Inland Waters &
Catchment Ecology

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Fish monitoring for the 'Drought Action Plan for South Australian Murray-Darling Basin threatened freshwater fish populations': Summary for 2010/11

C. Bice, M. Hammer, P. Wilson and B. Zampatti

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Cover: (Clockwise from top left) Angas River gauge site, young-of-year river blackfish (*Gadopsis marmoratus*), Turvey's Drain and Murray hardyhead (*Craterocephalus fluviatilis*).

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1. EXECUTIVE SUMMARY

A combination of over-abstraction of water and persistent drought conditions in south-eastern Australia from 1997-2010, resulted in significantly diminished inflows to the South Australian Murray-Darling Basin (MDB) over the period 2006-2010. This had many significant impacts on aquatic systems and indeed entire regions, including severe water level recession in the Lower Lakes, extensive disconnection and desiccation of wetlands associated with the River Murray and fragmentation and desiccation of tributaries in the eastern Mount Lofty Ranges (EMLR). Hydrological conditions across the South Australian MDB in 2010/11 were vastly improved relative to preceding years, with significant inflows in the River Murray and tributaries of the EMLR and a return of typical water levels in the Lower Lakes.

There are currently five species of small and medium-bodied freshwater fish of national or state conservation significance in the South Australian MDB; namely Yarra pygmy perch (*Nannoperca obscura*) and Murray hardyhead (*Craterocephalus fluviatilis*), listed as *vulnerable* under the *EPBC Act* (1999), and river blackfish (*Gadopsis marmoratus*), southern purple-spotted gudgeon (*Mogurnda adspersa*) and southern pygmy perch (*Nannoperca australis*), protected under the state *Fisheries Management Act* (2007). The remaining populations of all five species were exposed to a considerable threat of extirpation by the predominating drought conditions. Subsequently, the South Australian Department of Environment and Natural Resources (DENR) initiated the 'Drought Action Plan (DAP) for South Australian MDB threatened freshwater fish populations' with the aim of providing a framework for the management and conservation of these populations during unfavourable conditions. Since 2007, the DAP has been underpinned and informed by extensive monitoring of known wild populations, and subsequently involved several conservation measures including in-situ maintenance of populations (i.e. on-ground management intervention (e.g. environmental watering)), captive breeding and establishment of surrogate refuge populations for later reintroductions with the return of favourable environmental conditions.

As part of the DAP, 28 significant wild sites for these species within the South Australian MDB were monitored from 2008-2011. Fish populations were sampled, using a variety of techniques (i.e. electro-fishing, fyke nets, seine nets and/or box traps) in the spring and autumn of each year to monitor changes in abundance and

assess recruitment. Site condition assessments (i.e. water level, water quality and habitat cover) were undertaken in conjunction with fish sampling in spring and autumn, with additional assessments undertaken in winter and summer. Fish sampling and condition assessments allow temporal variation in population dynamics and site trends (e.g. declining water levels) to be investigated, thus identifying populations and sites that are at greatest risk and hence in need of immediate or future management intervention.

Additionally, from 2009-2011, four newly established surrogate refuge sites were monitored in alignment with wild site monitoring in spring and autumn. This monitoring aimed to investigate the status of these populations with respect to their suitability as source populations for later reintroductions upon the return of favourable environmental conditions at wild sites.

A summary of 2010/11 monitoring results is presented in Table 1, including site information (i.e. name, number, species originally present), fish population monitoring (i.e. abundances, evidence of recruitment), the status of water level (i.e. rising, falling, stable, dry) and brief comments on the site/population. This information was used to determine the level of risk (low, medium, high or population lost) for each population. The risk of species loss from a site was determined using the following criteria;

- Low risk (green) – moderate-high abundance in 2010/11, evidence of recent recruitment and favourable/improved habitat conditions.
- Moderate risk (orange) – moderate abundance in 2010/11, lack of recruitment in 2010/11 (river blackfish) and/or diminished habitat quality.
- High risk (red) – substantial declines in abundance (between spring 2010 and autumn 2011 or relative to 2008/09 and 2009/10), lack of recruitment (pygmy perch species, southern purple-spotted gudgeon and Murray hardyhead), extended lack of recruitment (i.e. >3 years, river blackfish) and/or severely diminished habitat quality.
- Population potentially lost (purple) - not detected in 2010/11

The return of favourable hydrological conditions to the South Australian MDB in 2010/11 resulted in improvements in the short to medium-term water security of most catchments and sites and generally facilitated improvements in aquatic habitats. Nonetheless, positive responses were only detected from a select number of wild threatened fish populations. Indeed, some species (i.e. Murray hardyhead), were sampled from fewer sites and in diminished abundance relative to preceding years. There are potentially several factors influencing these results, including potential dispersal and/or increased difficulty of detecting individuals during times of high water levels and increased habitat availability. Nevertheless, limited detection of positive population responses highlights the need for continuation of the DAP and transition into a 'recovery' phase to build on early success achieved by the project. Of particular importance is the development of a framework to guide the reintroduction of individuals bred in captivity, utilising best scientific practice, to ensure the greatest chance of positive outcomes for individual species. Furthermore, future conservation efforts should be focused upon further enhancing threatened fish populations (i.e. increasing abundance, distribution and connectivity between populations) to build a greater capacity to persist through both natural and human induced disturbances in the future.

Table 1. The population status of threatened fish species (abundance, recruitment and site conditions) at each site monitored under the Drought Action Plan and associated risk level to the persistence of the population in 2010/11 (colours: green – low risk, orange – medium risk, red – high risk, purple – population lost). NS = not sampled.

Site Name	DAP Site Number	Target species	No. caught spring 2010	No. caught autumn 2011	Recruitment within the last 12 months (Y/N)	Water level (Rising, stable, falling, dry)	Site comments
Jury Swamp	1.1.1	Southern purple spotted gudgeon	0	0	No	Stable	Likely lost but if still present abundance probably very low
Rodwell Creek	2.1.1	River blackfish	4	4	Yes	Variable (pumping)	Pool was maintained by watering prior to significant flows. Significant recruitment in 2010/11
Marne	2.2.1	River blackfish	3	1	No	Stable	No recruitment detected within last 4 years and may not have occurred for ≥9 years. Pool in poor condition (i.e. presence of unknown white plume on bottom of pool)
Angas Gauge	2.3.1	River blackfish	11	25	Yes	Seasonally variable	Pool in good condition, consistent abundances and recent recruitment evident.
Willowburn Road	2.4.1a	River blackfish	8	58	Yes	Seasonally variable	Pools in good condition (i.e. consistent cool base flow). High abundance and substantial recent recruitment in autumn 2011.
	3.4.1a	Southern pygmy perch	45	38	Yes	Seasonally variable	Pools in good condition (i.e. consistent cool base flow). High abundance and recent recruitment in autumn 2011.
Deep Creek Road	2.4.1b	River blackfish	1	8	Yes	Seasonally variable	Pool in good condition (i.e. consistent cool base flow). Consistent abundance and recent recruitment evident.
	3.4.1b	Southern pygmy perch	22	12	Yes	Seasonally variable	As above
Middle Creek Junction	3.1.1	Southern pygmy perch	69	15	Yes	Seasonally variable	Increase in abundance from 2010/11, improved habitat quality.
Boundary Creek Drain	3.2.1a	Southern pygmy perch	0	0	-	Stable	Population probably lost.
	4.1.1a	Yarra pygmy perch	0	0	-	Stable	Population probably lost. Potential re-introduction site?
	5.1.1a	Murray hardyhead	0	0	-	Stable	Population probably lost. Potential re-introduction site?
Eastick	3.2.1b	Southern pygmy perch	0	0	-	Stable	Population probably lost.
	4.1.1b	Yarra pygmy perch	0	0	-	Stable	Population probably lost. Potential re-introduction site?
	5.1.1b	Murray hardyhead	0	0	-	Stable	Population probably lost. Potential re-introduction site?
Steamer Drain	3.2.1c	Southern pygmy perch	0	0	-	Stable	Population probably lost.
	4.1.1c	Yarra pygmy perch	0	0	-	Stable	Population probably lost. Potential re-introduction site?
	5.1.1c	Murray hardyhead	0	0	-	Stable	Population probably lost. Potential re-introduction site?

Table 1 continued.

Site Name	DAP Site Number	Target species	No. caught spring 2010	No. caught autumn 2011	Recruitment within the last 12 months (Y/N)	Water level summer-autumn (Rising, stable, falling, dry)	Site comments
Black Swamp	3.2.2a	Southern pygmy perch	2	0	No	Stable	Population likely to be small. No individuals detected in autumn 2010. Conditions in the area may be favourable for this species with continued higher water levels and habitat regeneration.
	4.1.3	Yarra pygmy perch	0	0	-	Stable	Population probably lost
Black Swamp Drain	3.2.2	Southern pygmy perch	0	0	No	Stable	Potentially present given presence at Black Swamp but also may be absent. Conditions in the area may be favourable for this species with continued higher water levels and habitat regeneration.
Turvey's Drain	3.2.3	Southern pygmy perch	2	0	No	Stable	Despite environmental watering, marked decrease in abundance from 2008/09 and 2009/10 and no recruitment detected.
	5.1.3a	Murray hardyhead	0	0	No	Stable	As above
Meadows	3.3.1	Southern pygmy perch	28	48	Yes	Seasonally variable	Consistent or marginally increased numbers and significant recruitment, albeit restricted distribution within the site and potential for drying and fragmentation with extended periods of hot, dry weather.
Waterfalls	3.3.3	Southern pygmy perch	0	0	No	Seasonally variable	Following extended recruitment failure (>3 years) – population lost. Present further downstream
Inman	3.5.1	Southern pygmy perch	16	10	Yes	Seasonally variable	Abundance similar to 2009/10. Recruitment evident
Currency Creek	4.1.2A	Yarra pygmy perch	0	0	-	Stable	Population probably lost
	-	Murray hardyhead	109	0	No	Stable	Sampled in high abundance in spring but absent in autumn 2011. The species is highly mobile and dispersive and may have moved away from the site. Individuals may be present in local area.
Finniss River Confluence	4.1.2	Yarra pygmy perch	0	0	No	Stable	Population probably lost
	-	Murray hardyhead	0	0	No	Stable	Population lost from the site but may be present in local area.
Boggy Creek	5.1.1d	Murray hardyhead	0	0	No	Stable	Not detected throughout 2010/11. Likely moved dispersed from site with increased water level and connectivity. Individuals may be present in local area.
Mundoo Drain West		Murray hardyhead	NS	NS	No	Stable	Population was likely lost but requires further sampling to determine status.
		Southern pygmy perch	NS	NS	No	Stable	Population was likely lost but requires further sampling to determine status.

Table 1 continued.

Site Name	DAP Site Number	Target species	No. caught spring 2010	No. caught autumn 2011	Recruitment within the last 12 months (Y/N)	Water level summer-autumn (Rising, stable, falling, dry)	Site comments
Mundoo Drain East		Murray hardyhead	0	0	No	Stable	Population likely lost. Pools previously dried or very shallow. With increased water level, individuals may re-colonise or may be a favourable reintroduction site.
Clayton	5.1.2	Murray hardyhead	0	0	No	Stable	Individuals were sampled further within Dunn's Lagoon by Wedderburn and Barnes (In Prep) in spring 2010. Likely some individuals present in the local area.
Milang Jetty	5.1.3b	Murray hardyhead	0	0	No	Stable	Not sampled since spring 2010, population likely lost. However, water levels have now risen and as such conditions may become favourable for Murray hardyhead and the species may re-colonise the site if an appropriate source population exists.
Bremer River Mouth	5.1.3c	Murray hardyhead	0	0	No	Stable	Population likely lost. Habitat conditions have improved and the species may recolonise the site if an appropriate source population exists.
Rocky Gully	5.1.4	Murray hardyhead	26	14	Yes	Stable	This population has declined since autumn 2010, with increased water levels and connection with the River Murray. Individuals may have dispersed into the River Murray or increased water levels in Rocky Gully may have diluted individuals decreasing sampling efficiency. Furthermore, decreased salinity at this site may favour less salt tolerant species that may compete with Murray hardyhead.
Riverglades	5.1.5	Murray hardyhead	0	0	-	Stable	Population was lost following desiccation. With increased water levels and reinundation, site may become favourable for recolonisation or reintroduction.
Disher Creek	5.2.1	Murray hardyhead	15	0	No	Stable	Decreasing abundance and then absence in autumn 2011. High water levels and connectivity may have resulted in dispersal and/or dilution of individuals decreasing sampling efficiency. Follow up sampling required to determine status. Very high abundance of gambusia may be impacting Murray hardyhead
Berri	5.2.1	Murray hardyhead	3	0	No	Stable	Decreasing abundance and then absence in autumn 2011. High water levels and connectivity may have resulted in dispersal and/or dilution of individuals decreasing sampling efficiency. Continued increase in non salt-tolerant species that may compete with Murray hardyhead

2. INTRODUCTION

Currently, there are five key small-bodied freshwater fish species of national or state conservation significance, with populations under threat of loss in the lower River Murray, South Australia. These are Yarra pygmy perch (*Nannoperca obscura*) and Murray hardyhead (*Craterocephalus fluviatilis*), nationally listed as 'Vulnerable' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and southern pygmy perch (*Nannoperca australis*), southern purple-spotted gudgeon (*Mogurnda adspersa*) and river blackfish (*Gadopsis marmoratus*), considered endangered in the region and 'Protected' under the *Fisheries Management Act 2007*. Each of these species now exist in the South Australian Murray-Darling Basin (MDB) in a limited number of small isolated populations and several species have undergone severe declines in abundance in recent years (Hammer *et al.* 2009b).

Drought conditions across south-eastern Australia from 1997-2010 (Murphy and Timbal 2008; Ummenhofer *et al.* 2009), combined with a history of over-extraction of water (Kingsford 2000), led to reduced inflows in the Murray-Darling Basin (MDB) and receding water levels in many freshwater habitats. These conditions profoundly impacted threatened fish populations in the South Australian MDB (Hammer 2007; Bice *et al.* 2008; Hammer 2008b; Hammer *et al.* 2009b). Consequently, the South Australian Department of Environment and Natural Resources (DENR; formerly the Department for Environment and Heritage (DEH)) developed the 'Drought Action Plan (DAP) for South Australian MDB threatened freshwater fish populations' (Hall *et al.* 2009) to manage and conserve these populations. The DAP is a collaborative, multi-agency approach which identifies sites and/or populations of significance, summarizes information on past and current population status and threats to these populations and most importantly, provides a framework for determining management actions needed to conserve, rescue and recover populations. A total of 26 sites were initially included in the DAP based on the presence of at least one of the species of concern and to ensure that different conservation/management units within species were included (Bice *et al.* 2009; Hall *et al.* 2009); however this number has risen with the subsequent discovery of further sites.

A major component of the DAP involves regular monitoring of the identified populations and monitoring of habitat quality at these sites in order to determine the ongoing status of these populations and identify any need for management. Sites have been monitored under the current program since mid-2008. In spring (October-

November) and autumn (March-May) each year, fish populations were sampled and site condition assessments (i.e. habitat and water quality) were conducted. Additional site checks were conducted in winter (August) and summer (February) each year, to assess site condition. These data provide insight on the presence/absence of threatened species, the status of populations (e.g. declining/increasing abundance, recruitment success) and site condition (e.g. decreasing/increasing water levels or salinity, general habitat quality) and facilitate in the identification of populations and habitats at greatest risk of loss and therefore in need of management intervention.

The following document presents the results of fish sampling in spring 2010 and autumn 2011 with reference to results from 2008/09 and 2009/10 (see Bice *et al.* 2009; Bice *et al.* 2010a) including a summary of site condition assessments throughout 2010/11. It aims to support the DAP by providing a 'report card' on the status of each population and identifying those in need of management. This year's assessment also includes surrogate refuges; dams or managed wetlands where captive bred fish have been released, with the aim of establishing larger populations for future reintroductions (Hammer *et al.* 2009a). This document does not provide a comprehensive summary of management actions undertaken to date or provide thorough suggestions on potential management actions, but simply aims to highlight the current status of populations and thus facilitate discussion of potential management options by the DAP team (i.e. DENR, SARDI Aquatic Sciences, Aquasave Consultants, the South Australian Murray-Darling Basin Natural Resources Management Board (SA MDB NRMB), Native Fish Australia (NFA), Primary Industries and Resources South Australia (PIRSA) and the Department for Water (DFW)).

3. METHODS

3.1. Wild sites

A total of 28 'wild' sites were selected for monitoring based on the previous presence of at least one of the five small-bodied threatened species (Table 2). Sites are widespread across a range of geographic locations from Disher Creek and Berri evaporation basin in the Riverland near the Victorian border to Dunn's Lagoon (Clayton) and Currency Creek near the terminus of the MDB and cover three broad habitat types – wetlands associated with the River Murray Channel; fringing wetlands of western Lake Alexandrina; and stream tributaries of the Eastern Mount Lofty Ranges (Figure 1).

Site monitoring has occurred since 2008, however, not all sites were sampled and assessed throughout the duration of the project, either due to complete drying, lack of access or continued absence of threatened species (i.e. during this project and previous monitoring programs). Several sites were not monitored in 2009/10 and thus site summaries are not included in this report (see Bice *et al.* 2009). Table 2 presents the sites, the species originally present at each site and the seasons in which they were monitored.

Adelaide University also conducted 'condition monitoring' of threatened fish populations in the Lower Lakes from 2008 – 2011 as part of the Murray-Darling Basin Authorities' (MDBA) *The Living Murray* program (funded by the SA MDB NRMB) (Wedderburn and Barnes 2009; Wedderburn and Hillyard 2010). Due to the current precarious status of threatened fish populations in this region and their potential susceptibility to interference, a data sharing agreement was made between the two projects to avoid excessive sampling of populations. Sampling events were coordinated to occur on similar dates. Sites monitored by Adelaide University are indicated in Table 2.

Table 2. Drought Action Plan sites, species originally present and seasons sampled (colours: blue – sampled, red – not sampled).

Location/ catchment	Site Name	Site No.	Species	Monitoring season											
				2008/09				2009/10				2010/11			
				Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
Lower Murray	Jury Swamp	1.1.1	Southern purple spotted gudgeon	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
Bremer River	Rodwell Creek	2.1.1	River blackfish	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
Marne River	Marne	2.2.1	River blackfish	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
Angas River	Angas Gauge	2.3.1	River blackfish	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
Tookayerta Creek	Willowburn Road	2.4.1	River blackfish, southern pygmy perch	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
Tookayerta Creek	Deep Creek Road	2.4.1	River blackfish, southern pygmy perch	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
Angas River	Middle Creek Junction	3.1.1	Southern pygmy perch	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue
Hindmarsh Island	Boundary Creek Drain	3.2.1a, 4.1.1a, 5.1.1a	Southern pygmy perch, Yarra pygmy perch, Murray hardyhead	blue	blue	red	blue	red	red	red	red	red	blue	red	blue
Hindmarsh Island	Eastick Creek	3.2.1b, 4.1.1b, 5.1.1b	Southern pygmy perch, Yarra pygmy perch, Murray hardyhead	blue	blue	red	red	red	red	red	red	blue	blue	blue	blue
Hindmarsh Island	Steamer Drain	3.2.1c, 4.1.1c, 5.1.1c	Southern pygmy perch, Yarra pygmy perch, Murray hardyhead	blue	red	red	red	red	red	red	red	red	blue	blue	blue
Finniss River arm of L.Alex.	Black Swamp	3.2.2a, 4.1.3	Southern pygmy perch, Yarra pygmy perch	blue	red	red	red	red	blue	blue	blue	blue	blue	blue	blue
Finniss River arm of L.Alex.	Black Swamp Drain	3.2.2b	Southern pygmy perch	blue	blue	red	red	red	blue	blue	blue	blue	blue	blue	blue
Lake Alexandrina	Turvey's Drain	3.2.3, 5.1.3a	Southern pygmy perch, Murray hardyhead	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue	blue

Location/ catchment	Site Name	Site No.	Species	Monitoring season											
				2008/09				2009/10				2010/11			
				Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
Finniss River	Meadows	3.3.1	Southern pygmy perch												
Finniss River	Waterfalls	3.3.3	Southern pygmy perch												
Inman River	Inman	3.5.1	Southern pygmy perch												
Goolwa Channel	Currency Creek	4.1.2a	Yarra pygmy perch, Murray hardyhead												
Goolwa Channel	Finniss River Confluence	4.1.2b	Yarra pygmy perch, Murray hardyhead												
Hindmarsh Island	Boggy Creek*	5.1.1d	Murray hardyhead												
Hindmarsh Island	Mundoo Drain West*		Murray hardyhead, southern pygmy perch												
Hindmarsh Island	Mundoo Drain East*		Murray hardyhead												
Lake Alexandrina	Clayton	5.1.2	Murray hardyhead												
Lake Alexandrina	Milang Jetty	5.1.3b	Murray hardyhead												
Lake Alexandrina	Bremer River Mouth	5.1.3c	Murray hardyhead												
Lower Murray	Rocky Gully	5.1.4	Murray hardyhead												
Lower Murray	Riverglades	5.1.5	Murray hardyhead												
Riverland	Disher Creek	5.2.1	Murray hardyhead												
Lower Murray	Berri Evaporation Basin	5.2.2	Murray hardyhead												
Surrogate	Crouch Dam	S.R.	Yarra pygmy perch	-	-	-	-	-		-		-		-	
Surrogate	Oster Dam	S.R.	Yarra pygmy perch	-	-	-	-	-		-		-		-	
Surrogate site	Munday Dam	S.R.	Murray hardyhead	-	-	-	-	-	-	-	-	-		-	
Lower Murray	Paiwalla wetland[@]	S.R. W.R.	Southern purple-spotted gudgeon	-	-	-	-	-	-	-	-	-		-	

* denotes sites sampled by Adelaide University (Wedderburn and Barnes 2009; Wedderburn and Hillyard 2010)
[@]denotes sites sampled in conjunction with the South Australian Murray-Darling Basin Natural Resource Management Board
-denotes that surrogate refuge populations were yet to be established

3.2. Surrogate refuge sites

From 2007-2011, captive breeding programs have been established through the Drought Action Plan, for at least one population of each of the five threatened species under investigation (this involves multiple agencies – see site summaries). The primary objective of these programs was to spread risk from imperilled wild populations, providing a 'back up', and to then produce juveniles for introduction into surrogate refuges and ultimately wild sites.

Following the initial success of captive breeding programs, a project was conducted to identify suitable 'surrogate refuges' for these populations (Hammer *et al.* 2009a), due to the greater capacity of such habitats to produce larger numbers of individuals when compared to aquarium/pond held populations. Furthermore, individuals raised in surrogate refuges are exposed to near-natural conditions, including ambient weather conditions and potential predation pressure (e.g. from piscivorous birds), and as such require no 'training' prior to reintroduction to wild sites. Subsequently, juvenile Yarra pygmy perch were released into two surrogate refuge dams (i.e. Oster and Crouch dams) and juvenile Murray hardyhead were been released into another surrogate refuge dam (i.e. Munday dam) (Table 2; Figure 1). Furthermore, there have been multiple releases of southern purple-spotted gudgeon into Paiwalla Wetland, which is managed by the SA MDB NRMB and the Wetland Habitats Trust. The Yarra pygmy perch populations in the Oster and Crouch Dams were monitored during 'fish sampling' surveys (spring and autumn) as per 'wild sites' in 2009/10 and 2010/11, whilst the Munday Dam and Paiwalla Wetland were monitored in 2010/11 (Table 2; Figure 1). Results of surrogate refuge monitoring are presented in this report.

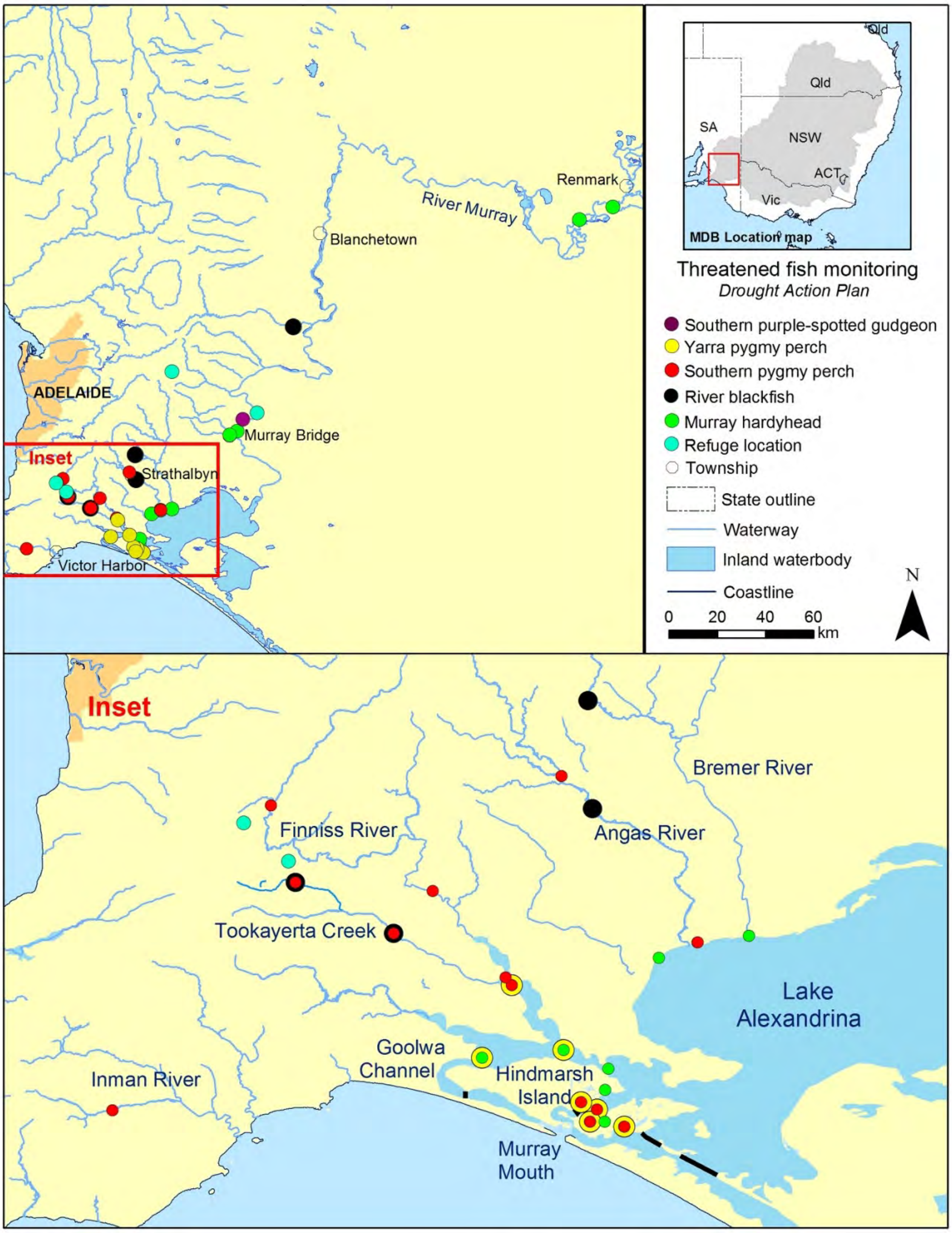


Figure 1. Map of the South Australian Murray-Darling Basin indicating Drought Action Plan Monitoring sites and the fish species sampled at each site (see colour coding in legend). The expanded inset map shows the western Lower Lakes and Eastern Mount Lofty Ranges region in greater detail.

