lower River Murray, Australia. *Ecology of Freshwater Fish* **16**: 442–449.
- Zampatti, B. P., C. M. Bice and P. R. Jennings (2011). Movements of female congolli (*Pseudaphritis urvilli*) in the Coorong and Lower Lakes of the River Murray. SARDI Aquatic Sciences, Adelaide, 32.

Appendix 1. The Living Murray condition monitoring fish catch summary November 2013

Site	Murray hardyhead <i>Craterocephalus fluviatilis</i>	Unspecked hardyhead <i>C. s. fulvus</i>	Smallmouth hardyhead <i>Atherinosoma microstoma</i>	Southern pygmy perch <i>Nannoperca australis</i>	Yarra pygmy perch <i>Nannoperca obscura</i>	Bony herring <i>Nematalosa erebi</i>	Common galaxias <i>Galaxias maculatus</i>	Australian smelt <i>Retropinna semoni</i>	Lagoon goby <i>Tasmanogobius lasti</i>	Congolli <i>Pseudaphritis urvillii</i>	Flathead gudgeon <i>Philypnodon grandiceps</i>	Dwarf flathead gudgeon <i>P. macrostomus</i>	Carp gudgeon <i>Hypseleotris spp.</i>	Tamar River goby <i>Afurcagobius tamarensis</i>	Western blue spot goby <i>Pseudogobius olorum</i>	Golden perch <i>Macquaria ambigua</i>	River Murray rainbowfish <i>Melanotaenia fluviatilis</i>	Sandy sprat <i>Hyperlophus vittatus</i>	Greenback flounder <i>Rhombosolea tapirina</i>	Redfin <i>Perca fluviatilis</i>	Gambusia <i>Gambusia holbrooki</i>	Carp <i>Cyprinus carpio</i>	Goldfish <i>Carassius auratus</i>	Tench <i>Tinca tinca</i>
2	0	0	0	1	0	0	2	0	0	6	10	0	0	0	5	0	0	0	0	0	4	3	0	
4	0	0	0	0	0	6	0	2	0	3	53	0	0	0	0	3	0	0	12	1	1	3	0	
6	0	1	0	0	0	0	14	20	5	11	7	0	2	0	0	0	0	0	1	0	2	8	0	
9	0	0	0	0	0	0	1	0	0	4	12	6	0	0	0	0	0	0	1	4	2	0	0	
10	0	3	0	0	0	10	31	14	4	15	4	0	2	0	0	0	0	0	9	7	0	3	0	
11	0	0	0	0	0	0	43	0	0	8	35	1	2	0	0	1	0	0	3	0	1	0	0	
15	0	0	0	0	0	0	5	2	1	2	26	1	11	0	1	0	0	0	1	0	0	4	1	
16	0	1	0	0	0	0	0	0	0	5	21	2	2	0	0	0	0	16	0	2	0	1	0	
19	0	7	0	0	0	0	1	8	6	5	61	0	0	1	1	0	0	0	9	0	12	5	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	51	0	0	0	
25	2	1	1	0	0	1	9	110	12	9	23	0	4	1	1	0	0	0	10	1	2	5	0	
26	0	2	0	0	0	4	35	11	0	6	31	5	4	0	0	0	0	0	20	11	1	1	0	
27	0	1	0	0	0	1	15	10	20	3	8	0	0	0	0	0	0	0	4	6	8	0	0	
28	0	0	0	0	0	4	10	50	1	30	0	0	0	1	0	0	0	0	4	0	0	0	0	
29	0	1	0	0	0	0	5	0	0	5	8	1	1	0	0	0	3	0	3	3	0	2	0	
30	0	0	0	0	0	0	0	1	0	2	13	0	1	0	1	0	0	0	1	4	0	1	0	
31	0	0	0	0	0	0	1	0	0	2	26	2	95	0	0	0	0	0	1	3	31	0	0	
32	0	0	0	0	0	0	0	0	0	0	73	0	154	0	0	0	0	0	0	25	0	0	0	
34	0	0	0	0	1	1	0	19	0	5	99	3	16	0	0	0	0	0	6	4	16	12	0	
36	0	0	25	0	0	0	29	52	29	4	14	0	0	5	26	0	0	0	8	0	1	9	0	
48	0	1	0	0	0	0	65	12	0	23	33	0	1	0	11	0	0	0	4	0	0	1	0	
49	0	0	47	0	0	89	29	139	62	2	70	0	0	12	13	0	0	0	56	0	0	1	0	
60	0	0	0	0	0	0	0	0	0	2	10	2	0	0	0	0	0	0	3	0	0	0	0	
62	0	0	50	0	0	2	31	1	0	8	50	2	0	0	49	0	0	0	5	6	0	0	0	