3.3. Fish sampling

Fish sampling was conducted in spring and autumn. Various methods were used to sample fish populations at different sites, depending on individual site characteristics. At each site one or a combination of the following methods were used:

- Backpack electro-fishing
    - A Smith-Root model LR-24 backpack electrofisher was used to sample all microhabitats (e.g. snags, vegetation, open water) represented within a site. 'On time' of electro-fishing differs between sites and at sites between seasons due to differences in available habitat area (e.g. changes in water level). However, a standard reach of stream is sampled on each occasion and abundance data is standardised for electro-fishing 'on time' (e.g. number of fish.100 s^{-1}) to account for differences in sampling effort between seasons
- Fyke netting
    - Single-winged fyke nets (3-6 m wing length, 0.6 m entry diameter, 3 mm mesh) are set perpendicular to the bank where possible. The number of fyke nets used at each site varies based upon the areal extent of the sampling site
- Seine netting (4 m length, 1.5 m depth, 6 mm mesh)
    - Seine hauls are *c.* 10 m in length and the number of hauls is based upon the areal extent of the site/habitat.
- Box trapping (0.4 x 0.24 x 0.24 m (L x W x H), 0.03 – 0.07 m opening, 1 mm mesh)
    - The number of box traps used at each site varies based upon the areal extent of the sampling site

The specific sampling gear types and effort used at each site are indicated in individual site summaries (see results section). As many of these populations and sites are highly restricted and thus vulnerable to interference, sampling effort was often low and tailored to provide representative data yet minimize impact on fish populations. This is most notable for river blackfish populations at Rodwell Creek and the Marne River.

Where possible, the sampling methods used at each site were kept consistent across seasons to allow for robust comparison of catch data over time. This is often difficult, particularly at sites in the EMLR where backpack electro-fishing is used; these streams often have highly variable water levels and consequently the area that may be effectively sampled also fluctuates resulting in lesser/greater effort or lesser/greater fishing efficiency.

All fish captured were identified to species, counted and length measurements (total length (TL) mm) were taken for all threatened species. Sampling was conducted under a *Section 115 permit* in accordance with the *Fisheries Management Act 2007* and PIRSA Animal Ethics Committee standards.

Assessing recruitment

Southern purple-spotted gudgeon, Yarra pygmy perch, southern pygmy perch and Murray hardyhead are all short-lived species (i.e. 1-4 years) and thus annual recruitment is highly important to support self-sustaining populations. River blackfish are 'longer lived' than the aforementioned species and thus annual recruitment success is not as critical for supporting self-sustaining populations. Recruitment was determined for these species at each site by investigating length-frequency distributions generated from fish length measurements taken during fish sampling.

Recruitment is largely assessed by the presence of young-of-year (YOY) cohorts in autumn sampling (although newly recruited YOY cohorts are often present in spring). Southern purple-spotted gudgeon, Yarra pygmy perch, southern pygmy perch and Murray hardyhead all typically spawn during spring/summer and thus YOY cohorts are usually detectable in autumn. The size range that differentiates YOY from older fish was largely determined from previous monitoring of these populations (see Wedderburn and Hammer 2003; Hammer 2004; Hammer 2005; Bice and Ye 2006; Bice and Ye 2007; Bice *et al.* 2008; Hammer 2009) and knowledge of the species' lifecycle. For example, southern pygmy perch <40 mm TL sampled in autumn are likely YOY individuals spawned the previous spring/summer (see Hammer 2009). In the case of river blackfish, YOY are highly cryptic and not easily detected with passive gear types (nets and traps). Recruitment is therefore often only detected the subsequent year to spawning by the presence of one year old fish (i.e. ~100-150 mm).

3.4. Site condition assessments

Site condition assessments were carried out in winter and summer, and also during fish sampling trips in spring and autumn. This involved taking photos from established photo points (when possible), estimating the amount of available physical habitat, determining changes in water levels and measuring water physico-chemical characteristics at each site.

Physical habitat cover was described (by visual estimation) as the proportion of aquatic habitat area (i.e. below the water surface) comprised of submerged vegetation (e.g. *Vallisneria*, *Potamogeton* spp., algae, moss), emergent vegetation (e.g. reeds, *Triglochin*, sedges), other physical structure (i.e. woody debris, rock) and open water. Water level and depth were measured using a number of methods, to provide a confident measure of changes in water levels (i.e. rising or falling) and overall habitat availability. Maximum depth (m) was measured at each site and graduated (m) depth stakes were installed to monitor changes in water level (depth was also measured at these stakes). Where possible, elevation readings were also measured. Elevation readings were taken from the site photo point and from the current water level, providing a measure of the 'difference' between these elevations. Variation in the 'difference' between these elevation reference points over time indicates rising or falling water levels.

Various physico-chemical parameters were measured at each site. Turbidity was measured as secchi depth (m) using a secchi disk, whilst the following parameters were measured using a TPS 90-FLT water quality meter,

- Conductivity ($\mu S.cm^{-1}$)
- pH
- Dissolved oxygen concentration (ppm)
  - Surface reading at depth of ~0.2 m and at sites where depth is >1.5 m bottom measurements are also taken
- Temperature (°C)

Data from site condition assessments is presented in tabulated format in the following site summaries.

4. RESULTS

4.1. Hydrology

Reduced rainfall and above average temperatures across south-eastern Australia over the period 2006-2010 (Murphy and Timbal 2008) resulted in significantly reduced inflows in the MDB. Subsequently, flow to South Australia from the River Murray was below average over this period and flows in tributaries in the EMLR were also reduced. In 2010/11, however, there was significant rainfall across the MDB resulting in significant increases in flow volumes and water levels in the River Murray and its associated off-channel habitats, as well as in the Lower Lakes. Furthermore, flow volumes and water levels in the tributaries of the EMLR were also significantly greater than preceding years.

As a consequence, the hydrological environment in the waterways of the South Australian MDB and at DAP monitoring sites, has been highly variable over the project. The influence of increased rainfall and inflows on the hydrology of waterways and therefore the hydrology in the three broad geographic regions or habitat types (i.e. wetlands associated with the River Murray channel; fringing wetlands of western Lake Alexandrina; and stream tributaries of the EMLR) sampled in this project from 2008-2011 is varied. The hydrologic conditions experienced in the three broad geographic regions are summarised below.

River Murray channel hydrology

Flow into South Australian (taken at the SA-Vic border) during the 1990's regularly exceeded 20,000 ML.day^{-1} throughout the 1990's (Figure 2). Between 2002 and 2009, however, flow at the border did not once exceed 20,000 ML.day^{-1} and from 2007-2009 was regularly < 2000 ML.day^{-1} (Figure 2). As such, floodplain habitats in the Riverland region remained disconnected from the River Murray for an extended period and salinity in many remaining aquatic habitats increased considerably (e.g. Disher Creek). In 2010, there were significant increases in River Murray flows at the South Australian border with flows of > 20,000 ML.day^{-1} from September 2010 to June 2011 and a peak flow of > 93,000 ML.day^{-1} in February 2011 (Figure 2). Increased flows were accompanied by the most significant floodplain inundation in almost a decade and re-connection of off-channel habitats with the River Murray.

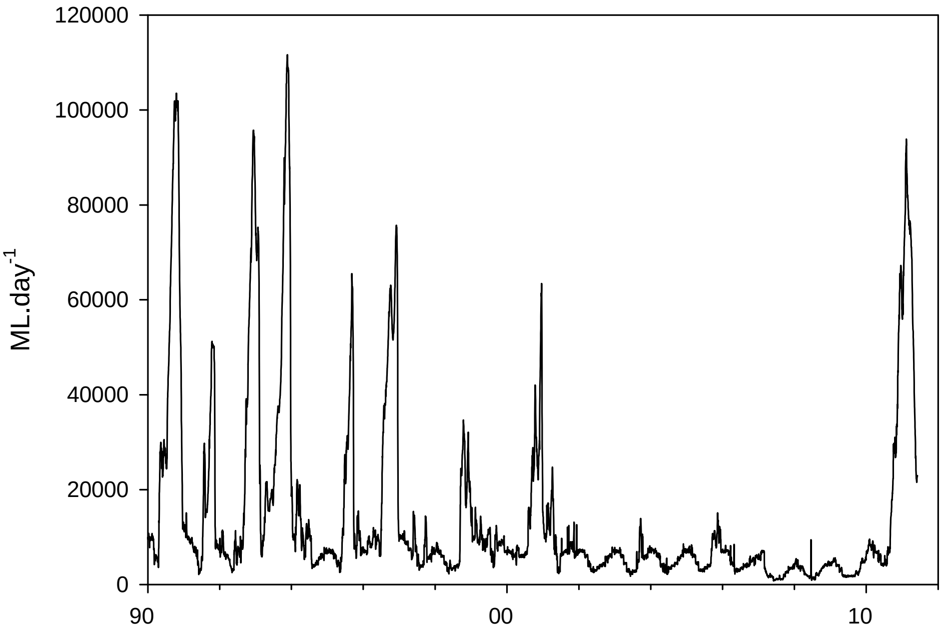


Figure 2. Daily River Murray flow (ML.day^{-1}) to South Australia from 1990 to 2011.

Lower Lakes hydrology

Water level in Lake Alexandrina is typically regulated at approximately +0.75 m AHD and was maintained around this level for the majority of the period from 2000 to 2006 (Figure 3). Significantly reduced inflows in 2007, 2008 and 2009, however, resulted in rapidly receding water levels. Since regulation in the MDB (i.e. post-1940's), mean annual inflow to Lake Alexandrina is ~4723 GL (CSIRO 2008), however; inflows in 2007, 2008 and 2009 were <600 GL.yr^{-1} (DFW 2011). Water level fell below sea-level for the first time in recorded history in 2008 and continued receding, reaching a minimum of approximately -1.0 m AHD (Figure 3). This resulted in the drying and desiccation of many wetland and irrigation channel habitats, the disconnection of remaining water from fringing edge habitats, increased salinity and the almost total loss of submerged vegetation (Marsland and Nicol 2009). The Lower Lakes hydrology is also used to indicate broader changes (water level decline) to lower River Murray hydrology below Lock 1 at Blanchetown.

In 2010, significantly increased River Murray inflows resulted in rapidly increasing water levels in Lake Alexandrina. Following more than 2 years below sea level, levels in Lake Alexandrina rose above 0 m AHD in July 2010 and reached typical regulated levels (approximately +0.75 m AHD) by October 2010 (Figure 3). Furthermore, following September 2010, the Murray Barrages were largely ‘open’ and significant volumes of freshwater were being released to the Coorong resulting in greater connectivity between habitats within the region. Increased water level resulted in the re-inundation of exposed lake bed, fringing habitats, and wetlands and channels at higher elevations. As of autumn 2011, there had been significant germination and re-colonisation of certain habitats by aquatic vegetation but the plant community has not yet fully recovered to a pre-drought state (Gehrig *et al* 2011).

The return of typical regulated water levels in the Lower Lakes resulted in the re-inundation of several DAP monitoring sites (e.g. Steamer Drain) and increased water level at others (e.g. Currency Creek junction) (see site specific summaries). Furthermore, several wetland sites associated with the River Murray downstream of Lock and Weir 1 are influenced by water levels in Lake Alexandrina (i.e. Jury Swamp, Rocky Gully and Riverglades) and were subsequently re-inundated and re-connected with the River Murray.

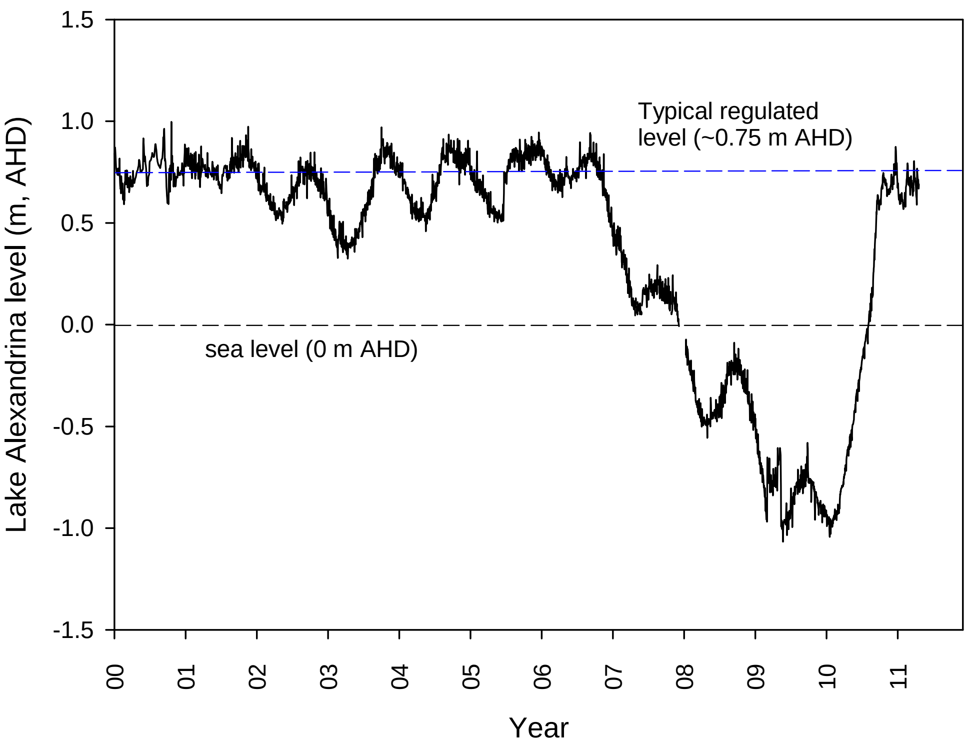


Figure 3. Mean daily water level (Australian Height Datum, m AHD) in Lake Alexandrina from 2000 – 2011 (April). Data obtained from the Department for Water (DFW 2011) ‘Milang’ monitoring station.

Eastern Mount Lofty Ranges hydrology

The Angas River was chosen as a representative catchment to indicate hydrological conditions in streams of the EMLR over the study period. Whilst hydrology is likely to exhibit variation between catchments and stream reaches, the Angas River is geographically located between the other catchments (i.e. the Inman, Finniss, Tookayerta, Bremer and Marne) and annual variation in hydrology is likely to indicate relative hydrological variation in other catchments (except for localised instances of groundwater discharge/baseflow – this is detailed in site summaries). Furthermore, adequate time-series flow date was available for this catchment.

Similar to many other catchments in the EMLR, the Angas River exhibits seasonality of flow and annual hydrological variation. The river typically ceases to flow for a period each year from January to April, flowing for the remainder of the year with peak flows typically in winter and spring (July – September) (Figure 4). Flow peaks of > 1000 $ML.day^{-1}$ occurred commonly in the Angas River in the 1990's. From 1997 – 2009, however, flows did not once exceed 1000 $ML.day^{-1}$ and in 2007, 2008 and 2009, flow peaked at approximately 183, 87 and 333 $ML.day^{-1}$ respectively (Figure 4). Following significant rains across the EMLR in 2010, the hydrology of the Angas River was substantially different from preceding years with a flow peak of ~1600 $ML.day^{-1}$ in September 2010. Furthermore, the river did not cease to flow through summer. The hydrology of other catchments in the EMLR over the same period likely varied in terms of total flow volumes and flow peaks, however, general patterns of reduced flow volumes and duration during the period 2007-2009 and increased flow volumes and duration during 2010-11 are likely parallel to those in the Angas River (with the exception of the lower Marne River where stream flow remained diminished in 2010/11).

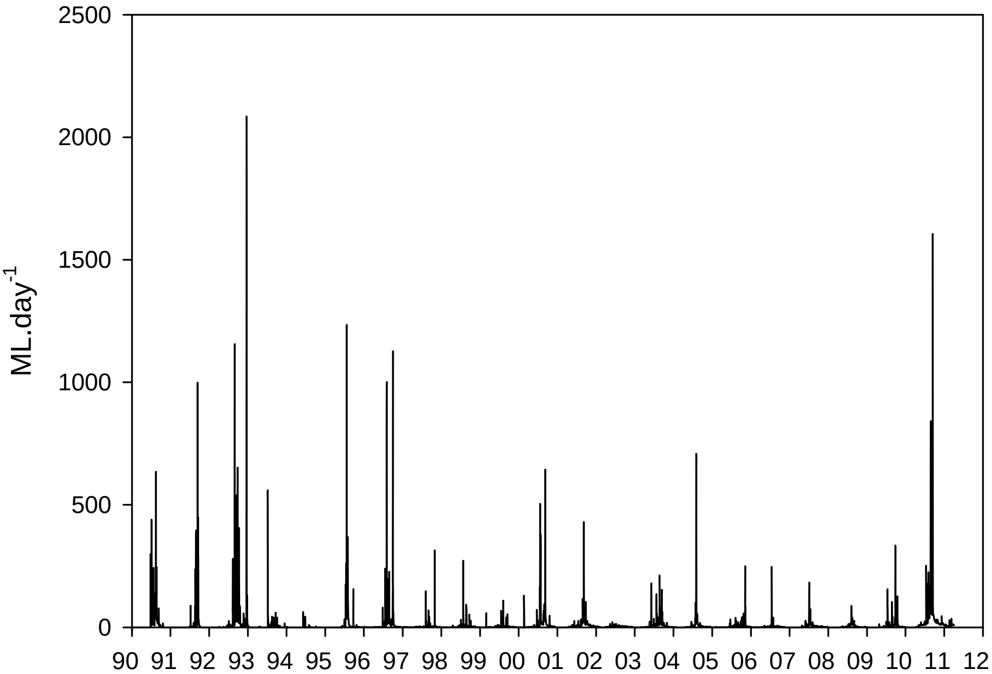


Figure 4. Daily flow in the Angas River (ML.day^{-1}) from 1990 to 2011. Data obtained from the Department for Water (DFW 2011).

4.2. Jury Swamp (River Murray: southern purple-spotted gudgeon)

Jury Swamp is an off-channel wetland located in the lower swamps region of the Murray River below Lock and Weir 1 (Blanchetown). Southern purple-spotted gudgeon were believed to be extinct in South Australia until 2004 when this species was rediscovered at this site. Genetic analysis confirmed that this was a remnant wild population (Hammer 2008a). This species was moderately abundant at this site until April 2007 (Hammer 2007).

With severely diminished inflows into South Australia and dramatically receding water levels below Lock 1, the water level within Jury Swamp began receding in late 2006, became disconnected at a river height of ~0.3 m AHD and eventually dried completely in April 2007. Prior to drying (Figure 5), a number of southern purple-spotted gudgeon were removed from this site for captive maintenance (Hammer 2007). The River Murray channel at the entrance to Jury Swamp was monitored for the presence of this species from 2009-2010. Increased River Murray flows in 2010 resulted in the re-connection Jury Swamp with the main channel and increased water levels (Figure 6 and 7a). Subsequently, fish sampling resumed within the swamp.

Figure 5. Jury Swamp during low water levels in spring 2009, showing wetland desiccation and subsequent colonisation by terrestrial weeds.

Fish sampling effort

Spring 2008

- 10 baited box traps set overnight within Jury Swamp.
- 10 baited box traps and 3 fyke nets set overnight in the River Murray around the mouth of Jury Swamp.

Autumn 2009, spring 2009 and autumn 2010

- 10 baited box traps set overnight in the River Murray.
- As a result of reduced water levels box traps could not be set within the wetland (Jury Swamp) and fyke nets could not be set in the River Murray

Spring 2010 and autumn 2011

- 10 baited box traps set overnight within Jury Swamp.
- 4 fyke nets set overnight within Jury Swamp.

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 6. Photo-point images of the Jury Swamp site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

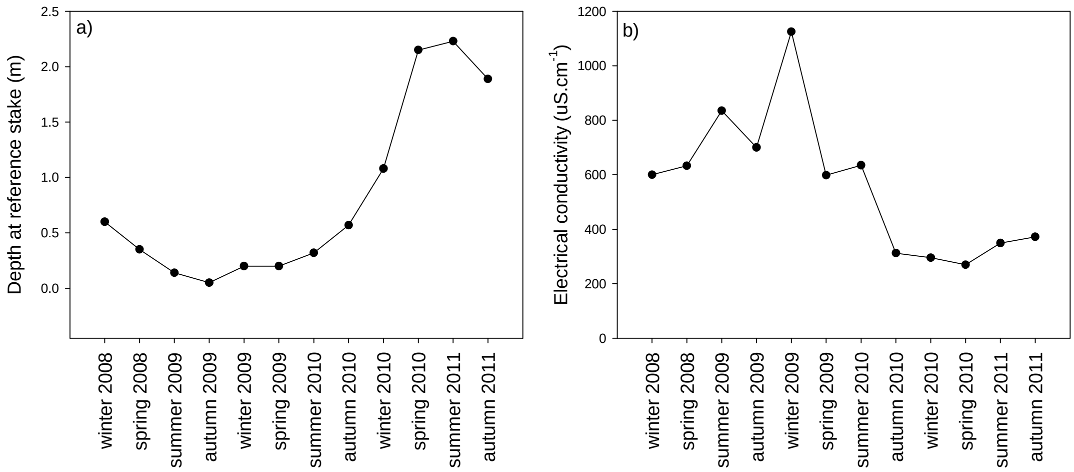


Figure 7. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Jury Swamp site between winter 2008 and autumn 2011. Note the data for spring 2008 - winter 2010 relates to the River Murray channel adjacent Jury Swamp as the wetland was dry.

Table 3. Percent cover of available habitat measured at Jury Swamp during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	70 (*Triglochin,* grasses)	10 (debris)	20
Spring 2010	5 (algae)	50 (*Typha, Triglochin, Aster,* grasses)	0	45
Summer 2011	20 (*Ceratophyllum, Azolla*)	30 (*Triglochin, Aster,* grasses)	0	50
Autumn 2011	60 (*Grass, Triglochin, Aster)*	30 (*Ceratophyllum, Azolla*)	5 (Rock)	5

Table 4. Water quality parameters measured at Jury Swamp during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	13.0	6.84	2.20	-	0.35	0.45
Spring 2010	19.4	6.91	1.3	1.1	0.22	1.4
Summer 2011	28.1	7.06	1.97	2.15	0.35	1.2
Autumn 2011	14.5	7.63	3.61	2.57	0.91	1.5

Catch summary and length-frequency analysis

No southern purple-spotted gudgeon were sampled in spring 2010 or autumn 2011 (Table 5), despite single individuals being sampled in spring 2008, autumn 2009 and spring 2009 (Table 5). The individuals were captured from the River Murray, among willow roots near the mouth of Jury Swamp. Both fish sampled in 2008/09 were medium-sized adult fish (>70 mm TL (total length)) (Figure 8 a & b) but the individual sampled in spring 2009 (TL = 52 mm) was likely to have been spawned the previous spring/summer (Figure 8 c and 9). Other species sampled and their respective abundances are also presented in Table 5.

Table 5. Total numbers of fish species collected from Jury Swamp between spring 2008 and autumn 2011. Species in bold denote target species for the site.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Southern purple-spotted gudgeon	***Mogurnda adspersa***	**1**	**1**	**1**	**0**	**0**	**0**
Flat-headed gudgeon	*Philypnodon grandiceps*	52	4	18	0	5	3
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	7	0	1	0	0	0
Carp gudgeon complex	*Hypseleotris* spp.	386	6	26	13	395	209
Unspecked hardyhead	*Craterocephalus stercusmucarum fulvus*	108	0	0	2	28	549
Murray rainbowfish	*Melanotania fluviatilis*	31	0	0	1	0	253
Australian smelt	*Retropinna semoni*	36	0	0	0	0	0
Common galaxias	*Galaxias maculatus*	2	0	1	0	0	0
Bony herring	*Nematalosa erebi*	1	0	0	0	0	0
Golden perch	*Macquaria ambigua*	1	0	0	0	0	0
Common carp	*Cyprinus carpio*	1	0	0	0	1515	13
Goldfish	*Carrasius auratus*	0	0	0	0	0	13
Gambusia	*Gambusia holbrooki*	0	0	0	0	0	204

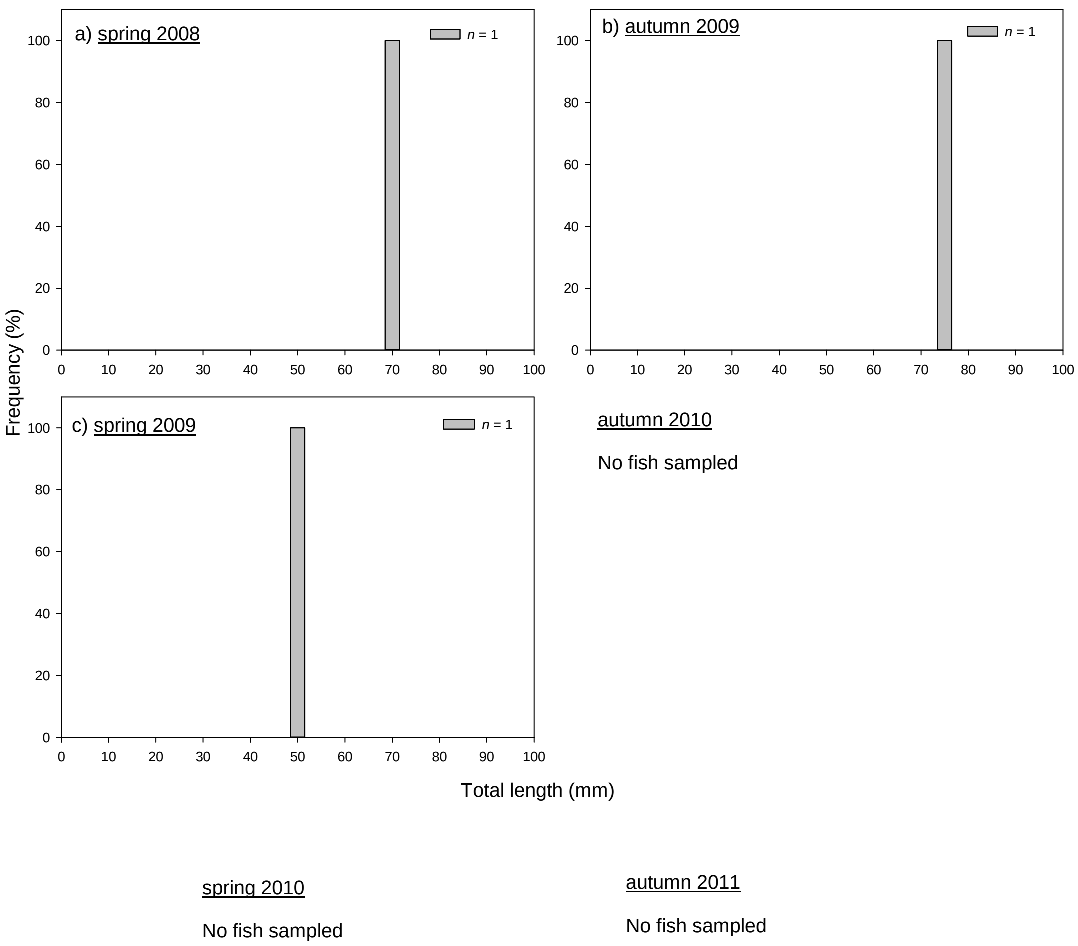


Figure 8. Length frequency distribution of southern purple-spotted gudgeon from Jury Swamp in a) spring 2008, b) autumn 2009 and c) spring 2009.

Figure 9. Southern purple-spotted gudgeon sampled from the Murray River adjacent Jury swamp in spring 2009.

Site summary

As of autumn 2011, there was no evidence of re-colonisation of Jury Swamp by southern purple-spotted gudgeon upon the re-connection and refilling of the wetland. Individuals were sampled in 2008 and 2009, and there was evidence of recent recruitment at that time, however, the population was likely to be very small. As such, the species may have been lost from the site or avoided sampling. Physical habitat (i.e. aquatic vegetation) is recovering to pre-2007 conditions; however rooted submerged aquatic plants (e.g. *Vallisneria australis*) and emergent cover (i.e. *Schoenoplectus validus*) are still lacking.

Individuals from this population are currently part of a successful captive breeding program being guided and undertaken by several agencies including Aquasave and Native Fish Australia (SA) with support from Alberton Primary School and Urrbrae Agricultural High School. A number of juvenile southern purple-spotted gudgeon, produced in captivity, were released into a restored ‘wild’ refuge at the Paiwalla wetland near Jury Swamp from March 2010 (see section 4.33 for site summary). It is hoped that this action will result in a self-sustaining population that can form part of a broader species recovery (e.g. range restoration, additional population security) and contribute to the reintroduction at Jury Swamp when conditions are deemed to be favourable.

4.3. Rodwell Creek (Bremer River: river blackfish)

Rodwell Creek is a tributary of the Bremer River in the EMLR (Figure 10). Based on anecdotal evidence, river blackfish were present historically at this site. Their presence was confirmed at this location in 2004 (Hammer 2004) and this population has been monitored since (Hammer 2009). Originally widespread in the Bremer River catchment (i.e. pre-1950's) (Hammer 2004), this species is now known from just one short reach of Rodwell Creek and in some years is restricted to one individual pool (~ 20 m length x 5 m width).

Whilst historically the stream section was likely perennial (due to refilling from ground water through springs), farm dam abstraction has resulted in these pools now receiving only intermittent surface water flow (Hammer 2009). In fact, there were no surface water flows in 2007 and 2008, and subsequently receding water levels over summer and autumn seasonally threatened this river blackfish population (water levels decreased to a depth of ~0.5 m). Whilst lower water levels resulted in decreased habitat area and disconnection of water from emergent vegetation, the lack of significant inflows also led to diminished dissolved oxygen concentrations. Furthermore, when flows have occurred, 'built up' organic matter has been deposited in the pool, with a high biological demand for oxygen as it is broken down, exacerbating concerns over low dissolved oxygen concentrations. This site has thus been intensively managed since autumn 2008. Environmental water has been transported to the site, on a regular basis, in order to mitigate the impact of reduced water levels and reduced dissolved oxygen concentrations. An aerator system was also installed to further mitigate conditions of low dissolved oxygen. In 2010, however, Rodwell Creek experienced increased flow conditions, which subsequently increased water levels and connectivity throughout the reach. Furthermore, the creek flowed for a greater duration than in preceding years.

Fish sampling effort

Spring 2008, autumn 2009, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 10 baited box traps set for 1.5 hours on dusk

Sampling effort at this site is minimal for several reasons. Firstly, blackfish are nocturnal and are most active on dusk and hence the sampling method targets peak activity and thus sampling efficiency. Secondly, trapping time is limited to 1.5 hours to limit the risk of fish death due to localised low dissolved oxygen concentrations often recorded at this site (Table 7).

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 10. Photo-point images of the Rodwell Creek site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

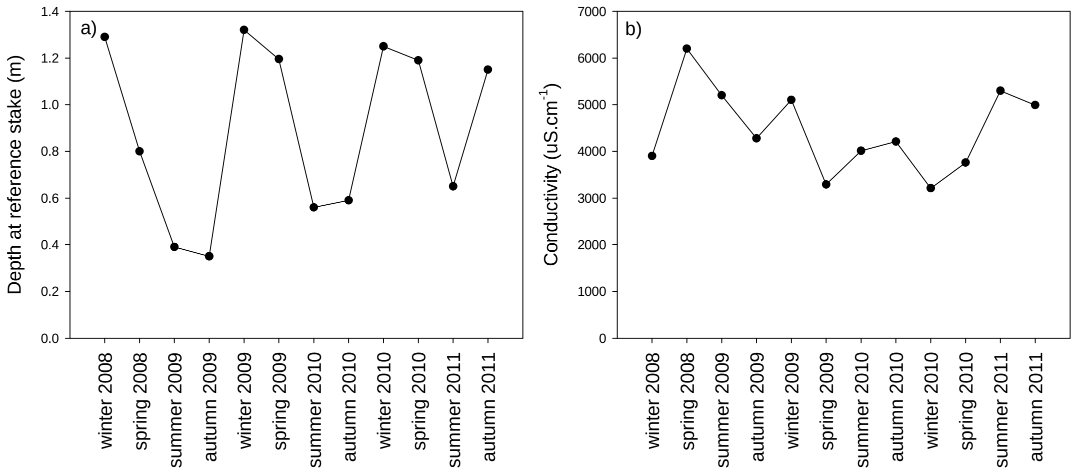


Figure 11. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (μS.cm^{-1}) at the Rodwell Creek site between winter 2008 and autumn 2011.

Table 6. Habitat cover measured at Rodwell Creek during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	50 (*Typha,* grasses)	10 (rock)	40
Spring 2010	0	40 (*Typha, Triglochin*)	10 (rock)	50
Summer 2011	0	40 (*Typha*)	10 (rock)	50
Autumn 2011	0	30 (*Typha, Triglochin*)	20 (rock)	50

Table 7. Water quality parameters measured at Rodwell Creek during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	6.8	7.94	8.79	7.21	1.5	2.0
Spring 2010	21.6	7.81	8.14	8.48	1.5	2.0
Summer 2011	19.5	7.86	7.42	6.68	0.7	1.9
Autumn 2011	13.7	7.80	8.67	7.91	0.5	2.5

Catch summary and length-frequency analysis

River blackfish were sampled in consistently low numbers in 2010/11, as in 2009/10 (Table 8). Individuals ranged from 126-169 mm and 161-226 mm TL in spring 2008 and autumn 2009, 170-232 mm and 185-234 mm TL in spring 2009 and autumn 2010, and 128-209 mm and 195-249 mm TL in spring 2010 and autumn 2011 respectively (Figure 12a-f). As such, growth of resident fish was evident and recruitment of individuals in the past 2 years was indicated by individuals 128-136 mm TL in spring 2010. Additionally, supplementary sampling of a pool upstream of the standardised monitoring pool by Aquasave in February 2011, a site which had dried in previous years, indicated there was substantial recruitment of young-of-year (YOY) individuals in 2010/11 that was not detected in DAP sampling (Figure 13, 14a and b). Carp gudgeon and eastern gambusia were also sampled at this site over the study period.

Table 8. Total numbers of fish species collected from Rodwell Creek between spring 2008 and autumn 2011. Species in bold denote target species for the site.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
River blackfish	***Gadopsis marmoratus***	**6**	**11 (+ 3 obs)**	**4**	**4 (+ 1 obs)**	**4**	**4**
Carp gudgeon complex	*Hypseleotris* spp.	0	2	0	30	15	0
Gambusia	*Gambusia holbrooki*	0	3	2	0	0	0

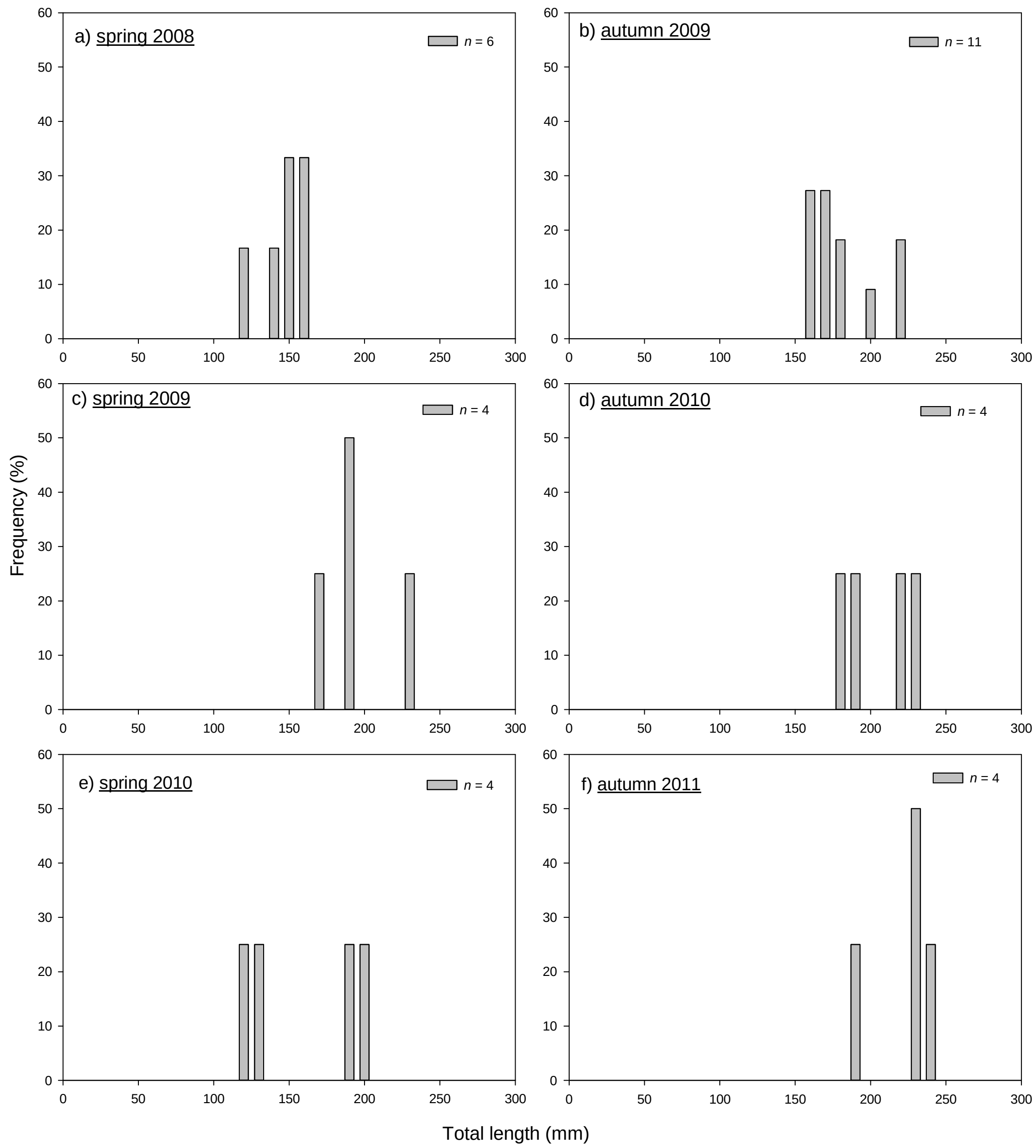


Figure 12. Length frequency distribution of river blackfish from Rodwell Creek in a) spring 2008, b) autumn 2009, c) spring 2009 d) autumn 2010, e) spring 2010 and f) autumn 2011.

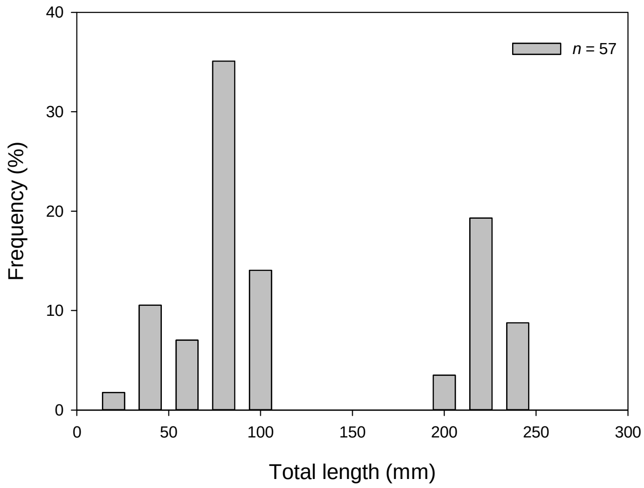


Figure 13. Length-frequency distribution of river blackfish sampled from a pool upstream of the regular DAP monitoring site during supplementary monitoring in February 2011.

a) b)

Figure 14. (a) YOY river blackfish sampled during supplementary sampling of a pool (b) upstream of the standardised sampling site in February 2011.

Site summary

Adult river blackfish are persisting at this site in low numbers and significant recruitment of YOY was detected in the area in 2010/11. This site has been intensively managed for the past 2 years due to the risk posed by low water levels and low dissolved oxygen concentrations (< 3 ppm) (Table 7). The delivery of environmental water to the site and installation of an aeration system appear to have been effective in maintaining the adult population of river blackfish. Furthermore, significant flows and increased water levels in 2010/11 appeared to facilitate a positive biological response noted by significant recruitment of YOY fish.

Interestingly, this significant recent recruitment was only detected during supplementary monitoring in a pool that is normally seasonally disconnected from the standard monitoring site. This may indicate the dispersal of adults and subsequent spawning in this pool upon early season flows or the dispersal of YOY from the standardised sampling pool prior to monitoring; however, patterns of reproduction and dispersal exhibited by this population require further research. Nevertheless, the status of the river blackfish population at this site has improved from preceding years but the population remains under threat due to catchment flow alteration in the system and intensive management of the site may again be required in the future in the event of poor flow conditions similar to the period 2006-2009.

A captive breeding trial is being undertaken with adult fish from this population by SARDI Aquatic Sciences, which aims to develop propagation techniques and allow for a captive breeding program (Westergaard and Ye 2010).

4.4. Marne River (Marne River: river blackfish)

The Marne River flows in an easterly direction from the EMLR before entering the River Murray below Lock 1. This site is on the lowland section lower Marne River at Black Hill Springs. Habitat consists of a series of perennially ground-fed, cool, clear-water pools with abundant emergent vegetation (Figure 15) (Hammer 2009). Stream surface water flows from further upstream have been minimal since 2005 (Hammer 2009). Flow gauge data for the site (DFW 2011) shows a short (one day duration) spike of less than 0.4m which may be attributable to flows reaching the springs from further upstream. Certainly, no sustained surface water flows reached the site.

Sampling at this site has been conducted since 2002, with river blackfish consistently sampled in low numbers (Hammer 2009). Importantly, new recruits have not been observed since 2002 (Hammer 2009).

Fish sampling effort

Spring 2008, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 10 baited (yabbie) box traps set for 1 hour at dusk.

Autumn 2009

- 6 baited (yabbie) box traps set for 1 hour at dusk.

Sampling effort at this site is minimal for several reasons. Firstly, blackfish are nocturnal and are most active on dusk, and hence the sampling method targets peak activity and thus sampling efficiency. Secondly, trapping time is limited to 1 hour to limit the risk of fish death due to localised low dissolved oxygen concentrations often recorded at this site (Table 10). A white plume of unknown composition has been observed at the bottom to lower half of the pool on several occasions, which appears to be producing anoxic conditions in its vicinity.

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 15. Photo-point images of the Marne River site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

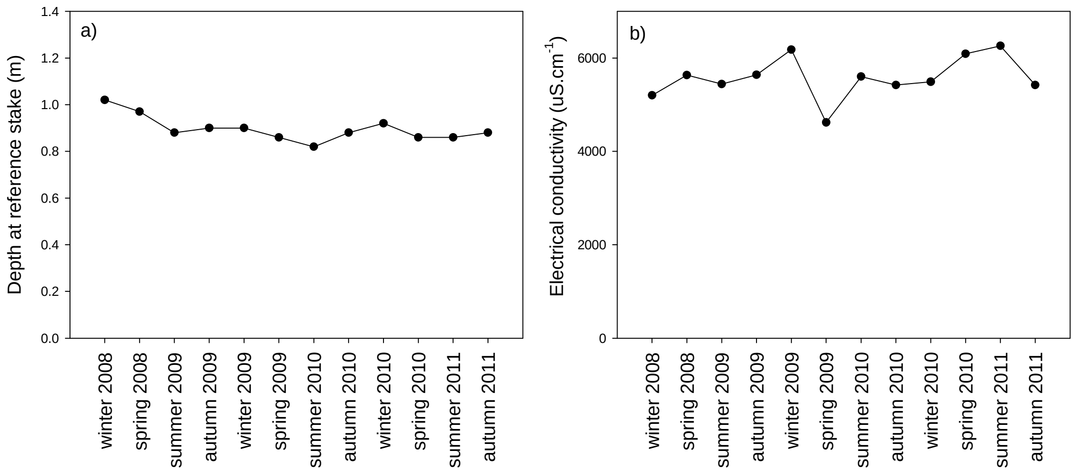


Figure 16. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Marne River site between winter 2008 and autumn 2011.

Table 9. Habitat cover measured at the Marne River site during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	5 (algae)	40 (*Typha*)	5 (snag)	50
Spring 2010	0	40 (*Typha*)	20 (debris)	40
Summer 2011	0	60 (*Typha, Phragmites*)	0	40
Autumn 2011	0	40 (*Typha*)	10 (snag)	50

Table 10. Water quality parameters measured at the Marne River site during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	10.6	7.82	6.1	1.93	>1.2	1.2
Spring 2010	17.7	7.4	8.29	0.68	>1.3	1.3
Summer 2011	18.6	7.3	7.02	2.43	>1.4	1.4
Autumn 2011	15.3	7.5	7.11	6.38	1.0	1.0

Catch summary and length-frequency analysis

Consistently low numbers of river blackfish were sampled over the period 2008-2011, however, just one individual was sampled in autumn 2011 (Table 11). Carp, gudgeon, mountain galaxias and eastern gambusia have also been sampled at the site (Table 11). All river blackfish sampled at this site throughout the project have been large adult fish (>200 mm TL) and thus no recent recruitment has been detected (Figure 17a-f). Furthermore, fish have been sampled in increasingly 'poor condition' (e.g. emaciated, infections, scratches) (Figure 18).

Table 11. Total numbers of fish species collected from the Marne River between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
River blackfish	***Gadopsis marmoratus***	**3 (+3 observed)**	**1 (+4 observed)**	**5**	**4**	**3 (+1 observed)**	**1**
Carp gudgeon complex	*Hypseleotris* spp.	3	1	1	0	0	28
Mountain galaxias	*Galaxias olidus*	4	0	0	1	0	0
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	0	0	0	0	0	1
Gambusia	*Gambusia holbrooki*	0	1	3	17	0	2

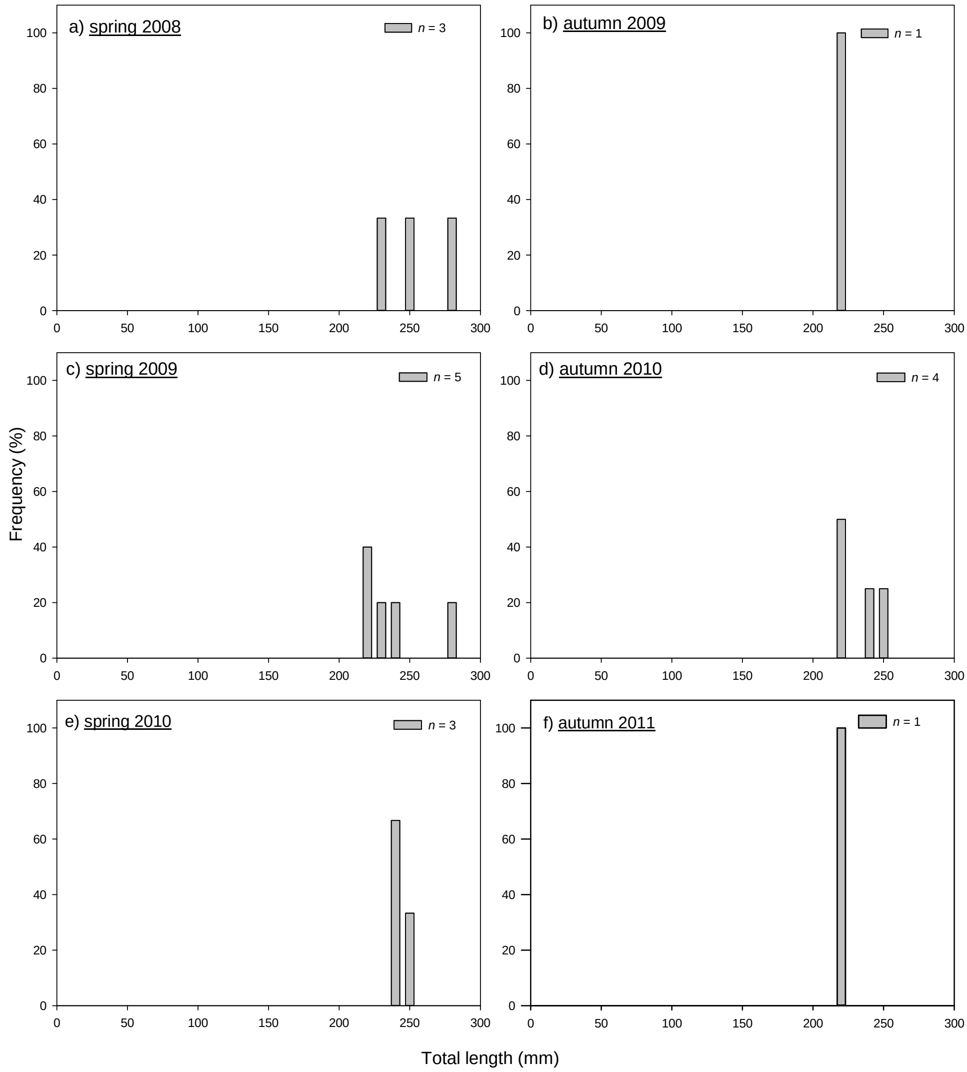


Figure 17. Length frequency distribution of river blackfish from the Marne River in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e) spring 2010 and f) autumn 2011.

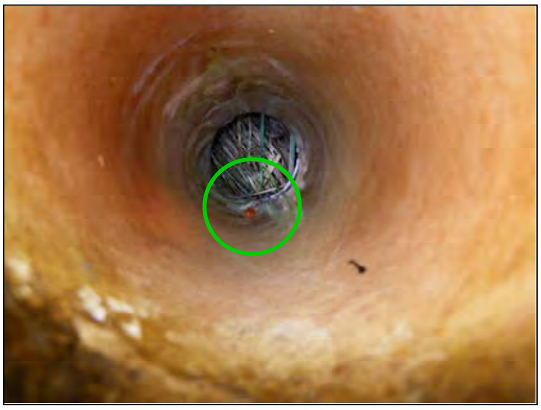
Figure 18. River blackfish in 'poor condition' sampled from the Marne River site in autumn 2011.