Appendix 2. The Living Murray condition monitoring fish catch summary March 2014

Site	Murray hardyhead <i>Craterocephalus fluviatilis</i>	Unspecked hardyhead <i>C. s. fulvus</i>	Small-mouth hardyhead <i>Atherinosoma microstoma</i>	Southern pygmy perch <i>Nannoperca australis</i>	Yarra pygmy perch <i>Nannoperca obscura</i>	Bony herring <i>Nematalosa erebi</i>	Common galaxias <i>Galaxias maculatus</i>	Australian smelt <i>Retropinna semoni</i>	Lagoon goby <i>Tasmanogobius lasti</i>	Congoli <i>Pseudaphritis urvillii</i>	Flathead gudgeon <i>Philypnodon grandiceps</i>	Dwarf flathead gudgeon <i>P. macrostomus</i>	Carp gudgeon <i>Hypseleotris spp.</i>	Tamar River goby <i>Afurcagobius tamarensis</i>	Western blue spot goby <i>Pseudogobius olorum</i>	Sandy sprat <i>Hyperlophus vittatus</i>	River garfish <i>Hyporhamphus regularis</i>	Golden perch <i>Macquaria ambigua</i>	River Murray rainbowfish <i>Melanoetaenia fluviatilis</i>	Redfin <i>Perca fluviatilis</i>	Gambusia <i>Gambusia holbrooki</i>	Carp <i>Cyprinus carpio</i>	Goldfish <i>Carassius auratus</i>
2	0	0	0	0	0	0	0	0	0	0	61	8	0	0	5	0	0	0	0	0	144	7	0
4	0	10	0	0	0	22	5	0	0	0	16	0	0	0	0	0	0	1	0	3	0	7	0
6	1	8	0	0	0	18	18	3	0	10	71	1	0	0	0	0	0	1	0	6	10	2	0
9	0	0	0	0	0	0	1	0	0	1	10	3	0	0	0	0	0	0	0	0	41	0	2
10	0	43	0	0	0	10	24	2	0	2	17	2	2	0	1	0	0	0	0	3	16	0	1
11	0	0	0	0	0	3	1	0	0	4	5	0	0	0	0	0	0	0	0	0	189	0	0
15	0	0	0	0	0	2	32	0	0	8	6	0	0	0	1	0	0	0	0	11	12	1	0
16	0	0	0	0	0	15	1	0	0	10	7	0	0	0	0	1	0	0	0	6	15	0	0
19	0	0	0	0	0	20	6	0	0	2	23	0	0	0	0	0	0	1	0	4	1	5	0
22	0	0	0	14	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	177	0	0
25	7	1	0	0	0	37	54	6	2	5	16	0	0	0	1	0	0	0	0	4	75	0	3
26	22	36	0	0	0	9	114	12	0	1	71	0	0	0	0	0	1	0	0	4	295	3	0
27	0	0	0	0	0	38	68	0	0	7	4	0	0	0	2	0	0	0	0	4	39	2	1
28	0	0	0	0	0	26	26	0	0	7	8	0	0	0	0	0	0	0	0	9	3	3	3
29	0	7	1	0	0	96	15	0	0	5	28	0	0	0	0	0	0	0	1	2	6	0	0
30	0	1	0	0	0	45	2	0	0	3	7	0	2	0	1	0	0	0	0	5	15	0	1
31	0	0	0	0	0	0	0	0	0	0	2	3	37	0	0	0	0	0	0	0	3	0	1
32	1	0	1	0	0	0	0	0	0	2	117	2	20	0	0	0	0	0	0	0	178	0	2
34	0	0	0	0	1	0	20	0	0	3	75	0	0	0	0	0	0	0	0	1	105	9	0
36	0	0	1	0	0	19	23	13	1	0	32	0	0	5	1	0	0	0	0	1	0	0	0
48	0	0	0	0	0	36	65	26	0	7	2	0	0	0	8	0	0	0	0	0	1	2	0
49	0	0	3	0	0	52	36	5	15	5	45	0	0	0	20	0	0	0	0	1	9	0	0
60	0	0	0	0	0	23	0	0	0	3	13	0	0	0	0	0	0	1	0	1	0	0	0
62	0	0	12	0	0	61	66	9	1	4	33	0	0	0	6	0	0	0	0	3	180	0	0