Site summary

River blackfish are still present in the Marne River but the continued lack of recruitment represents a highly significant risk to this population. Previous data suggest that recruitment has not occurred for ~ nine years (Hammer 2009). Artificial spawning tubes (PVC pipes of different diameters) have been installed at this site and in spring 2009 eggs were found attached to the inner surface of a spawning tube (Figure 19a). Thus, it appears attempts to spawn are being made and recruitment is not occurring due either to limited fertilisation or egg/larval/juvenile survival. The lack of recruitment observed at this site over the study period is cause for great concern and this population is likely at a high risk of loss.

Salinity remains elevated. An anoxic white plume was observed several times through 2008/09 and 2009/10, and again in spring 2010, at the bottom of the pool and fish appear to be avoiding this area (pers obs), which may be reducing available habitat and feeding area (Figure 19b). The composition of this plume remains unknown.

a)



b)

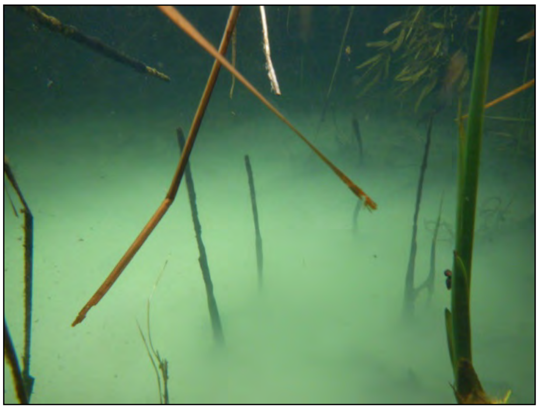


Figure 19. a) River blackfish eggs within an artificial spawning tube installed in the Marne River and b) underwater image of an anoxic white plume regularly observed at this site.

4.5. Angas Gauge site (Angas River: river blackfish)

This site is on the Angas River, which drains part of the EMLR before discharging into Lake Alexandrina near Milang. The reach of the Angas River where this site is located is dominated by a series of large, deep, bedrock-based clear-water pools separated by small waterfalls (Figure 20) (Hammer 2009). Fringing emergent vegetation (i.e. *Typha domingensis* and *Phragmites australis*) is abundant. Flow through this reach is largely permanent with significant ground-water base flows (Hammer 2009).

This site has been sampled since 2004. Whilst river blackfish were most abundant in 2004 they have typically been sampled in moderate – high numbers in subsequent years (Hammer 2009).

Fish sampling effort

Spring 2008, autumn 2009, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 3 fyke nets set overnight

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 20. Photo-point images of the Angas Gauge site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

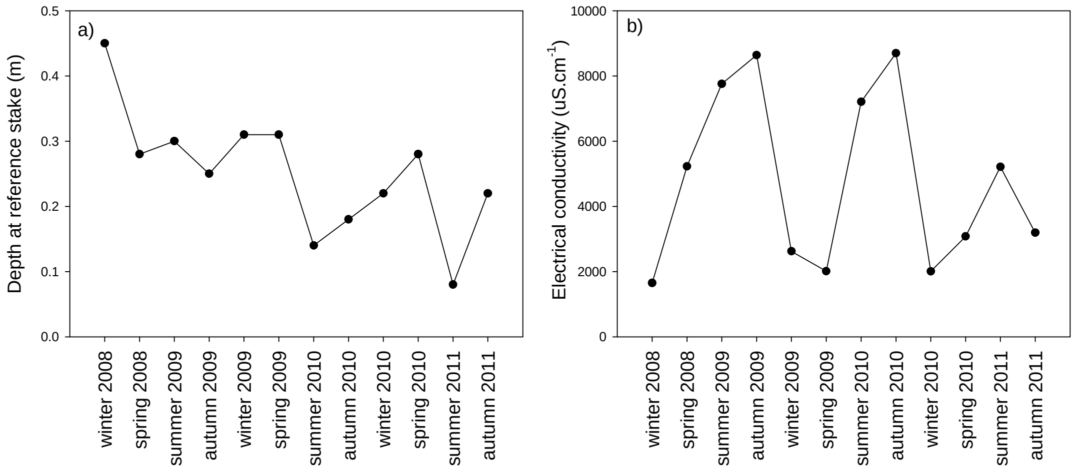


Figure 21. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Angas River Gauge site between winter 2008 and autumn 2011.

Table 12. Habitat cover measured at the Angas River Gauge site during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	5 (algae)	10 (*Typha, Juncus*)	20 (rock)	65
Spring 2010	1 (algae)	5 (*Typha,* grass)	25 (rock)	69
Summer 2011	5 (algae)	10 (*Typha, Phragmites,* grass)	20 (rock)	65
Autumn 2011	5 (algae)	20 (*Typha*)	20 (rock)	55

Table 13. Water quality parameters measured at the Angas River Gauge site during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	9.9	7.91	8.68	8.26	0.95	2.0
Spring 2010	19.4	8.14	7.28	6.85	1.5	2.0
Summer 2011	22.3	7.92	8.01	6.05	>2	2
Autumn 2011	18.2	7.99	7.04	-	>2.5	2.5

Catch summary and length-frequency analysis

River blackfish were sampled in reduced numbers in spring 2010 but were sampled in numbers consistent with previous sampling events in autumn 2011 (Table 14). Other species sampled include carp gudgeon, flat-headed gudgeon, dwarf flat-headed gudgeon, mountain galaxias and tench (Table 14).

Table 14. Total numbers of fish species collected from the Angas River Gauge site between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
River blackfish	***Gadopsis marmoratus***	**17**	**26**	**27**	**28**	**11**	**25**
Carp gudgeon complex	*Hypseleotris* spp.	20	36	41	20	2	2
Flat-headed gudgeon	*Philypnodon grandiceps*	12	14	14	32	10	4
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	8	2	1	7	1	0
Mountain galaxias	*Galaxias olidus*	1	0	2	10	1	0
Tench	*Tinca tinca*	1	9	4	0	0	0

River blackfish exhibited broad length distributions in 2008/09 with fish ranging 105 – 265 mm TL in spring 2008 and 118 – 228 mm TL in autumn 2009 (Figure 22a & b). Similarly in spring 2009, fish ranged in length from 95 – 237 mm TL and 120 – 239 mm TL (Figure 22c & d). As such separate recruitment events were observed at this site in 2008/09 and 2009/10. In 2009/10, river blackfish again exhibited broad length frequency distributions ranging between 133 – 260 mm and 145 – 275 mm TL in spring 2010 and autumn 2011 respectively (Figure 22e & f). The population appeared ‘larger’ in 2010/11 than in previous sampling seasons with a smaller proportion of individuals <150 mm TL and greater proportion of individuals >220 mm TL (Figure 23).

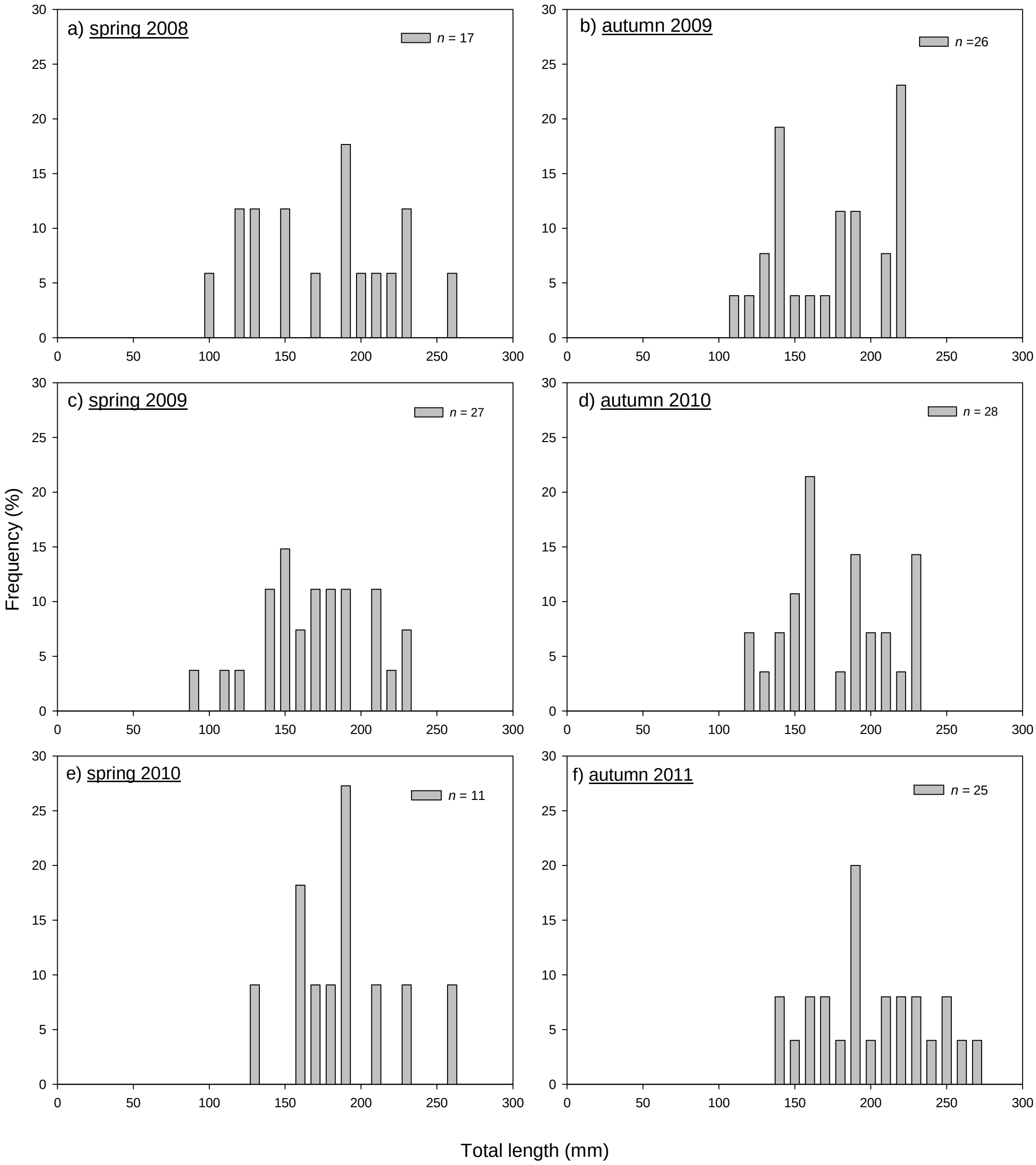


Figure 22. Length frequency distribution of river blackfish from the Angas River Gauge site in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e) spring 2010 and f) autumn 2011.

Figure 23. Large adult river blackfish sampled at the Angas River gauge site in autumn 2011.

Site summary

The river blackfish population at this site appears stable, with moderate abundance and distinct recruitment observed over the last two years, and a range of different aged (length) fish in the population. Whilst YOY individuals have not been collected, the annual presence of a 1+ cohort indicates that recruitment has occurred annually. The physical characteristics of this site (e.g. depth ≥2 m) and use of fyke nets to sample this site may result in newly recruited YOY not being sampled but these individuals are likely to be present at the site.

Electrical conductivity has been steadily increasing since 2004 (Hammer 2009) and reached ~8000 $\mu S.cm^{-1}$ in autumn 2009 and 2010, which is likely to be unfavourable for river blackfish. The site was generally freshened in winter (~2000 $\mu S.cm^{-1}$). Electrical conductivity, however, exhibited reduced seasonal fluctuation in 2010/11, reaching a peak of ~5000 $\mu S.cm^{-1}$ in summer 2011, owing to increased flows in 2010/11.

4.6. Willoburn Road, Nangkita Creek (Tookayerta Creek: river blackfish and southern pygmy perch)

This site is on Nangkita Creek, a tributary of Tookayerta Creek, which flows out of the southern EMLR before meeting the Finniss River and flowing into the Goolwa Channel on the south-western side of Lake Alexandrina. This catchment has highly contrasting geomorphology and hydrology to other catchments of the EMLR (Hammer 2009). There are significant ground-water interactions and subsequently perennial lotic habitats are present in some reaches. Habitat at the site is comprised of a mosaic of braided lotic channels, deep pools and riffles with complex physical structure/habitat (i.e. debris, willow roots and emergent vegetation) (Figure 24) and low salinity (typically <500 $\mu S.cm^{-1}$).

This site has been monitored since 2001 (see Hammer 2004; Hammer 2009). Both river blackfish and southern pygmy perch have been regularly captured in consistent numbers over time at this site.

Fish sampling effort

Spring 2008

- Backpack electrofishing (685 seconds, 75 Hz, 250 v, 8% DC)

Autumn 2009

- Backpack electrofishing (945 seconds, 75 Hz, 300 v, 10% DC)

Spring 2009

- Backpack electrofishing (807 seconds, 75 Hz, 220 v, 10% DC)

Autumn 2010

- Backpack electrofishing (637 seconds, 75 Hz, 220 v, 10% DC)

Spring 2010

- Backpack electrofishing (1560 seconds, 75 Hz, 220 v, 10% DC)

Autumn 2011

- Backpack electrofishing (1047 seconds, 60 Hz, 250 v, 10% DC)

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 24. Photo-point images of the Willowburn Rd Nangkita Creek site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

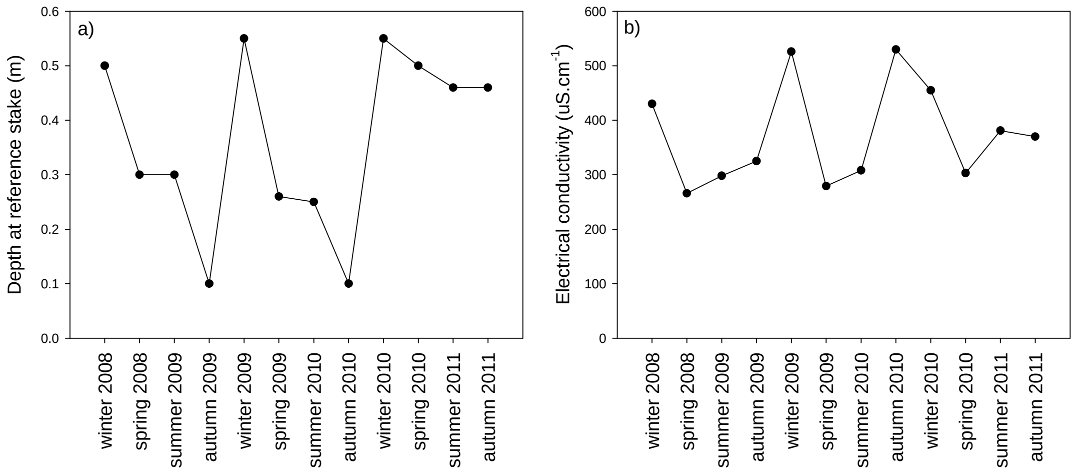


Figure 25. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Willowburn Road site between winter 2008 and autumn 2011.

Table 15. Habitat cover measured at Willowburn Road during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	20 (Willow, *Persicaria, Callatriche, Carex, Azolla*)	20 (snag)	60
Spring 2010	0	20 (Willow, *Callatriche*)	20 (snag)	60
Summer 2011	0	10 (Willow, *Callatriche*)	30 (snag)	60
Autumn 2011	0	30 (Willow)	20 (snag)	50

Table 16. Water quality parameters measured at Willowburn Road during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	10.3	8.03	8.03	-	0.7	1.3
Spring 2010	13.8	7.45	8.04	-	0.4	1.3
Summer 2011	16.3	7.07	4.46	6.05	0.7	1.1
Autumn 2011	16.3	8.24	8.02	7.58	0.8	1.5

Catch summary and length-frequency analysis

River blackfish and southern pygmy perch were sampled in consistent numbers across all sampling events in 2008/09 and 2009/10 (Table 17). In 2010/11, southern pygmy perch were again sampled in similar abundances, whilst river blackfish were sampled in high abundance in autumn 2011 (Table 17). Mountain galaxias was the only other species sampled in 2008, 2010 and 2011, whilst the non-native eastern gambusia and rainbow trout were also sampled in spring 2009 (Table 17).

Table 17. Total numbers and abundance (in bracket; number of fish.100 seconds of e-fishing^{-1}) of fish species collected from the Willowburn Road site between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
River blackfish	***Gadopsis marmoratus***	**8 (1.22)**	**7 (0.74)**	**13 (1.61)**	**11 (1.73)**	**8 (0.51)**	**58 (5.54)**
Southern pygmy perch	***Nannoperca australis***	**7 (1.02)**	**24 (2.54)**	**24 (2.97)**	**21 (3.30)**	**45 (2.88)**	**38 (3.63)**
Mountain galaxias	*Galaxias olidus*	7 (1.02)	153 (16.19)	19 (2.35)	35 (5.49)	39 (2.5)	4 (0.38)
Eastern gambusia	*Gambusia holbrooki*	0	0	1 (0.12)	0	0	0
Rainbow trout	*Onchorrychus mykiss*	0	0	1 (0.12)	0	0	0

Juvenile river blackfish, 62 – 82 mm TL dominated the population in spring 2008 (Figure 26a). Data from autumn 2009 shows the growth of this cohort and the presence of a YOY individual (43 mm TL) (Figure 26b). Length-distribution in spring 2009 was broad with fish ranging 73 – 185 mm TL (Figure 26c). Growth of these individuals was evident by autumn 2010 with fish exhibiting a similarly broad but larger length range (97 – 195 mm TL) (Figure 26d). Two distinct cohorts were present in spring 2010, with newly recruited YOY present (< 70 mm TL) (Figure 26e). In autumn 2011, fish ranged from 31 – 215 mm TL and significant recent recruitment of YOY was evident with individuals 31 – 60 mm TL (Figure 26f and 27) comprising ~80% of the population (Figure 26f), numerically 10-fold that of catches from preceding years.

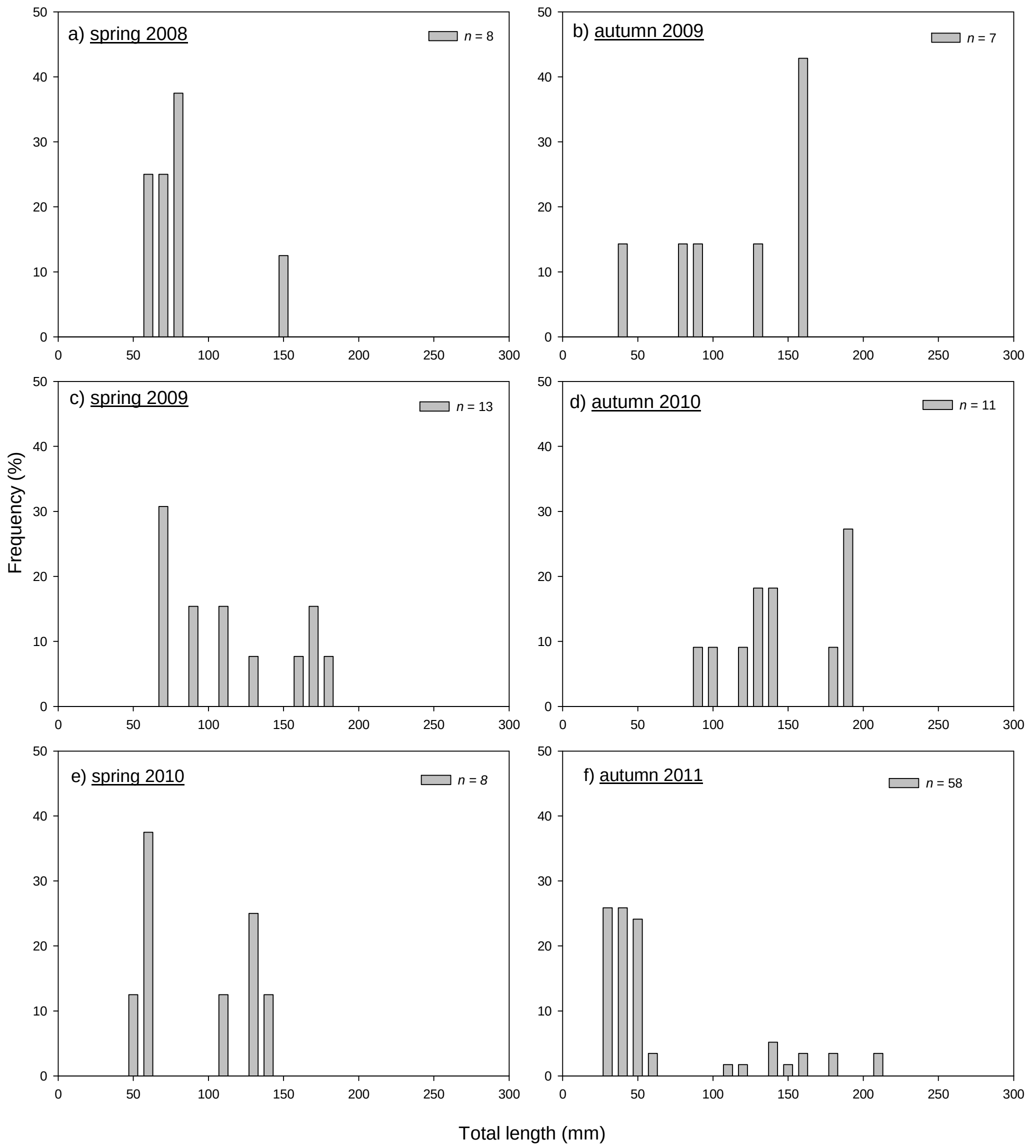


Figure 26. Length frequency distribution of river blackfish from the Willowburn Road site in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e) spring 2010 and f) autumn 2011.

Figure 27. Large numbers of YOY river blackfish captured from the Willowburn Road site in autumn 2011.

In spring 2008 the southern pygmy perch population was dominated by adult fish (> 40 mm TL) (Figure 28a) but significant recruitment was observed in autumn 2009 with > 45% of the population comprised of YOY individuals (Figure 28b). Similarly in spring 2009 the population was dominated by adult fish >40 mm TL (Figure 28c). In autumn 2010 recruitment was not as clear, however, fish <45 mm TL may represent YOY individuals (Figure 28d). Again in spring 2010, the population was dominated by large adult fish (>40 mm TL) (Figure 28e) but recent recruitment was evident in autumn 2011 with a likely YOY cohort measuring 28 – 43 mm TL (Figure 28f).

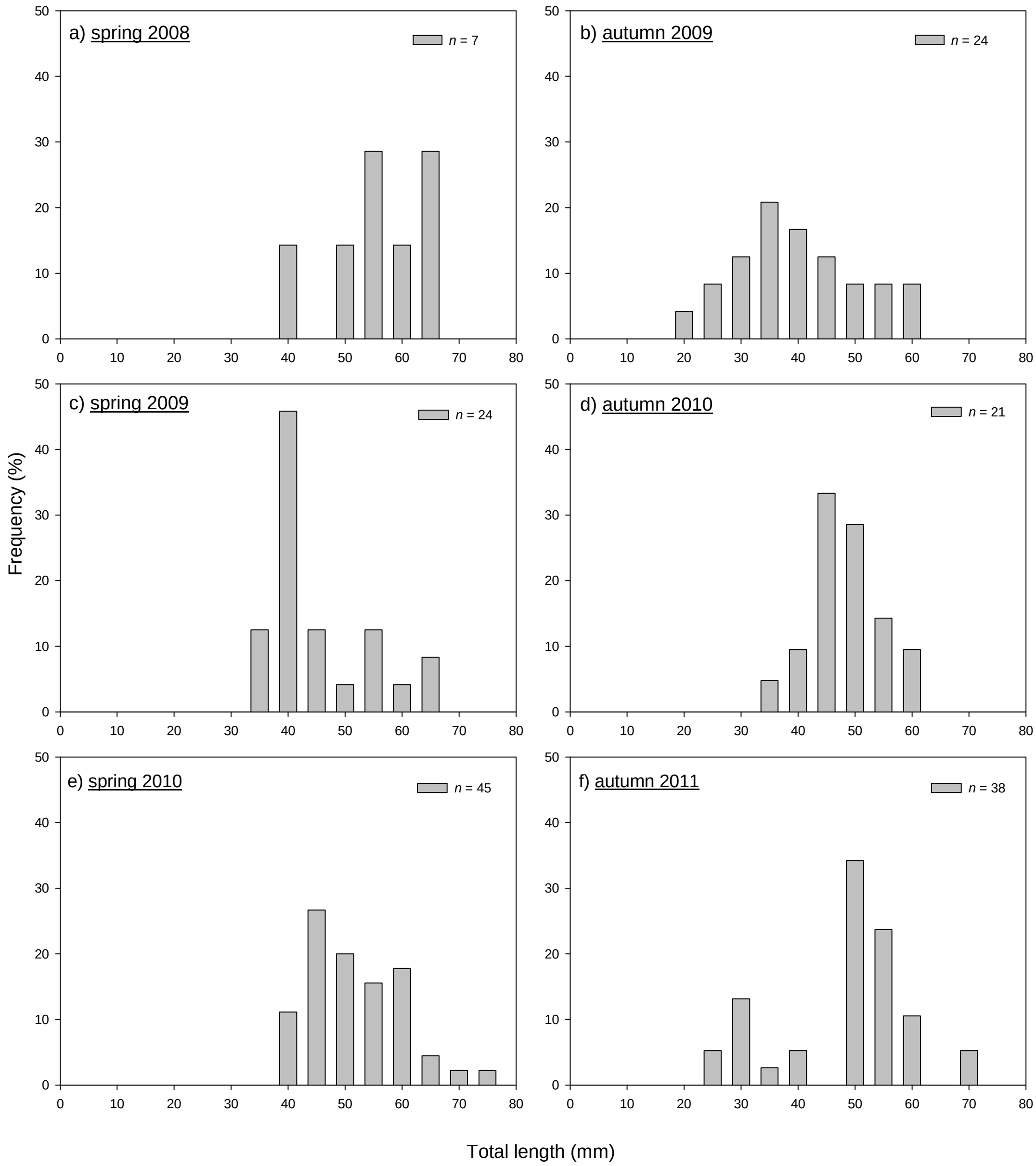


Figure 28. Length frequency distribution of southern pygmy perch from the Willowburn Road site in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e) spring 2010 and f) autumn 2011.

Site summary

Both river blackfish and southern pygmy perch populations appear stable and strong. Both populations exhibited annual recruitment over the study period and have diverse population structures (i.e. broad size ranges). Conditions in 2010/11 appeared highly conducive to river blackfish reproduction with substantially greater recruitment of YOY in autumn 2011 than in previous years. Furthermore, habitat conditions also appear stable and favourable for the persistence of these species. Scouring flows in 2010/11 resulted in consistently greater depths at this site compared to preceding years (Figure 25a).

4.7. Deep Creek Road (Tookayerta Creek: river blackfish and southern pygmy perch)

This site is on the lowland channel section of Tookayerta Creek, which flows out of the southern EMLR before meeting the Finniss River and flowing into the Goolwa Channel on the south-western side of Lake Alexandrina. This reach consists of large, deep pools dominated by fringing emergent vegetation (e.g. *Phragmites australis, Typha domingensis, Triglochin procerum*), interspersed with sections of swamp (Figure 29) (Hammer 2009).

Monitoring has occurred at this site since 2001 (see Hammer 2004; Hammer 2009). Southern pygmy perch were formerly sampled in moderate – high numbers, whilst river blackfish have been consistently sampled in low numbers, with occasional spikes in the abundance of YOY in autumn.

Fish sampling effort

Spring 2008

- Backpack electrofishing (800 seconds, 75 Hz, 250 v, 8% DC)

Autumn 2009

- Backpack electrofishing (600 seconds, 75 Hz, 250 v, 10% DC)

Spring 2009

- Backpack electrofishing (parameters not recorded)

Autumn 2010

- Backpack electrofishing (553 seconds, 75 Hz, 250 v, 10% DC)

Spring 2010

- Backpack electrofishing (906 seconds, 75 Hz, 250 v, 10% DC)

Autumn 2011

- Backpack electrofishing (862 seconds, 60 Hz, 250 v, 10% DC)

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 29. Photo-point images of the Deep Creek Rd site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

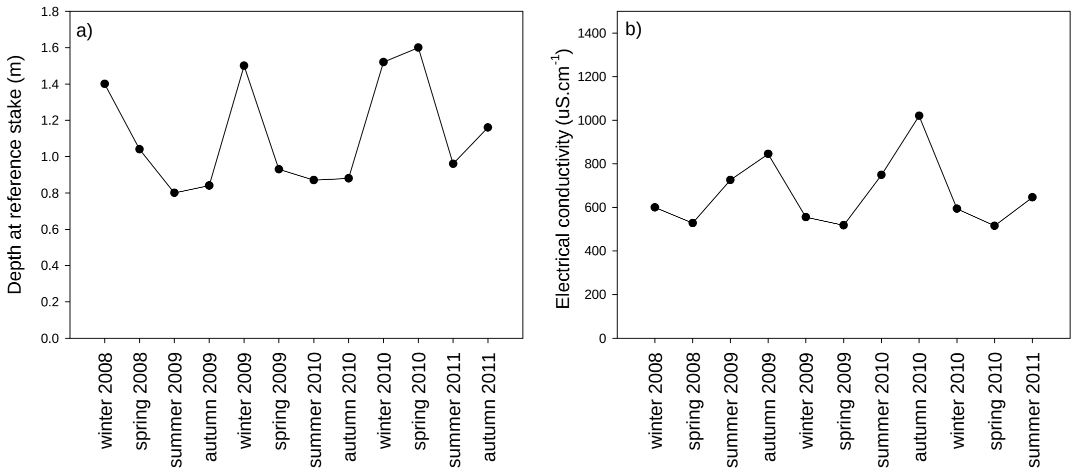


Figure 30. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Deep Creek Road site between winter 2008 and autumn 2011.

Table 18. Habitat cover measured at Deep Creek Road during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	50 (*Typha, Phragmites,* grass)	0	50
Spring 2010	0	50 (*Phragmites, Triglochin*)	5 (snag)	45
Summer 2011	0	70 (*Typha, Phragmites, Triglochin*)	10 (snag)	20
Autumn 2011	0	65 (*Typha, Phragmites, Triglochin*)	5 (snag)	30

Table 19. Water quality parameters measured at Deep Creek Road during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	9.7	7.51	7.48	7.37	0.46	2.0
Spring 2010	16.4	7.44	8.08	8.14	-	1.8
Summer 2011	17.0	7.15	7.07	5.60	0.6	1.5
Autumn 2011	17.1	7.77	7.85	7.59	0.8	1.8

Catch summary and length-frequency analysis

With the exception of spring 2010, river blackfish were present in consistent numbers over the study period (Figure 31a; Table 20). Conversely, with the exception of autumn 2010, southern pygmy perch were also present in consistent numbers over the study period (Figure 31a; Table 20). Mountain galaxias was the only other species sampled (Table 20).

a) b)

Figure 31. a) A young-of-year river blackfish sampled in autumn 2010 and b) adult southern pygmy perch also sampled in autumn 2010.

Table 20. Total numbers of fish species collected from the Deep Creek Road site between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
River blackfish	***Gadopsis marmoratus***	**3 (0.38)**	**5 (0.83)**	**4**	**16 (2.89)**	**1 (0.11)**	**8 (0.93)**
Southern pygmy perch	***Nannoperca australis***	**21 (2.65)**	**13 (2.17)**	**15**	**5 (0.9)**	**22 (2.43)**	**12 (1.39)**
Mountain galaxias	*Galaxias olidus*	1 (0.13)	0	0	0	0	0

In spring 2008 river blackfish ranged from 80-98 mm TL (Figure 32a), most likely representing recruits from the previous spring. This cohort was present in autumn 2009 but had grown to *c.* 120 mm TL, whilst a new cohort of YOY individuals was also present (39-51 mm TL; Figure 32b) suggesting recent recruitment. Growth of this YOY cohort was evident in spring 2009 with a cohort ranging 117 – 129 mm TL (Figure 32c). In autumn 2010, 16 individuals were sampled and three distinct cohorts (age classes) were evident (Figure 32d). Adult fish were present at 142 – 169 mm TL, whilst there were two juvenile cohorts; one ranging 81-98 mm TL and the other 37 – 58 mm TL, indicating that spawning occurred during the previous spring (Figure 32d). Just one individual was sampled in spring 2010 (116 mm TL) (Figure 32e), whilst recent recruitment was again evident in autumn 2011, with YOY individuals 43 – 54 mm TL comprising >60% of the population (Figure 31a and 32f)

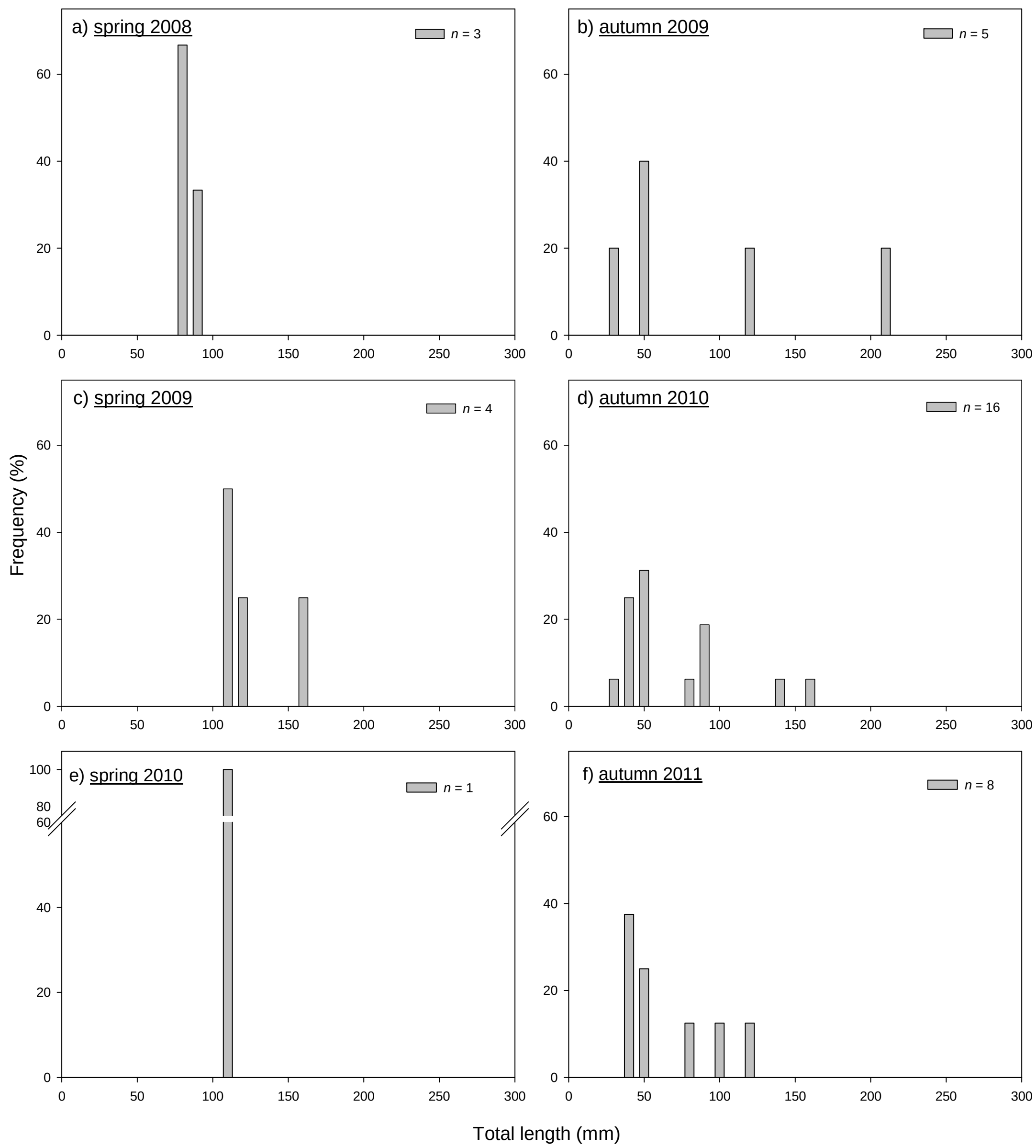


Figure 32. Length frequency distribution of river blackfish from the Deep Creek Road site in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e) spring 2010 and f) autumn 2011.

In spring 2008 *c.* 40% of southern pygmy perch individuals were < 35 mm TL and are likely to be recruits from late in the previous spawning season based upon similar length frequency distributions from this site in previous years (Hammer 2009) (Figure 33a). In autumn 2009, the population exhibited a very broad length distribution, with a cohort of YOY (10-35 mm TL) likely spawned in spring/summer 2008/09 (Figure33b). Large adult fish (>60 mm TL) were also present (Figure 33b). Growth of this YOY cohort was evident in spring 2009 and the length-frequency distribution appears similar to spring 2008 (Figure 33 a and c). Despite only 5 individuals being sampled in autumn 2010, the length-frequency distribution is dissimilar to the previous years (Figure 33d). The cohort centred around 30 mm TL is likely to represent YOY from spring/summer spawning but no recently recruited individuals were present as had previously been in autumn 2009. Again in spring 2010, the length distribution of southern pygmy perch was similar to spring in previous years with individuals ranging 31 – 63 mm TL (Figure 33e).Two distinct cohorts were present in autumn 2011, with adult fish >45 mm TL and recently spawned YOY individuals ranging 18- 22 mm TL (Figure 33f).

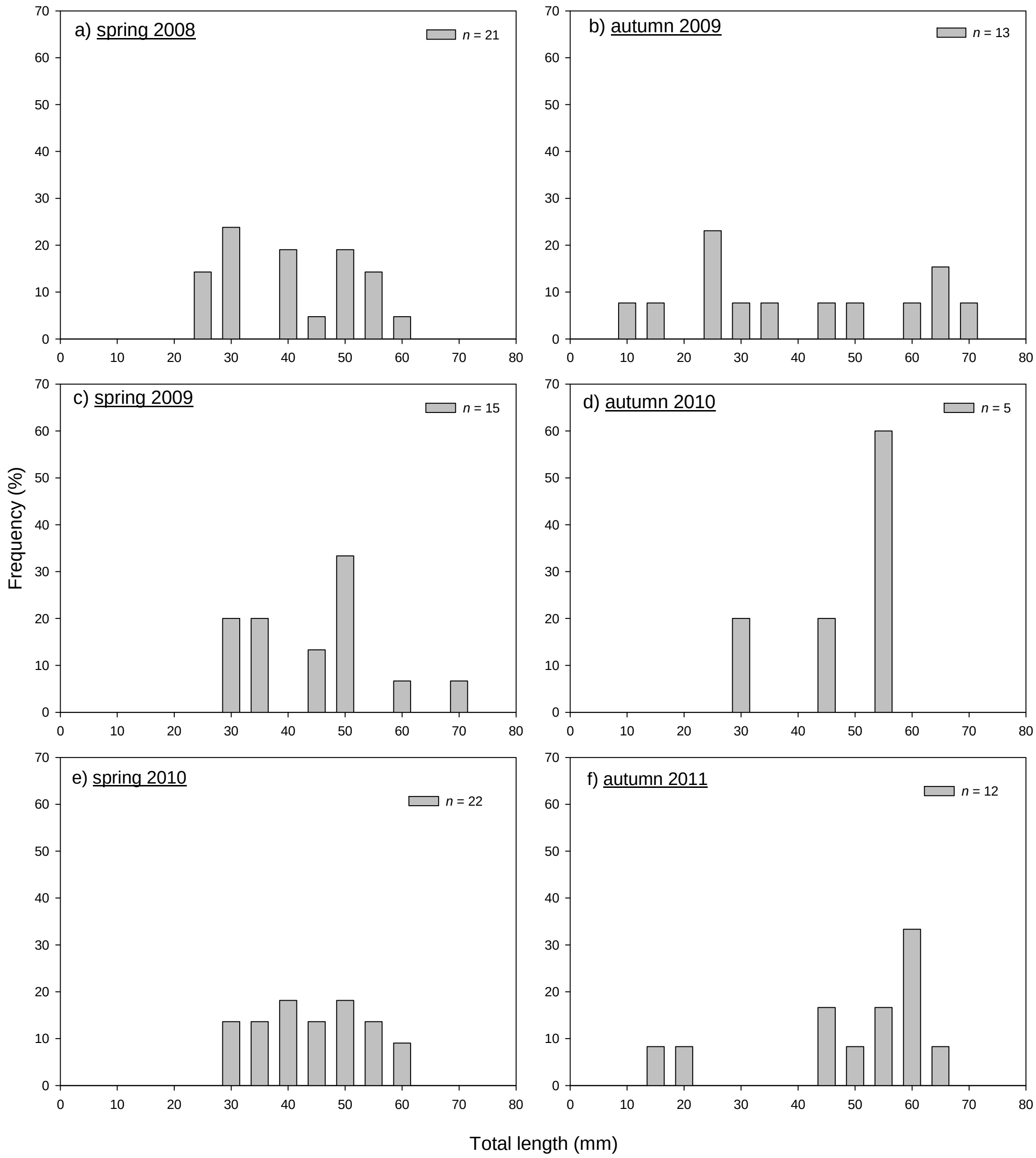


Figure 33. Length frequency distribution of southern pygmy perch from the Deep Creek Road site in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e) spring 2010 and f) autumn 2011.

Site summary

The river blackfish and southern pygmy perch populations at this site are likely to be stable and recent recruitment was evident in both populations. Patterns of abundance and recruitment appear to be similar annually through the study period, although southern pygmy perch have declined in abundance when compared to previous sampling at this site prior to 2008 (Hammer 2009). Nevertheless, there has been recent recruitment and this population is unlikely to be in immediate risk.

4.8. Middle Creek Junction (Angas River: southern pygmy perch)

Middle Creek is a tributary of the Angas River, flowing into the Angas River near Strathalbyn. The Angas River flows south-east from here before discharging into Lake Alexandrina near the township of Milang. This site could be characterised as a narrow creek reach and habitat is dominated by abundant emergent (*Phragmites australis, Typha domingensis, Schoenoplectus validus*) and submerged (*Potamogetan tricarinatus*) vegetation (Figure 34). Southern pygmy perch have been consistently sampled in low – moderate numbers at this site since 1999 (Hammer 2005; Hammer 2009). Increased rainfall and flow in 2010/11 resulted in consistently greater water levels and lower salinities (electrical conductivity) relative to preceding years (Figure 35)

Fish sampling effort

Spring 2008, autumn 2009, spring 2009 and autumn 2010

- 1 fyke net set overnight

Spring 2010 and autumn 2011

- 2 fyke net set overnight (sampling effort increased due to increased available habitat)

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 34. Photo-point images of the Middle Creek Junction site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

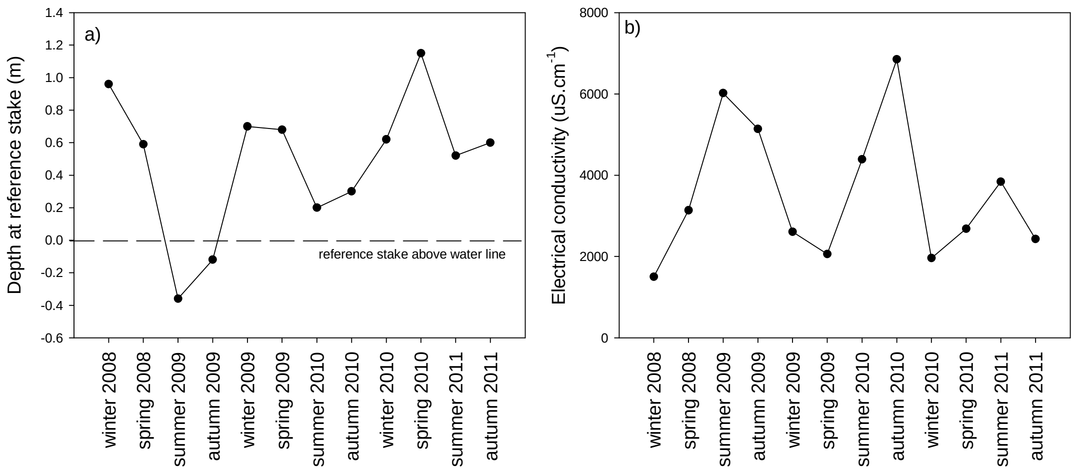


Figure 35. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (μS.cm^{-1}) at the Middle Creek Junction site between winter 2008 and autumn 2011.

Table 21. Habitat cover measured at Middle Creek Junction during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	10 (*Potamogeton tricarinatus*)	60 (*Phragmites*)	0	30
Spring 2010	20 (*Potamogeton tricarinatus*)	50 (*Typha, Phragmites*)	1 (snag)	29
Summer 2011	40 (*Potamogeton tricarinatus*)	50 (*Typha, Phragmites,* grass)	0	10
Autumn 2011	30 (*Potamogeton tricarinatus*)	60 (*Typha, Phragmites, Bolboschoenus*)	0	10

Table 22. Water quality parameters measured at Middle Creek Junction during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	9.5	7.53	9.46	0.65	1.32
Spring 2010	18.2	7.77	7.88	0.93	1.18
Summer 2011	16.9	7.21	5.31	0.9	1
Autumn 2011	17.7	7.76	7.42	0.8	1.4

Catch summary and length-frequency analysis

Southern pygmy perch were sampled in high abundance in spring 2010 (Figure 36) and moderate abundance in autumn 2011 relative to previous sampling events (Table 23). In spring 2008, individuals ranged from 34-66 mm TL (Figure 37a). A large proportion of individuals (*c.* 85%) were of a similar size in autumn 2009, however, a cohort of YOY (<24 mm TL) was also present, indicating recent recruitment (Figure 37b). The single individual captured in spring 2009 was a large adult (>50 mm TL; Figure 37 c). However, in autumn 2010, the population exhibited a broad range of lengths with a large proportion (50%) of likely YOY (<35 mm TL) (Figure 37d). Population length frequency distribution in spring 2010 was similar to spring 2008, with individuals ranging 33-70 mm TL (Figure 37e). Recruitment was again evident in autumn 2011 (Figure 37f), however, the YOY cohort appeared larger (26-41 mm TL) than in previous years (Figure 37).

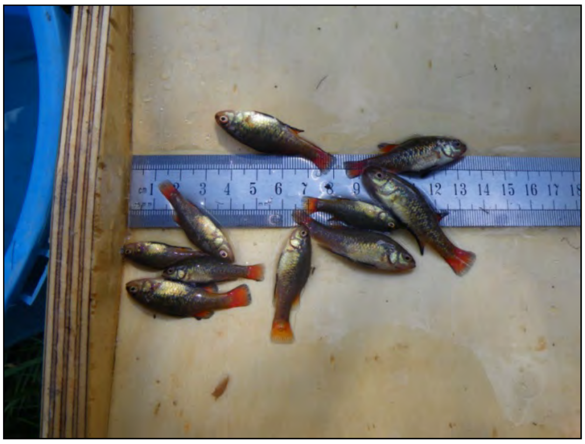


Figure 36. Adult southern pygmy perch sampled from Middle Creek Junction in spring 2010

Table 23. Total numbers of fish species collected from the Middle Creek Junction site between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Southern pygmy perch	***Nannoperca australis***	**35**	**53**	**2**	**9**	**101**	**30**
Carp gudgeon complex	*Hypseleotris* spp.	21	11	0	5	10	2
Flat-headed gudgeon	*Philypnodon grandiceps*	4	0	0	0	2	0
Mountain galaxias	*Galaxias olidus*	4	4	2	5	34	24
Common carp	*Cyprinus carpio*	0	0	0	0	1	

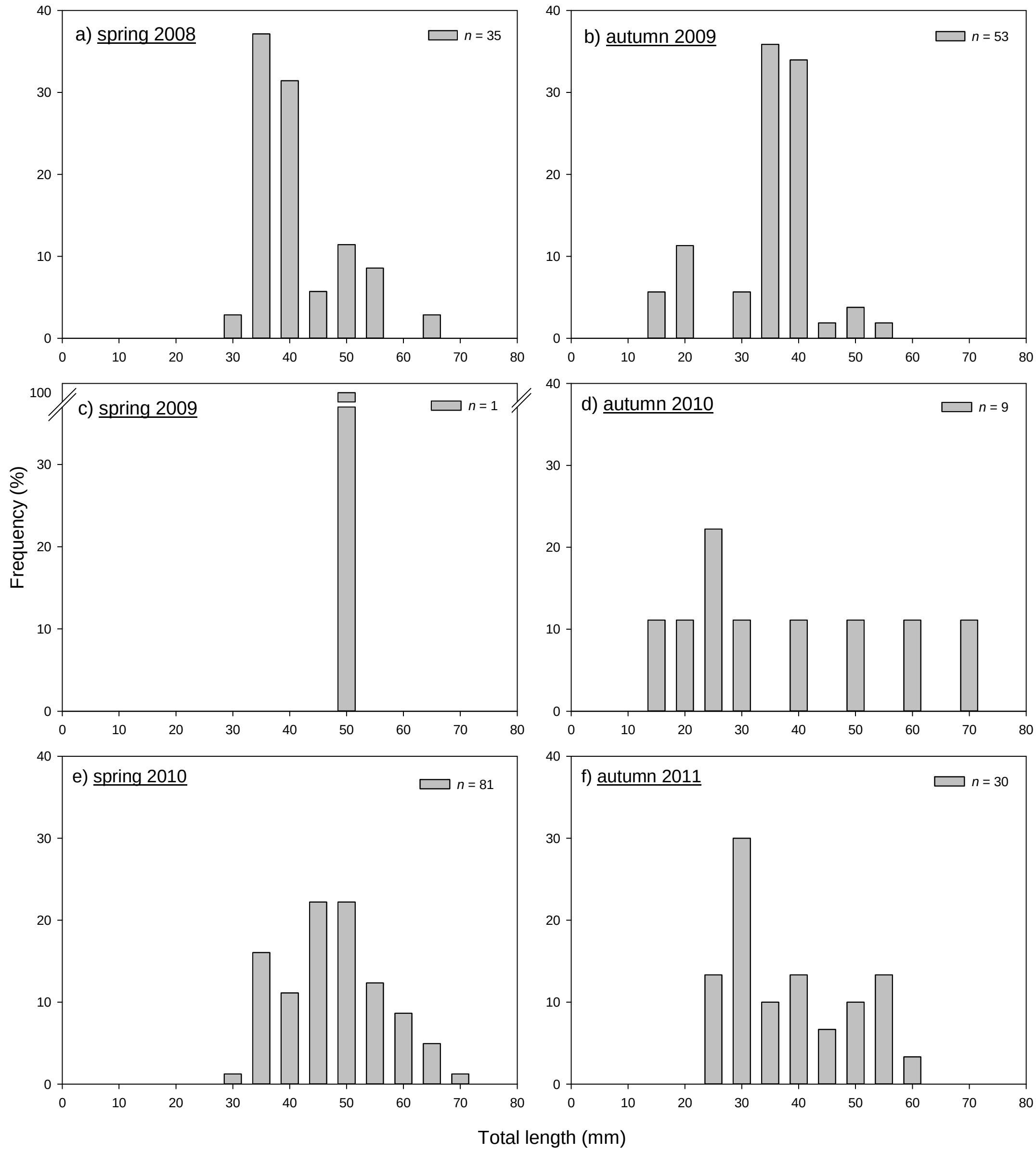


Figure 37. Length frequency distribution of southern pygmy perch from the Middle Creek Junction site in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e)spring 2010 and f) autumn 2011.

Site summary

Southern pygmy perch are persisting at this site in moderate numbers with recent recruitment observed in autumn 2011. Water level remained higher and salinity lower in 2010/11 (Figure 35a) than both preceding years inferring greater security of habitat and thus this population remains steady.

4.9. Eastick Creek mouth, Hindmarsh Island (Lake Alexandrina: Yarra pygmy perch, southern pygmy perch and Murray hardyhead)

Eastick Creek is on Hindmarsh Island in Lake Alexandrina and discharges into Holmes Creek (Figure 38). This site was formerly a sheltered edge habitat with abundant emergent (i.e. *Typha domingensis, Phragmites australis* and *Schoenoplectus validus*) and submerged vegetation (i.e. *Myriophyllum* spp.), but was impacted by diminished water levels in the Lower Lakes from 2007-2010. During this period, salinity was elevated, submerged vegetation was lost and fringing emergent vegetation was largely disconnected from the water. Increased water levels in the Lower Lakes in 2010 resulted in increased water level and reduced salinity at this site, emergent vegetation was re-inundated and submerged vegetation began to re-colonise. Data for this site from autumn 2010 and autumn 2011 were collected by SARDI Aquatic Sciences as part of a DENR funded project which aimed to investigate the response of fish species to the *Goolwa Water Level Management Plan* (Bice *et al.* 2010b; Bice and Zampatti 2011).

This site, together with several other sites in the vicinity, has been sampled since 2003 (Wedderburn and Hammer 2003; Higham *et al.* 2005; Bice and Ye 2006; Bice and Ye 2007; Bice *et al.* 2008) and was a rescue location for 16 Yarra pygmy perch (last records in February 2008; Hammer 2008b). Yarra pygmy perch, southern pygmy perch and Murray hardyhead were previously sampled in low abundances.

Fish sampling effort

Spring 2008, autumn 2010, spring 2010 and autumn 2011

- 4 fyke nets set overnight

Autumn 2009 and spring 2009

- Not sampled due to low water levels

2009/10 Photopoint images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 38. Photo-point images of the Eastick Creek mouth site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

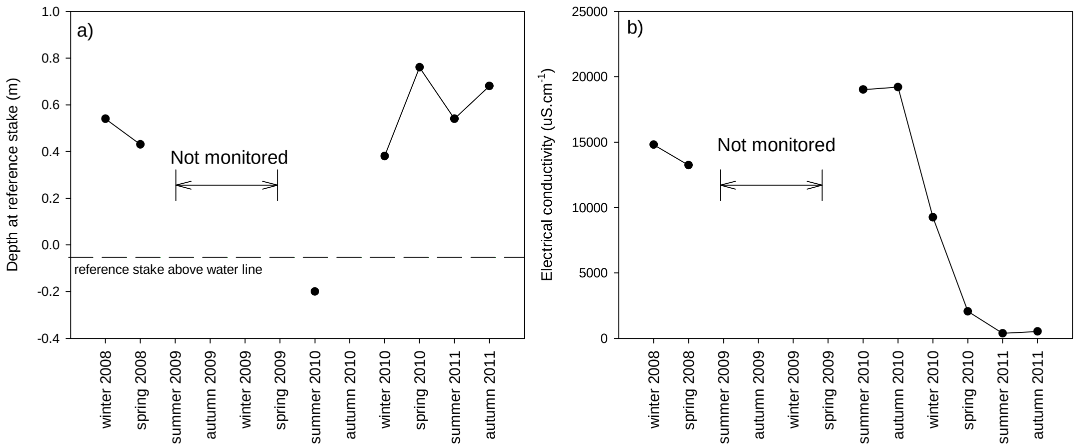


Figure 39. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity ($\mu S.cm^{-1}$) at the Eastick Creek mouth site between winter 2008 and autumn 2011.

Table 24. Habitat cover measured at Eastick Creek mouth during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	30 (*Typha, Juncus, Cotula,* grasses, terrestrial weeds)	0	70
Spring 2010	5 (algae)	20 (*Typha*)	5 (rock)	70
Summer 2011	1 (algae)	20 (*Typha, Phragmites, Schoenoplectus,* grasses)	20 (rock)	59
Autumn 2011	1 (*Myriophyllum*)	39 (*Typha, Phragmites, Schoenoplectus, Triglochin,* grasses)	0	60

Table 25. Water quality parameters measured at Eastick Creek mouth during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	13.5	8.35	7.97	0.3	0.8
Spring 2010	15.3	8.56	10.67	0.45	1.6
Summer 2011	25.2	8.22	10.01	0.15	1
Autumn 2011	16.6	7.65	4.72	0.25	>1

Catch summary and length-frequency analysis

No southern pygmy perch or Yarra pygmy perch were captured at this site throughout the project. Murray hardyhead were not sampled in 2010/11, with just one individual sampled in autumn 2010 (Table 26). The single Murray hardyhead sampled in autumn 2010 was likely a newly recruited YOY (43 mm TL) (Figure 40). A total of 16 other species were sampled at this site (Table 26).

Table 26. Total numbers of fish species collected from the Eastick Creek mouth between spring 2008 and autumn 2011. NS = not sampled.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**0**	**NS**	**NS**	**1**	**0**	**0**
Yarra pygmy perch	***Nannoperca obscura***	**0**	**NS**	**NS**	**0**	**0**	**0**
Southern pygmy perch	***Nannoperca australis***	**0**	**NS**	**NS**	**0**	**0**	**0**
Flat-headed gudgeon	*Philypnodon grandiceps*	25	NS	NS	734	478	145
Carp gudgeon	*Hypseleotris* spp.	0	NS	NS	13	19	0
Australian smelt	*Retropinna semoni*	156	NS	NS	112	442	41
Bony herring	*Nematalosa erebi*	5	NS	NS	163	0	265
Golden perch	*Macquaria ambigua*	0	NS	NS	0	0	1
Common galaxias	*Galaxias maculatus*	19	NS	NS	15	18	9
Congolli	*Pseudaphritus urvillii*	1	NS	NS	0	2	0
Small-mouthed hardyhead	*Atherinosoma microstoma*	2745	NS	NS	2190	337	6
Lagoon goby	*Tasmanogobius lasti*	66	NS	NS	158	64	14
Tamar River goby	*Afurcagobius tamarensis*	59	NS	NS	47	43	0
Blue-spot goby	*Pseudogobius olorum*	47	NS	NS	103	64	0
Bridled goby	*Arenogobius bifrenatus*	5	NS	NS	49	2	0
Redfin perch	*Perca fluviatilis*	5	NS	NS	3	0	20
Eastern gambusia	*Gambusia holbrooki*	0	NS	NS	0	0	3
Goldfish	*Carrasius auratus*	0	NS	NS	0	0	13
Common carp	*Cyprinus carpio*	0	NS	NS	0	9	90

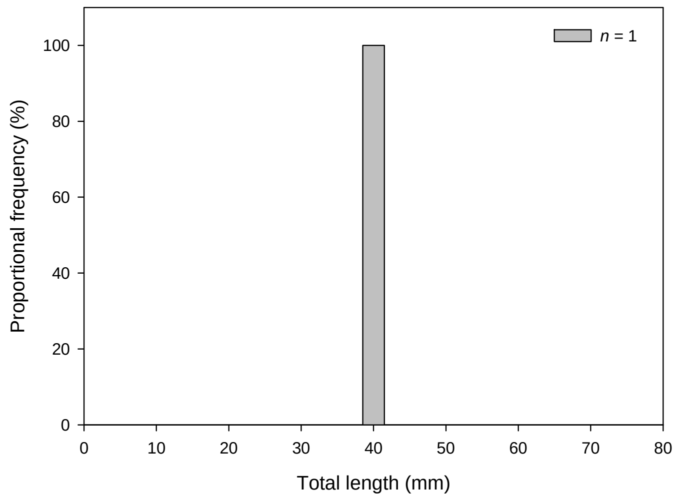


Figure 40. Length-frequency distribution of Murray hardyhead from the Eastick Creek mouth site in autumn 2010.

Site summary

Prior to autumn 2010, threatened species had not been recorded from this site since February 2008 (Hammer 2008b) and were again absent in 2010/11, with the exception of a single Murray hardyhead. This site was impacted by low water levels in Lake Alexandrina through 2007-2010, with fringing emergent vegetation disconnected from the water, diminished submerged vegetation and elevated salinity. Normal regulated water levels have now returned to Lake Alexandrina and subsequently available habitat and habitat quality have increased, and salinities have been reduced. Nonetheless, re-colonisation by Murray hardyhead, Yarra pygmy perch and southern pygmy perch has yet to occur. Yarra pygmy perch from this site were included in the captive breeding program being undertaken by Aquasave, Cleland Wildlife Park and Flinders University.

4.10. Boundary Creek Drain, Mundoo Island (Lake Alexandrina: Yarra pygmy perch, southern pygmy perch and Murray hardyhead)

The Boundary Creek Drain is on Mundoo Island in Lake Alexandrina and discharges into Boundary Creek (Figure 41). This site represents a modified natural channel/drain habitat and prior to 2007, was typically characterised by abundant emergent (i.e. *Typha domingensis, Phragmites australis* and *Schoenoplectus validus*) and submerged vegetation (i.e. *Vallisneria australis, Potamogetan pectinatus, Myriophyllum* spp.). This site was impacted by diminished water levels in the Lower Lakes from 2007-2010, when the site was desiccated and disconnected from Boundary Creek. With increased water levels in Lake Alexandrina in 2010, this site was re-inundated and re-connected to Boundary Creek. This site, was sampled by Wedderburn and Barnes (2009) and Wedderburn and Barnes (In Prep.) in 2008/09 and 2010/11.

Fish sampling effort

Spring 2008, autumn 2009, spring 2010 and autumn 2011

- 3 fyke nets set overnight
- 3 x 10 m seine hauls

2009/10 Photopoint images

Winter 2010

Not monitored

Spring 2010

Summer 2011

Not monitored

Autumn 2011

Figure 41. Photo-point images of the Boundary Creek Drain site from spring 2010 and autumn 2011.

Environmental conditions

Table 27. Habitat cover measured at Boundary Creek Drain during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Total aquatic vegetation cover (%)	Physical	Open water
Spring 2010	0	0	100
Autumn 2011	6	0	94

Table 28. Water quality parameters measured at Boundary Creek Drain during each site visit.

Season	EC ($\mu S.cm^{-1}$)	Temp (°C)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	Not monitored					
Spring 2010	3170	21.4	7.44	7.9	0.33	-
Summer 2011	Not monitored					
Autumn 2011	930	19.3	7.52	8.11	0.23	-

Catch summary and length-frequency analysis

No threatened species were sampled at Boundary Creek Drain in spring 2010 or autumn 2011. Murray hardyhead were sampled in spring 2008 in moderate numbers, with population dominated by adult fish (>38 mm TL) (Table 29 and Figure 42a), but only one individual (likely YOY) was sampled in autumn 2009 (Table 29 and Figure 42b). A total of 12 other species were sampled at the site (Table 29).

Table 29. Total numbers of fish species collected from Boundary Creek Drain between spring 2008 and autumn 2011. NS = not sampled.

Species		Sampling trip					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Yarra pygmy perch	***Nannoperca obscura***	**0**	**0**	**NS**	**NS**	**0**	**0**
Southern pygmy perch	***Nannoperca australis***	**0**	**0**	**NS**	**NS**	**0**	**0**
Murray hardyhead	***Craterocephalus fluviatilis***	**58**	**1**	**NS**	**NS**	**0**	**0**
Carp gudgeon complex	*Hypseleotris spp.*	2	0	NS	NS	0	0
Flat-headed gudgeon	*Philypnodon grandiceps*	5	0	NS	NS	45	19
Bony herring	*Nematalosa erebi*	0	0	NS	NS	19	95
Congolli	*Pseudaphritis urvillii*	0	0	NS	NS	0	2
Small mouthed hardyhead	*Atherinosoma microstoma*	10	0	NS	NS	0	0
Lagoon goby	*Tasmanogobius lasti*	1	0	NS	NS	0	0
Tamar River goby	*Afurcagobius tamarensis*	9	0	NS	NS	0	0
Blue-spot goby	*Pseudogobius olorum*	51	0	NS	NS	0	0
Redfin perch	*Perca fluviatilis*	0	0	NS	NS	654	40
Eastern gambusia		84	285	NS	NS	1	0
Common carp & goldfish	*Cyprinus carpio & Carrasius auratus*	-	-	NS	NS	1	-
Goldfish	*Carrasius auratus*	0	0	NS	NS	-	
Common carp	*Cyprinus carpio*	0	0	NS	NS	-	74

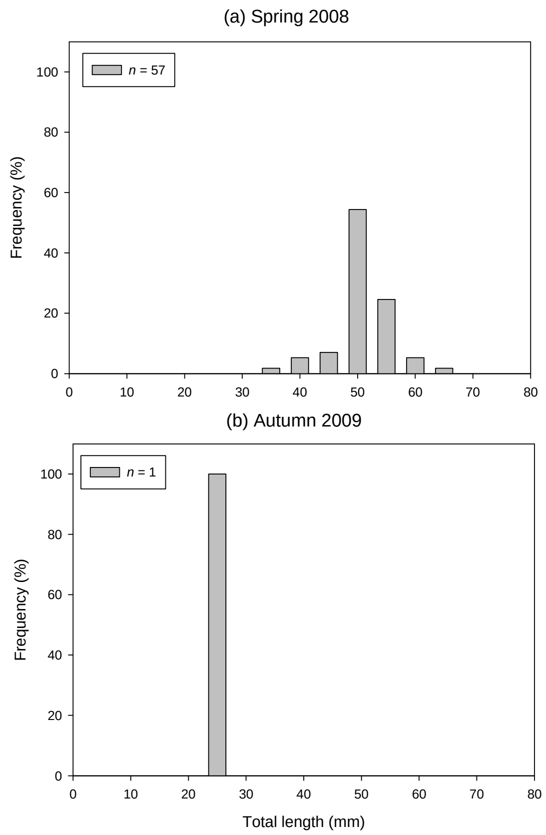


Figure 42. Length-frequency distribution of Murray hardyhead from the Boundary Creek Drain in (a) spring 2008 and (b) autumn 2009.

Site summary

Murray hardyhead were last recorded at this site in autumn 2009 whilst southern pygmy perch and Yarra pygmy perch have been absent throughout the project. This site was impacted by low water levels in Lake Alexandrina from 2007-2010, when it was desiccated and disconnected from Boundary Creek. With the return of regulated water levels in Lake Alexandrina, this site has been re-inundated and re-connected and there has been germination and growth of emergent and submerged vegetation. Nonetheless, re-colonisation by Murray hardyhead, Yarra pygmy perch and southern pygmy perch has not occurred. This may be favourable for reintroduction if habitat conditions continue to improve.

4.11. Steamer Drain, Hindmarsh Island (Lake Alexandrina: Yarra pygmy perch, southern pygmy perch and Murray hardyhead)

Steamer Drain is on Hindmarsh Island in Lake Alexandrina and discharges into Holmes Creek (Figure 43). This site represents a modified channel or irrigation drain habitat and prior to 2007, was typically characterised by abundant emergent (i.e. *Typha domingensis, Phragmites australis* and *Schoenoplectus validus*) and submerged vegetation (i.e. *Vallisneria australis, Potamogetan pectinatus, Myriophyllum* spp.). This site was impacted by diminished water levels in the Lower Lakes from 2007-2010, when the site was desiccated and disconnected from Holmes Creek. With increased water levels in Lake Alexandrina in 2010, this site was re-inundated and re-connected to Holmes Creek and there was a positive response from emergent and submerged vegetation.

This site, together with several other sites in the vicinity, has been sampled since 2003 (Wedderburn and Hammer 2003; Higham *et al.* 2005; Bice and Ye 2006; Bice and Ye 2007; Bice *et al.* 2008). Yarra pygmy perch, southern pygmy perch and Murray hardyhead were typically sampled in low abundances and the site was a rescue location for 54 Yarra pygmy perch (Hammer 2008b).

Fish sampling effort

Spring 2008, autumn 2009, spring 2009 and autumn 2010

- Not sampled - dry

Spring 2010 and autumn 2011

- 4 fyke nets set overnight

2009/10 Photopoint images

Winter 2010

Not monitored

Spring 2010

Summer 2011

Autumn 2011

Figure 43. Photo-point images of the Steamer Drain site from spring 2010, summer 2011 and autumn 2011.

Environmental conditions

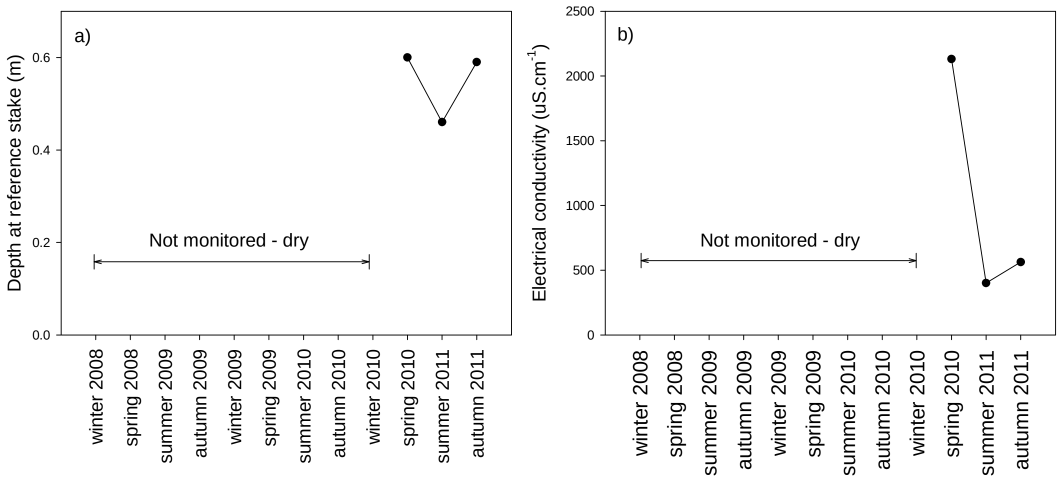


Figure 44. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Steamer Drain site between winter 2008 and autumn 2011.

Table 30. Habitat cover measured at Steamer Drain during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	Not monitored - dry			
Spring 2010	1 (*Potamogetan pectinatus, Myriophyllum*)	40 (*Typha,* grasses)	20 (debris)	39
Summer 2011	35 (*Potamogetan pectinatus*)	35 (*Typha,* grasses)	0	30
Autumn 2011	20 (*Potamogetan pectinatus*)	50 (*Typha*)	0	30

Table 31. Water quality parameters measured at Steamer Drain during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	Not monitored - dry				
Spring 2010	15.6	8.6	7.9	0.6	1.1
Summer 2011	22.5	7.98	6.1	0.2	1.5
Autumn 2011	17	8.59	8.11	0.1	1.5

Catch summary and length-frequency analysis

No threatened species were sampled at Steamer Drain in spring 2010 or autumn 2011. A total of 14 other species were sampled at the site including non-native common carp, which were highly abundant in autumn 2011 (Table 32).

Table 32. Total numbers of fish species collected from Steamer Drain between spring 2008 and autumn 2011. NS = not sampled.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Yarra pygmy perch	***Nannoperca obscura***	**NS**	**NS**	**NS**	**NS**	**0**	**0**
Southern pygmy perch	***Nannoperca australis***	**NS**	**NS**	**NS**	**NS**	**0**	**0**
Murray hardyhead	***Craterocephalus fluviatilis***	**NS**	**NS**	**NS**	**NS**	**0**	**0**
Carp gudgeon complex	*Hypseleotris* spp.	NS	NS	NS	NS	1	0
Flat-headed gudgeon	*Philypnodon grandiceps*	NS	NS	NS	NS	161	20
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	NS	NS	NS	NS	0	1
Bony herring	*Nematalosa erebi*	NS	NS	NS	NS	0	11
Australian smelt	*Retropinna semoni*	NS	NS	NS	NS	5	0
Congolli	*Pseudaphritis urvillii*	NS	NS	NS	NS	6	0
Common galaxias	*Galaxias maculatus*	NS	NS	NS	NS	24	1
Small mouthed hardyhead	*Atherinosoma microstoma*	NS	NS	NS	NS	243	0
Lagoon goby	*Tasmanogobius lasti*	NS	NS	NS	NS	2	0
Bridled goby	*Arenigobius bifrenatus*	NS	NS	NS	NS	5	0
Blue-spot goby	*Pseudogobius olorum*	NS	NS	NS	NS	8	0
Redfin perch	*Perca fluviatilis*	NS	NS	NS	NS	0	6
Goldfish	*Carrasius auratus*	NS	NS	NS	NS	0	44
Common carp	*Cyprinus carpio*	NS	NS	NS	NS	94	1113

Site summary

Threatened species were last recorded at this site in 2007 (Bice *et al.* 2008; Hammer 2008b). This site was impacted by low water levels in Lake Alexandrina through 2007-2010, when it was desiccated and disconnected from Holmes Creek. With the return of regulated water levels in Lake Alexandrina, this site has been re-inundated and re-connected and there has been germination and growth of emergent and select submerged vegetation. Nonetheless, re-colonisation by Murray hardyhead, Yarra pygmy perch and southern pygmy perch has not occurred. Yarra pygmy perch from this site were included in the captive breeding program being undertaken by Aquasave, Cleland Wildlife Park and Flinders University.

4.12. Black Swamp (Finniss River: Yarra pygmy perch and southern pygmy perch)

Black Swamp is in the lower Finniss River, where it meets the Tookayerta Creek (Figure 45). This area was once characterised by lowland wetlands with diverse submerged and emergent plant communities. Water level is influenced by water level in Lake Alexandrina and subsequently underwent complete drying through 2008-2009 followed by re-inundation under the *Goolwa Channel Water Level Management Plan* (GCWLMP) in late 2009 (SA Water 2009), before another (smaller) water level recession and subsequent increase in water levels with increasing lake levels in 2010 (Figure 46a). Salinity has also decreased substantially with naturally increased water levels from broader Murray flow and partial removal of the Clayton regulator in 2010/11 (Figure 46b).

Both Yarra pygmy perch and southern pygmy perch were sampled in low numbers at this site in 2003 (Wedderburn and Hammer 2003) and a single Yarra pygmy perch was sampled from this site in spring 2007 (Bice *et al.* 2008), prior to drying.

Fish sampling effort

Spring 2008 and autumn 2009

- not sampled

Spring 2009, autumn 2010, spring 2010 and autumn 2011

- 6 fyke nets set overnight

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 45. Photo-point images of the Black Swamp site from winter 2010, spring 2010, summer 2011 and autumn 2011**.**

Environmental conditions

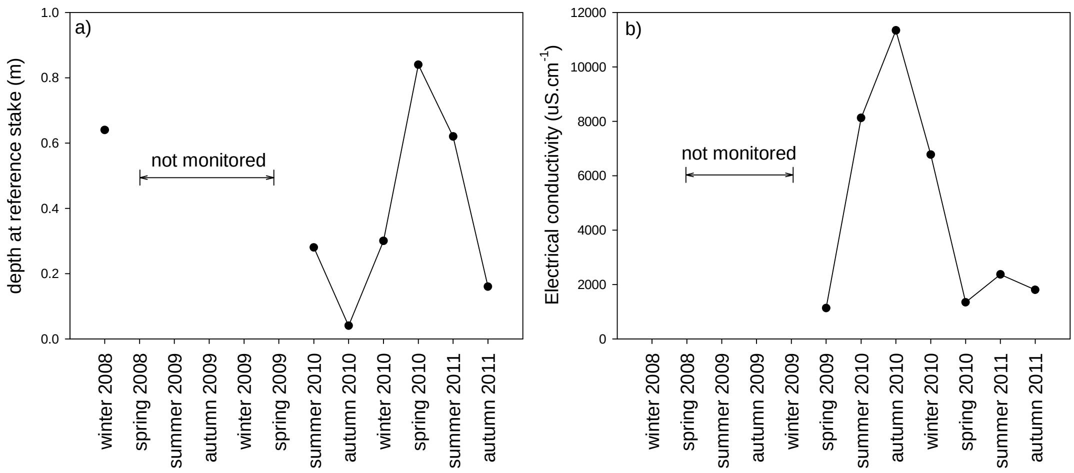


Figure 46. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Black Swamp site between winter 2008 and autumn 2011.

Table 33. Habitat cover measured at Black Swamp during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	30 (*Typha, Phragmites, Cladium*)	0	70
Spring 2010	0	45 (*Typha, Baumea*)	5 snag	50
Summer 2011	0	30 (*Typha, Phragmites*)	0	70
Autumn 2011	1 (*Myriophyllum*)	39 (*Typha, Phragmites, Baumea*)	5 (snag)	55

Table 34. Water quality parameters measured at Black Swamp during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	13.1	8.24	6.86	-	>0.9	0.9
Spring 2010	18.0	7.23	5.36	4.87	0.3	1.5
Summer 2011	21.3	7.51	6.24	4.64	0.4	1.2
Autumn 2011	16.0	7.59	5.97	-	0.4	1.3

Catch summary and length-frequency analysis

This site was not sampled in spring 2008 or autumn 2009 as it was dry and inaccessible. However, in spring 2009, southern pygmy perch were detected at the site and all fish sampled were large adults (>40 mm TL) (Figure 47). No southern pygmy perch were sampled in autumn 2010 but the species was again sampled in low abundance in spring 2010 (Table 35). Individuals ranged from 37-58 mm TL (Figure 47b) signifying recruitment had occurred from spawning the previous year. Nonetheless, no southern pygmy perch were detected in autumn 2011 (Table 35). A diverse range of 16 other species were sampled at this site over the study period (Table 35).

Table 35. Total numbers of fish species collected from Black Swamp between spring 2008 and autumn 2010. NS = not sampled.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Southern pygmy perch	***Nannoperca australis***	**NS (dry)**	**NS (dry)**	**7**	**0**	**10**	**0**
Flat-headed gudgeon	*Philypnodon grandiceps*	NS	NS	2	585	85	72
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	NS	NS	0	2	7	1
Carp gudgeon	*Hypseleotris* spp.	NS	NS	0	60	5	1
Australian smelt	*Retropinna semoni*	NS	NS	0	3	7	1
Bony herring	*Nematalosa erebi*	NS	NS	0	260	0	1
Congolli	*Pseudaphritis urvillii*	NS	NS	0	0	0	1
Common galaxias	*Galaxias maculatus*	NS	NS	0	3	1	0
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	NS	NS	0	2	0	0
Small-mouthed hardyhead	*Atherinosoma microstoma*	NS	NS	0	71	0	0
Tamar River goby	*Afurcagobius tamarensis*	NS	NS	0	11	0	0
Blue-spot goby	*Pseudogobius olorum*	NS	NS	0	4	1	0
Bridled goby	*Arenogobius bifrenatus*	NS	NS	0	3		0
Common carp	*Cyprinus carpio*	NS	NS	176	401	27	7
Goldfish	*Carrasius auratus*	NS	NS	0	11	1	0
Redfin perch	*Perca fluviatilis*	NS	NS	0	0	0	10
Eastern gambusia	*Gambusia holbrooki*	NS	NS	0	102	0	0

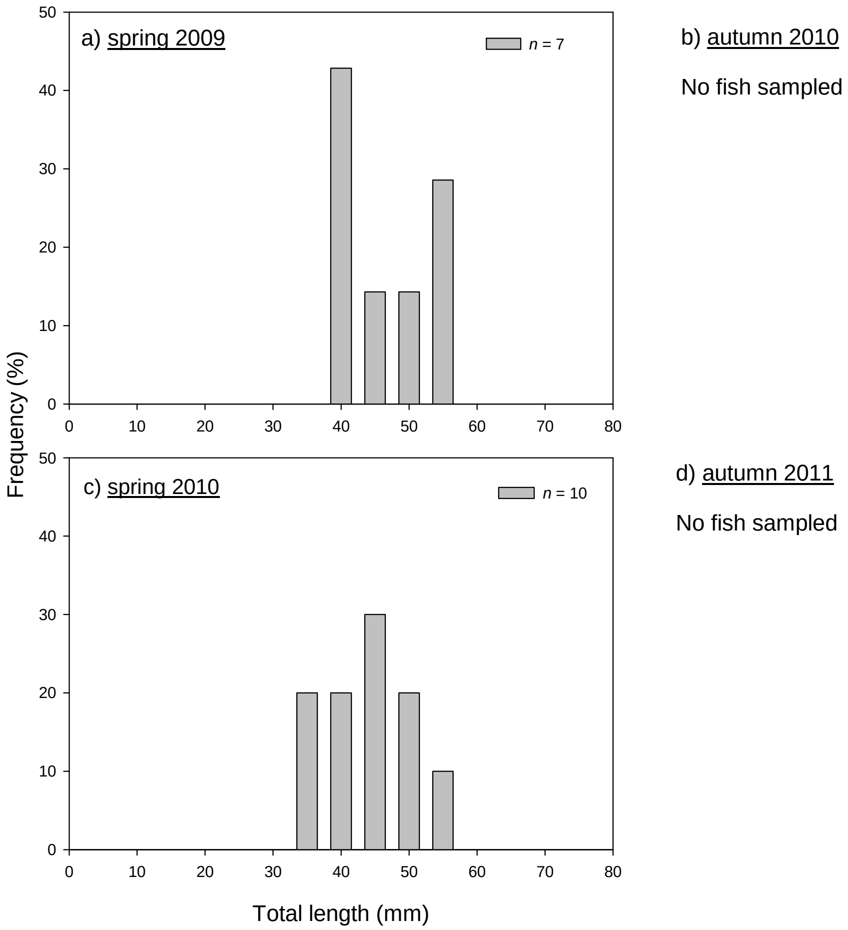


Figure 47. Length frequency distribution of southern pygmy perch from the Black Swamp site in a) spring 2009, b) autumn 2010, c) spring 2010 and d) autumn 2011.

Site summary

This site dried in spring 2008 and remained dry until spring 2009 when water levels were influenced by raised water levels within the Goolwa Channel as part of the GCWLMP. As such, the site was re-inundated and water returned to levels similar to pre-2007. Water levels again receded before rising again with naturally increased lake levels in 2010. Southern pygmy perch were detected in both spring 2009 and spring 2010 but were absent in the corresponding autumn of both years. Southern pygmy perch may be persisting in the area in low abundances; however, no Yarra pygmy perch were detected throughout the study period. Submerged aquatic vegetation, which was abundant prior to 2006, showed little local recovery. The return of higher lake levels, subsequent reduction in salinity and potential re-establishment of aquatic vegetation may see conditions favourable for re-colonisation or re-introduction of captively bred Yarra pygmy perch.

4.13. Black Swamp Drain (Finniss River: southern pygmy perch)

Black Swamp Drain is located in the lower Finniss River immediately upstream of Black Swamp. The drain channels water that flows into the top of Black Swamp from Tookayerta Creek and diverts it into the Finniss Channel. Water in the drain was typically tannin stained and habitat was dominated by abundant submerged (e.g. *Myriophyllum* spp.) and emergent (e.g. *Phragmites australis, Typha domingensis, Baumea* sp.) vegetation (Figure 48). Southern pygmy perch were located at this site during a ‘search’ for Yarra pygmy perch by Hammer (2008b), for the current captive breeding program.

Sampling as part of this project was initially focussed on a deep section at the upstream limit of this drain; however, low dissolved oxygen concentration prompted a shifting of the sampling site closer to the junction of the drain with the Finniss River in spring 2010.

Fish sampling effort

Spring 2008, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 4 fyke nets set overnight

Autumn 2009

- not sampled

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 48. Photo-point images of the Black Swamp Drain site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

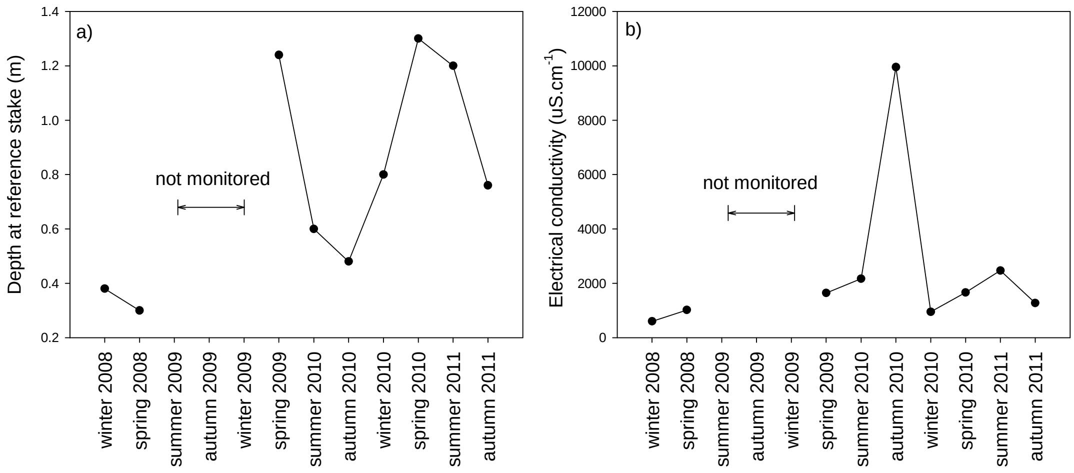


Figure 49. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Black Swamp Drain site between winter 2008 and autumn 2011.

Table 36. Habitat cover measured at Black Swamp Drain during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	40 (*Typha, Phragmites, Baumea, Cladium, Leptospermum*)	10 (debris)	50
Spring 2010	0	30 (*Typha, Phragmites, Leptospermum*)	10 (debris)	60
Summer 2011	1 (*Myriophyllum*)	60 (*Typha, Phragmites, Baumea, Gahnia*)	0	39
Autumn 2011	0	30 (*Typha, Phragmites, Leptospermum*)	10 (snag)	60

Table 37. Water quality parameters measured at Black Swamp Drain during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) Bottom	Secchi (m)	Max depth (m)
Winter 2010	9.1	7.81	3.84	-	0.8	1.9
Spring 2010	16.6	6.98	1.04	0.42	0.2	2.3
Summer 2011	19.2	6.85	0.44	0.26	0.25	1.7
Autumn 2011	15.3	6.59	0.51	0.11	0.45	1.3

Catch summary and length-frequency analysis

No southern pygmy perch were sampled in 2010/11, with the species only detected at this site once during the study period in autumn 2010 (Table 38). One individual was a large adult (55 mm TL), whilst the other was a likely YOY (35 mm TL) (Figure 50). A total of 13 other species were sampled at this site over the study period (Table 38).

Table 38. Total numbers of fish species collected from the Black Swamp Drain site between spring 2008 and autumn 2010. NS = not sampled.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Southern pygmy perch	***Nannoperca australis***	**0**	**NS (dry)**	**0**	**2**	**0**	**0**
Flat-headed gudgeon	*Philypnodon grandiceps*	0	NS	0	800	0	23
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	0	NS	0	5	0	0
Carp gudgeon	*Hypseleotris* spp.	1	NS	0	450	2	0
Australian smelt	*Retropinna semoni*	0	NS	0	10	0	0
Bony herring	*Nematalosa erebi*	0	NS	0	99	0	0
Congolli	*Pseudaphritis urvillii*	0	NS	0	0	0	1
Common galaxias	*Galaxias maculatus*	9	NS	0	9	0	0
Small-mouthed hardyhead	*Atherinosoma microstoma*	0	NS	0	3	0	0
Blue-spot goby	*Pseudogobius olorum*	0	NS	0	1	0	0
Common carp	*Cyprinus carpio*	0	NS	2	1115	5	29
Goldfish	*Carrasius auratus*	0	NS	0	14	0	0
Redfin perch	*Perca fluviatilis*	0	NS	0	0	0	38
Eastern gambusia	*Gambusia holbrooki*	0	NS	0	106	0	0

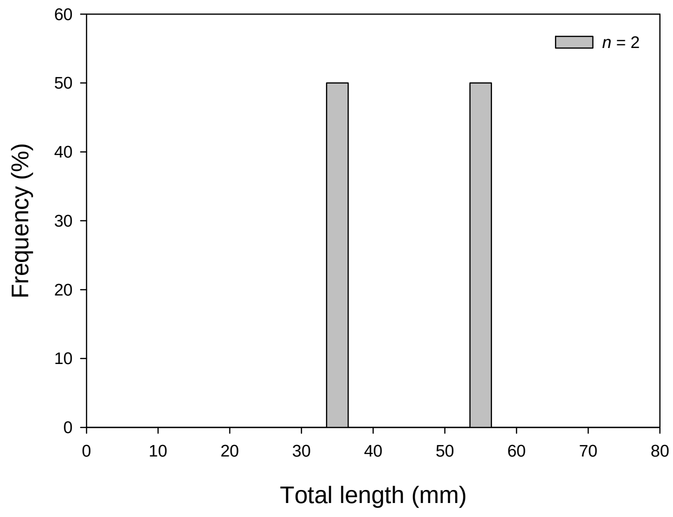


Figure 50. Length frequency distribution of southern pygmy perch from the Black Swamp Drain site in autumn 2010.

Site summary

Southern pygmy perch were sampled at this site on just one occasion (i.e. autumn 2010) during the period 2008-2011. Similar to the Black Swamp site, the return of typical regulated water levels to Lake Alexandrina and reduction in salinity may see a return of favourable conditions for southern pygmy perch and possible re-colonisation.

4.14. Turvey's Drain (Lake Alexandrina: Yarra pygmy perch, southern pygmy perch and Murray hardyhead)

Turvey's Drain is an irrigation channel on the western side of Lake Alexandrina near Milang (Figure 51). Water levels at this site were traditionally dictated by levels in Lake Alexandrina. However, from 2008-2010, the lower end of this drain was disconnected from Lake Alexandrina and water levels were maintained at a higher level than the lake through pumping for irrigation and environmental water delivery. With increased lake levels in 2010, the drain was re-connected with Lake Alexandrina. Re-connection was accompanied by consistently greater water levels and reduced salinities in 2010/11 relative to preceding years (Figure 51).

Monitoring has occurred at this site since 2001 with southern pygmy perch abundant from 2003 – 2006 (Wedderburn and Hammer 2003; Hammer 2009), however, Murray hardyhead have only recently been present at this site. No Yarra pygmy perch have been detected at the site over the last 10 years.

Fish sampling effort

Spring 2008, autumn 2009, spring 2009 and autumn 2010

- 4 fyke nets set overnight

Spring 2010 and autumn 2011

- 6 fyke nets set overnight

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 51. Photo-point images of the Turvey's Drain site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

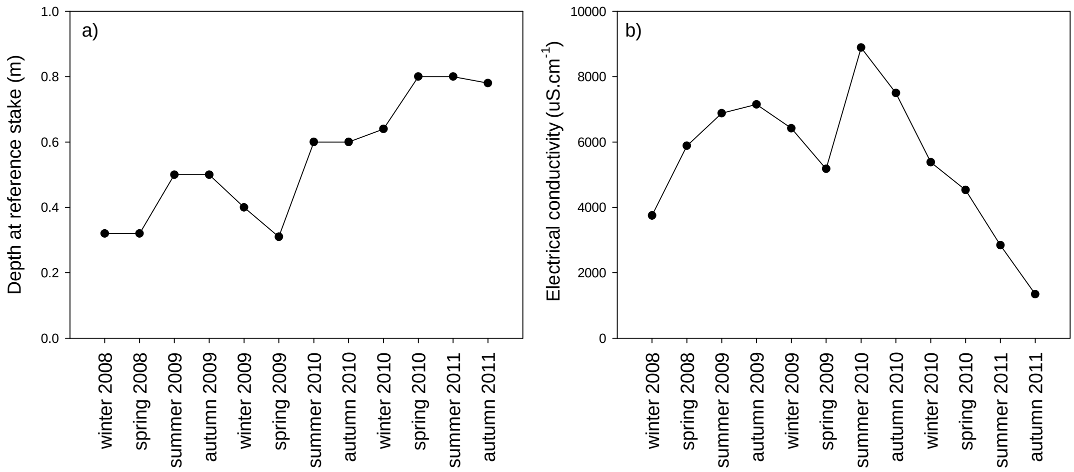


Figure 52. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Turvey's Drain site between winter 2008 and autumn 2011.

Table 39. Habitat cover measured at Turvey's Drain during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	10 (*Myriophyllum, Ceratophyllum*)	20 (*Typha, Phragmites)*	0	70
Spring 2010	30 (*Myriophyllum, Ceratophyllum*)	20 (*Typha)*	1 (debris)	49
Summer 2011	80 (*Myriophyllum, Ceratophyllum*)	10 (*Typha, Phragmites*, grasses)	0	10
Autumn 2011	70 (*Myriophyllum, Ceratophyllum*)	20 (*Typha,* grasses)	0	10

Table 40. Water quality parameters measured at Turvey's Drain during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	10.6	7.52	6.77	-	0.6	1.1
Spring 2010	18.3	7.42	2.28	0.48	0.6	1.1
Summer 2011	21.9	8.79	15.53	6.48	0.5	1
Autumn 2011	17.7	7.43	5.39	1.68	0.4	1.2

Catch summary and length-frequency analysis

Southern pygmy perch were sampled in declining numbers over the study period until autumn 2011 when they were absent (Table 41). Murray hardyhead were sampled in consistently low numbers from spring 2008 to 2009 but have been absent since then (Table 41).

Table 41. Total numbers of fish species collected from Turvey's Drain between spring 2008 and autumn 2011.

Species		Sampling trip					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Southern pygmy perch	***Nannoperca australis***	**81**	**5**	**10**	**1**	**2**	**0**
Murray hardyhead	***Craterocephalus fluviatilis***	**8**	**7**	**11**	**0**	**0**	**0**
Flat-headed gudgeon	*Philypnodon grandiceps*	44	8	321	67	95	46
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	4	0	28	1	8	0
Carp gudgeon	*Hypseleotris* spp.	0	0	0	1	4	7
Australian smelt	*Retropinna semoni*	0	0	2	0	1	0
Bony herring	*Nematalosa erebi*	0	0	0	0	0	1
Small-mouthed hardyhead	*Atherinosoma microstoma*	1	0	1	3	0	0
Congolli	*Pseudaphritis urvillii*	0	0	0	0	0	2
Common galaxias	*Galaxias maculatus*	11	0	1	0	0	0
Tamar goby	*Afurcagobius tamarensis*	1	0	0	0	0	0
Blue-spot goby	*Pseudogobius olorum*	34	0	12	2	36	5
Lagoon goby	*Tasmanogobius lasti*	0	0	1	0	1	0
Goldfish	*Carrasius auratus*	2	0	0	0	0	6
Gambusia	*Gambusia holbrooki*	157	390	1338	326	0	302
Common carp	*Cyprinus carpio*	0	0	2	0	0	36

In spring 2008, all Murray hardyhead sampled were large adult fish (>50 mm TL; Figure 53a). In autumn 2009, this adult cohort was not observed, however, a YOY cohort (30-37 mm TL) was captured signifying recent recruitment between sampling events (Figure 53 b). Subsequently, in spring 2009, Murray hardyhead exhibited a broad length distribution (Figure 53c). Suspected Murray hardyhead were observed in autumn 2010 but no individuals detected during this sampling event or subsequent sampling in 2010/2011.

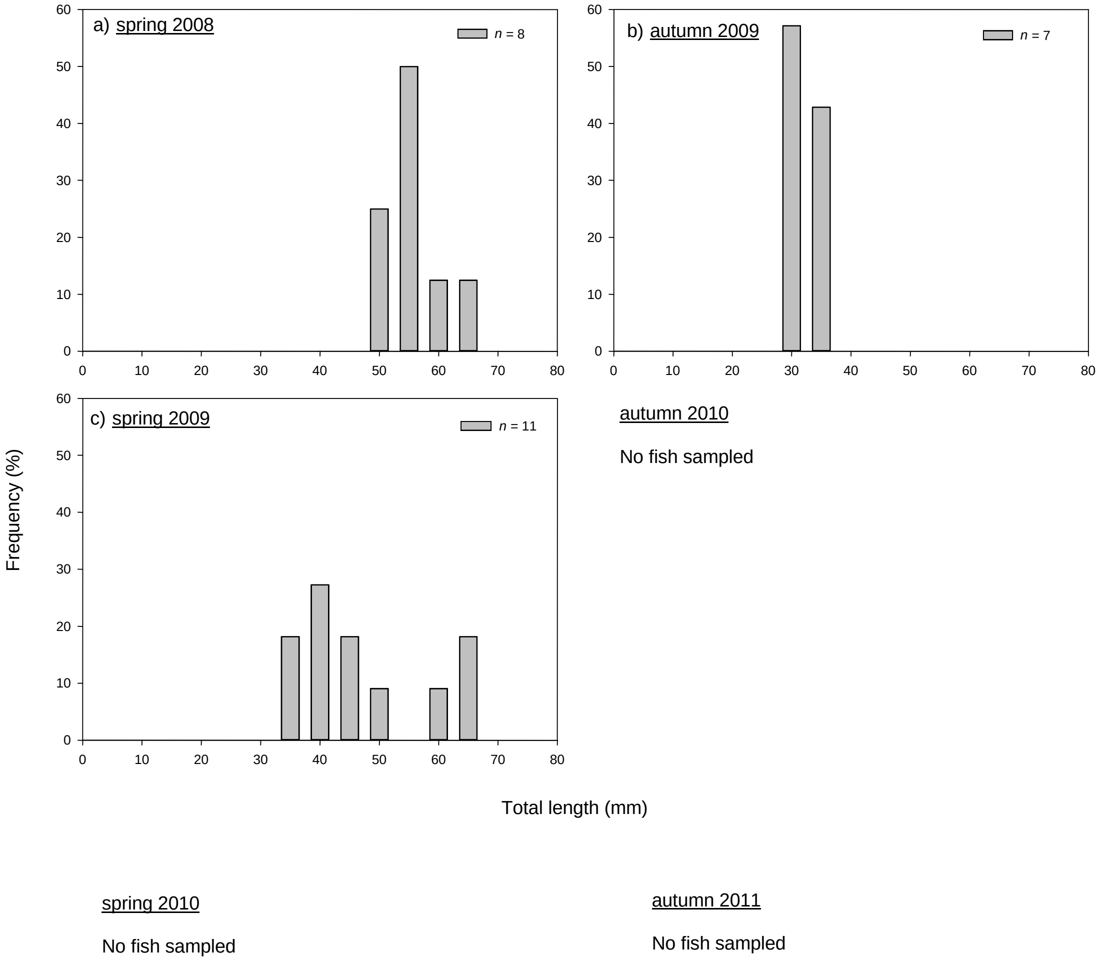


Figure 53. Length frequency distribution of Murray hardyhead from Turvey's Drain in a) spring 2008, b) autumn 2009 and c) spring 2009.

There were two distinct cohorts of southern pygmy perch in spring 2008 with adult fish >50 mm TL and YOY fish ranging from 19-28 mm TL (Figure 54a). In autumn 2009 the previous adult cohort was not sampled and YOY fish from spring had grown to >40 mm TL (Figure 54b). In spring 2009 this cohort had grown further to 51-64 mm TL but no YOY were present as in the previous year (Figure 54c). In autumn 2010 one individual sampled was a large adult (58 mm TL) and no recruitment was detected (Figure 54d). Correspondingly, the two individuals sampled in spring 2010 were large adults (58 and 71 mm TL) (Figure 55) and as such, no recent recruitment was detected (Figure 54e).

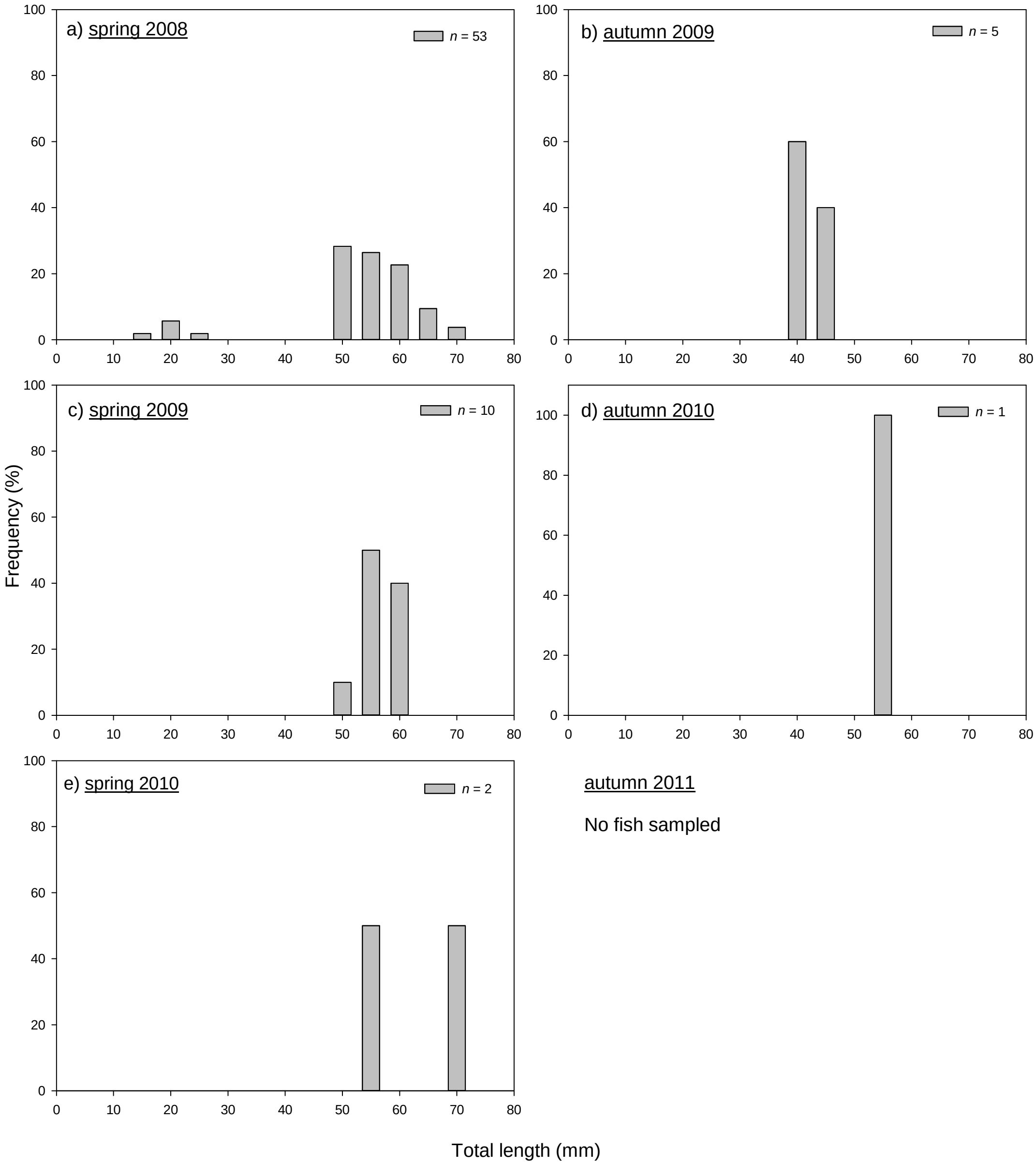


Figure 54. Length frequency distribution of southern pygmy perch from Turvey's Drain in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010 and e) spring 2010.

Figure 55. Adult southern pygmy perch sampled in spring 2010.

Site summary

Murray hardyhead were not detected from spring 2009 onwards and southern pygmy perch were sampled in declining numbers over the study period and were absent in autumn 2011. Two individual southern pygmy perch were also sampled from the site during southern bell frog tadpole monitoring, conducted by the SA MDB NRMB in December 2010. Importantly, there was no evidence of recent recruitment in the southern pygmy perch population from spring 2009 onwards. Thus, Murray hardyhead are likely to have been lost from the site and southern pygmy perch have either been extirpated or are at high risk of loss from this site.

Following re-connection with Lake Alexandrina, salinities at Turvey's Drain have decreased substantially and there has been significant growth of preferred pygmy perch habitat in the form of submerged vegetation (i.e. *Myriophyllum* spp. and *Ceratophyllum demersum*). Indeed, irrigation from this drain will likely recommence with reduced salinities, a situation the authors believe actually benefits native fish by 'drawing through' fresh water disturbing stagnant conditions. As such conditions may become more favourable for re-colonisation or re-introductions.

Thirty southern pygmy perch from this site have been incorporated into a captive breeding program at Flinders University (rescued winter 2010).

4.15. Meadows Creek (Finniss River: southern pygmy perch)

Meadows Creek is an upper catchment tributary of the Finniss River. Meadows Creek is a small to medium alluvial stream with intermittent pools and patchy emergent vegetation (Figure 56). Water levels and salinities typically exhibit seasonal fluctuations at this site but in 2010/11 water levels were consistently higher and salinities consistently lower than preceding years (Figure 57a and b).

Sampling has occurred regularly at this site since 2001 (Hammer 2005; Hammer 2009). Southern pygmy perch abundance is variable with typically low numbers sampled interspersed with irregular higher catch rates.

Fish sampling effort

Spring 2008

- Backpack electrofishing (2909 seconds, 70 Hz, 220 v, 7% DC)

Autumn 2009

- Backpack electrofishing (1500 seconds, 75 Hz, 250 v, 10% DC)

Spring 2009

- Backpack electrofishing (2308 seconds, 75 Hz, 220 v, 10% DC)

Autumn 2010

- Backpack electrofishing (2003 seconds, 75 Hz, 220 v, 10% DC)

Spring 2010

- Backpack electrofishing (3221 seconds, 70 Hz, 200 v, 10% DC)

Autumn 2011

- Backpack electrofishing (3156 seconds, 75 Hz, 220 v, 8% DC)

2009/10 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 56. Photo-point images of the Meadows Creek site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

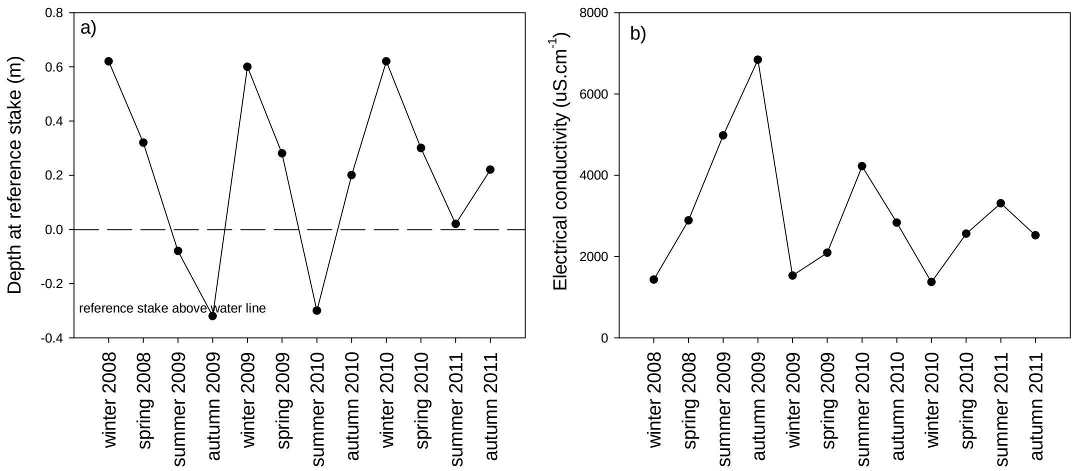


Figure 57. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Meadows Creek site between winter 2008 and autumn 2011.

Table 42. Habitat cover measured at Meadows Creek during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	20 (*Typha, Crassula, Mimulus,* grasses)	10 (rock, snag)	70
Spring 2010	5 (algae)	20 (*Typha, Triglochin,Crassula, Ranunculus*)	10 (snag)	65
Summer 2011	5 (algae)	25 (*Typha, Triglochin,Mimulus,* grasses)	15 (rock, snag)	55
Autumn 2011	5 (algae, *Chara*)	40 (*Typha, Crassula, Ranunculus,* grasses)	20 (rock, snag)	35

Table 43. Water quality parameters measured at Meadows Creek during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	8.1	7.59	8.9	0.75	1.2
Spring 2010	16.2	7.87	8.41	>1	1
Summer 2011	17.8	8.19	3.52	>0.6	0.6
Autumn 2011	16.4	8.15	4.34	>0.8	0.8

Catch summary and length-frequency analysis

Only two southern pygmy perch were sampled in spring 2008, however, the population exhibited a considerable increase in abundance in autumn 2009 (Table 44). This pattern was also observed in 2009/10 with low abundance in spring 2009 and increased abundance in autumn 2010 (Table 44). In 2010/11, however, southern pygmy perch were sampled in moderate-high abundance in both spring 2010 and autumn 2011.

Table 44. Total numbers of fish species and abundance (in bracket; number of fish.100 seconds of e-fishing^{-1}) collected from Meadows Creek between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Southern pygmy perch	***Nannoperca australis***	**2 (0.07)**	**38 (2.53)**	**3 (0.13)**	**24 (1.2)**	**28 (0.87)**	**48 (1.52)**
Mountain galaxias	*Galaxias olidus*	4 (0.14)	62 (4.13)	74 (3.21)	5 (0.25)	9 (0.28)	16 (0.51)
Flat-headed gudgeon	*Philypnodon grandiceps*	6 (0.21)	170 (11.33)	0	52 (2.6)	6 (0.19)	100 (3.17)
Gambusia	*Gambusia holbrooki*	2 (0.07)	100 (6.67)	12 (0.52)	11 (0.55)	0	17 (0.54)

Both southern pygmy perch collected in spring 2008 were large adult fish (>50 mm TL) (Figure 58a). However, in autumn 2009, >60% of the population was represented by newly recruited YOY fish (<35 mm TL) (Figure 58b). Similarly, in spring 2009, the few individuals sampled were large adults (>50 mm TL) (Figure 58c). Nevertheless, substantial recruitment had occurred by autumn 2010 with ~95% of the population comprised of YOY (<30 mm TL) (Figure 58d). The growth of this cohort was evident in spring 2010, with fish ranging from 32-62 mm TL and is likely to represent a mix of newly recruited YOY and older individuals (Figure 58e and 59). In autumn 2011, at least three cohorts were present, including a recently recruited YOY cohort (22-29 mm TL), a likely mixed age cohort (37-59 mm TL) and a larger and older (likely ≥ 2+ year) cohort (>70 mm TL) (Figure 58f).

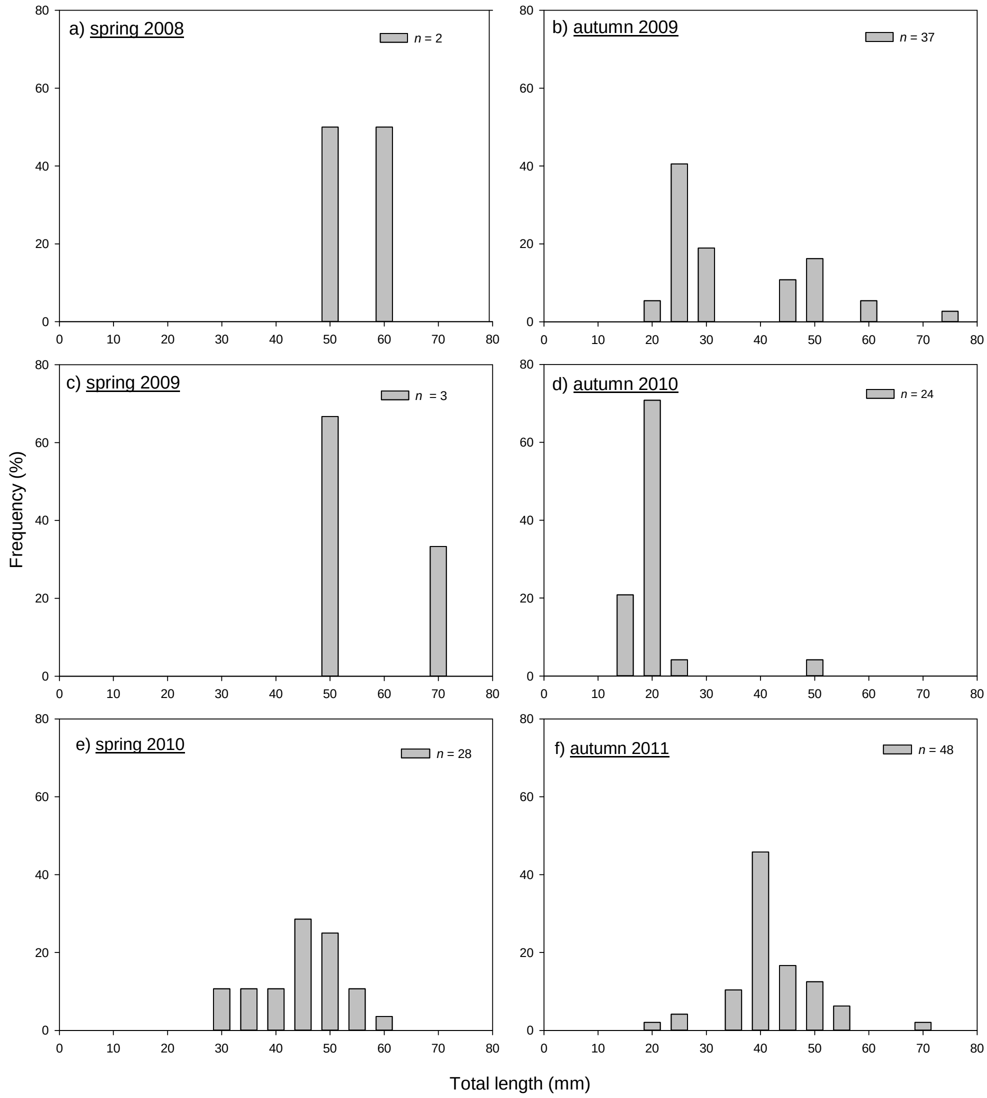


Figure 58. Length frequency distribution of southern pygmy perch from Meadows Creek in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e) spring 2010 and f) autumn 2011.

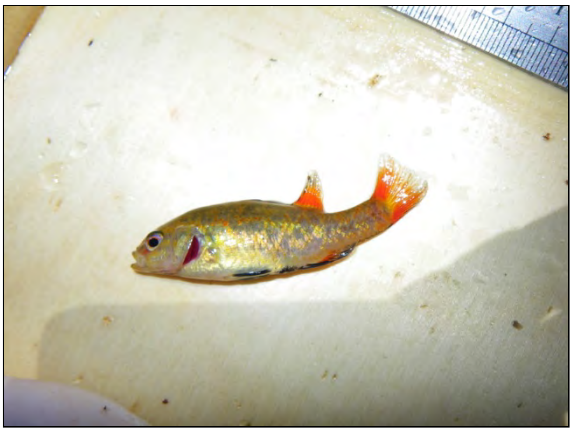


Figure 59. Adult southern pygmy perch sampled from Meadows Creek in spring 2010.

Site summary

Variation in abundance of southern pygmy perch between spring and autumn appeared cyclic through 2008-2010 with greater numbers encountered in autumn when water levels are lowest and fish are concentrated. In 2010/11, however, southern pygmy perch were captured in moderate-high abundance in both seasons. Furthermore, the population exhibited significant recruitment in 2010/11 and a complex population structure (i.e. presence of several different size/age cohorts), and subsequently this population remains stable, albeit highly restricted in distribution.

4.16. Waterfalls (Finniss River: southern pygmy perch)

The Waterfalls site is on the main channel of the mid-Finniss River. This reach is characterised by shallow rocky pools and riffles, with some emergent vegetation (i.e. *Typha domingensis, Triglochin procerum*) and is influenced by ground-water baseflows (Figure 60) (Hammer 2009). Nonetheless, the site typically exhibits seasonal fluctuations in water level and salinity (Figures 61a and b).

This site has been sampled since 2001 with the abundance of southern pygmy perch typically high to very high (Hammer 2005; Hammer 2009). Furthermore, strong recruitment was often evident.

Fish sampling effort

Spring 2008

- Backpack electrofishing (1300 seconds, 70 Hz, 220 v, 7% DC)

Autumn 2009

- Backpack electrofishing (1200 seconds, 75 Hz, 250 v, 10% DC)

Spring 2009

- Backpack electrofishing (1157 seconds, 75 Hz, 250 v, 10% DC)

Autumn 2010

- Backpack electrofishing (1037 seconds, 75 Hz, 250 v, 10% DC)

Spring 2010

- Backpack electrofishing (1060 seconds, 70 Hz, 250 v, 10% DC)

Autumn 2011

- Backpack electrofishing (1375 seconds, 75 Hz, 250 v, 10% DC)

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 60. Photo-point images of the Waterfalls site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

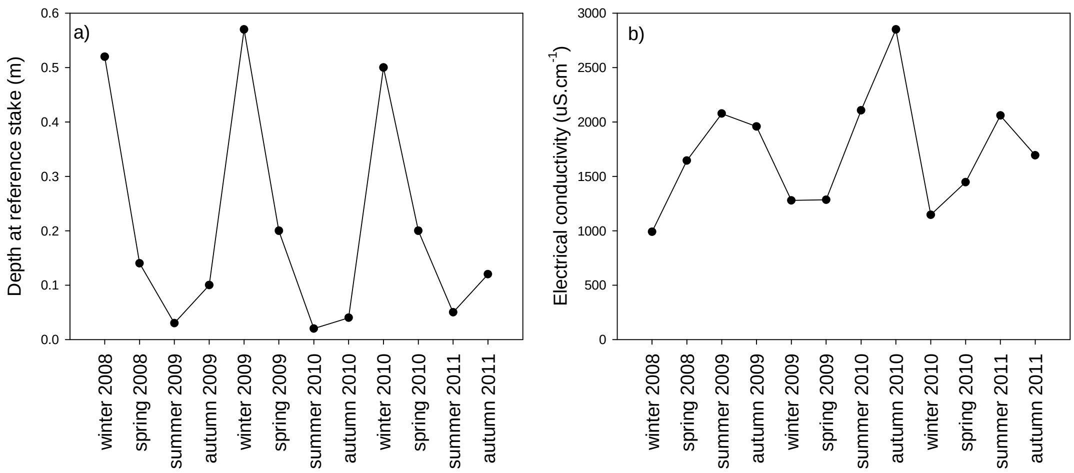


Figure 61. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Waterfalls site between winter 2008 and autumn 2011.

Table 45. Habitat cover measured at Waterfalls during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	30 (*Typha, Cyperus*)	0	70
Spring 2010	1 (moss)	10 (*Typha, Cyperus*)	30 (rock, snag)	59
Summer 2011	5 (algae)	10 (*Typha*)	20 (rock)	65
Autumn 2011	5 (moss)	10 (*Typha*)	30 (rock, snag)	55

Table 46. Water quality parameters measured at Waterfalls during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	11.5	8.56	9.2	0.6	1.5
Spring 2010	17.7	8.01	8.56	>1	1
Summer 2011	16.7	7.01	5.93	>1.2	1.2
Autumn 2011	18.1	7.63	6.82	>1.3	1.3

Catch summary and length-frequency analysis

Southern pygmy perch were sampled in considerable abundance in spring 2008 but exhibited a substantial decline in autumn 2009 (Table 47). In spring 2009 and autumn 2009, single individuals were sampled and no southern pygmy perch were detected in spring 2010 or autumn 2011.

Table 47. Total numbers of fish species collected from the Waterfalls site between spring 2008 and autumn 2010.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Southern pygmy perch	***Nannoperca australis***	**35 (2.69)**	**1 (0.08)**	**1 (0.09)**	**1 (0.1)**	**0**	**0**
Mountain galaxias	*Galaxias olidus*	11 (0.85)	15 (1.25)	76 (6.57)	18 (1.74)	36 (3.4)	177 (12.87)
Common galaxias	*Galaxias maculatus*	0	0	0	8 (0.77)	0	0
Flat-headed gudgeon	*Philypnodon grandiceps*	7 (0.54)	0	1 (0.09)	1 (0.1)	0	1 (0.07)
Dwarf flat-headed	*Philypnodon macrostomus*	0	0	0	0	0	3 (0.22)
Carp gudgeon complex	*Hypseleotris* spp.	3 (0.23)	0	0	31 (2.99)	2 (0.19)	0

Southern pygmy perch ranged from 42-63 mm TL in spring 2008 (Figure 62a) and there was no evidence of recent recruitment. The one individual collected in autumn 2009 was a large adult fish (59 mm TL) (Figure 62b) and thus no recruitment was detected 2008/09. Individual fish collected in both spring 2009 and autumn 2010 were very large adult fish (>70 mm TL) (Figure 63) and thus no recruitment was detected. In spring 2010 and autumn 2011 no individuals were captured.

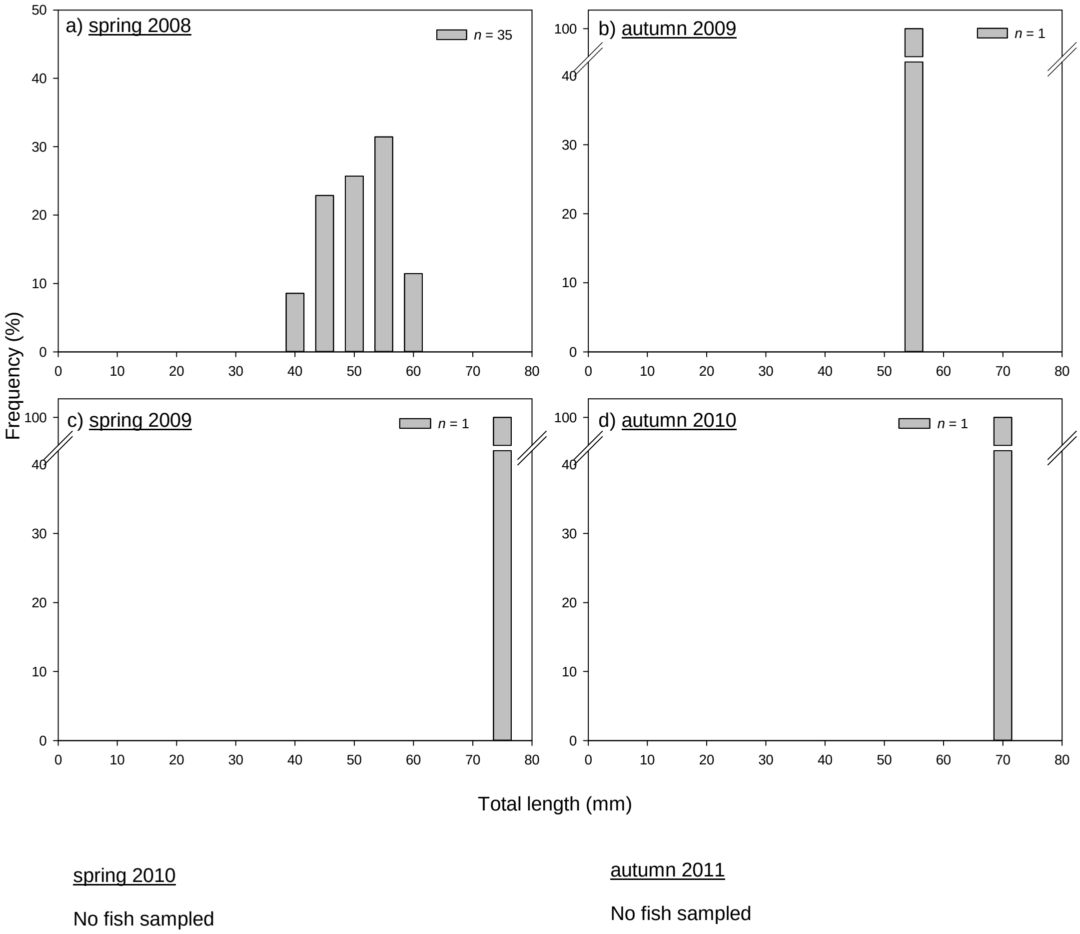


Figure 62. Length frequency distribution of southern pygmy perch from Waterfalls in a) spring 2008, b) autumn 2009, c) spring 2009 and d) autumn 2010.

Figure 63. Very large southern pygmy perch (75 mm TL) sampled at the Waterfalls site in spring 2009.

Site summary

In summer 2009, the usually perennial groundwater baseflow ceased from January – February and subsequently water levels receded dramatically, resulting in extensive habitat desiccation, with remaining aquatic habitat in poor condition (Figure 64). Concurrently, southern pygmy perch underwent a substantial decline in abundance through 2009/10, before being absent during 2010/11 sampling. Thus, it appears southern pygmy perch have been lost from this site, where they were formerly abundant prior to 2008 (Hammer 2005; Hammer 2009).

There was no evidence of recruitment in this population following spring 2008 indicating that the loss of this population was potentially due to recruitment failure. Opportunistic sampling below a waterfall downstream of the site detected the presence of southern pygmy perch; however, natural re-colonisation from this population is unlikely as the waterfall represents a natural barrier to upstream movement.

Figure 64. Severely reduced water level, habitat desiccation and fragmentation at the Finniss Waterfalls site in summer 2009.

4.17. Inman (Inman River: southern pygmy perch)

This site is on Back Valley Creek, a tributary of the Inman River on the southern Fleurieu Peninsula, which drains into the Southern Ocean near the town of Victor Harbour. The site is characterised by shallow stream and swamp habitat interspersed with deeper pools and fringing emergent vegetation (i.e. *Typha domingensis, Phargmites australis, Triglochin procerum*) (Figure 65). Water level and salinity typically exhibit seasonal variation (Figure 66a and b). This site has been monitored since 2001, with abundance of southern pygmy perch being variable (low abundance interspersed with irregular high catches) (Hammer 2009).

Fish sampling effort

Spring 2008

- 5 baited box traps set for 1.5 hours

Autumn 2009, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 10 baited box traps set for 1.5 hours

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 65. Photo-point images of the Inman River site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

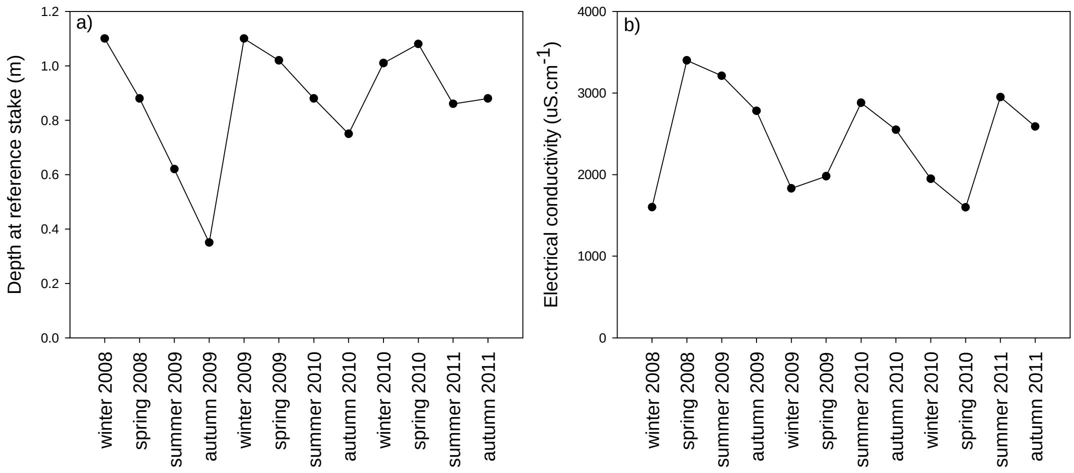


Figure 66. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Inman River site between winter 2008 and autumn 2011.

Table 48. Habitat cover measured at Inman River during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	30 (*Typha, Phragmites, Triglochin*)	0	70
Spring 2010	1 (algae)	40 (*Typha, Phragmites, Triglochin*)	0	59
Summer 2011	0	40 (*Typha, Phragmites, Triglochin*)	10 (snag)	50
Autumn 2011	1 (algae, *Lemna*)	25 (*Typha, Phragmites, Triglochin*)	4 (snag)	70

Table 49. Water quality parameters measured at Inman River during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	9.4	7.34	5.88	4.22	0.3	1.2
Spring 2010	17.6	7.19	5.88	3.95	0.2	1.2
Summer 2011	18.6	7.24	2.24	2.99	0.2	1.1
Autumn 2011	16.5	7.74	1.87	0.35	0.3	1.1

Catch summary and length-frequency analysis

Southern pygmy perch were captured in low numbers in spring 2008 but in high abundance in autumn 2009 (Table 50). From spring 2009 – autumn 2011, they were sampled in consistently low numbers (Table 50). Carp gudgeon were the only other species captured throughout the project (Table 50).

Table 50. Total numbers of fish species collected from the Inman River site between spring 2008 and autumn 2011.

Species		Sampling trip					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Southern pygmy perch	***Nannoperca australis***	**12**	**101**	**8**	**19**	**16**	**10**
Carp gudgeon complex	*Hypseleotris* spp.	2	8	6	3	30	22

Recent recruitment was evident in spring 2008 with likely YOY individuals <25 mm TL and adult fish 34-41 mm TL both present in the catch (Figure 67a). Individuals ranged 23-62 mm TL in autumn with recent recruitment also evident in this season (Figure 67b). Length-frequency distribution in spring 2009 differed from that of the previous year with the population dominated by adult fish (>40 mm TL) (Figure 67c). Nonetheless in autumn 2010 southern pygmy perch exhibited a broad range of lengths from 34-60 mm TL with recent recruitment evident (Figure 67d). The length distribution of the population spring 2010 again differed from preceding years with the population dominated by large individuals (>50 mm TL), with a small proportion of fish 40-45 mm TL (Figure 67e). Contrasting previous years, the population remained dominated by large adult fish (>50 mm TL) in autumn 2011, with no evidence of recent recruitment (Figure 67f).

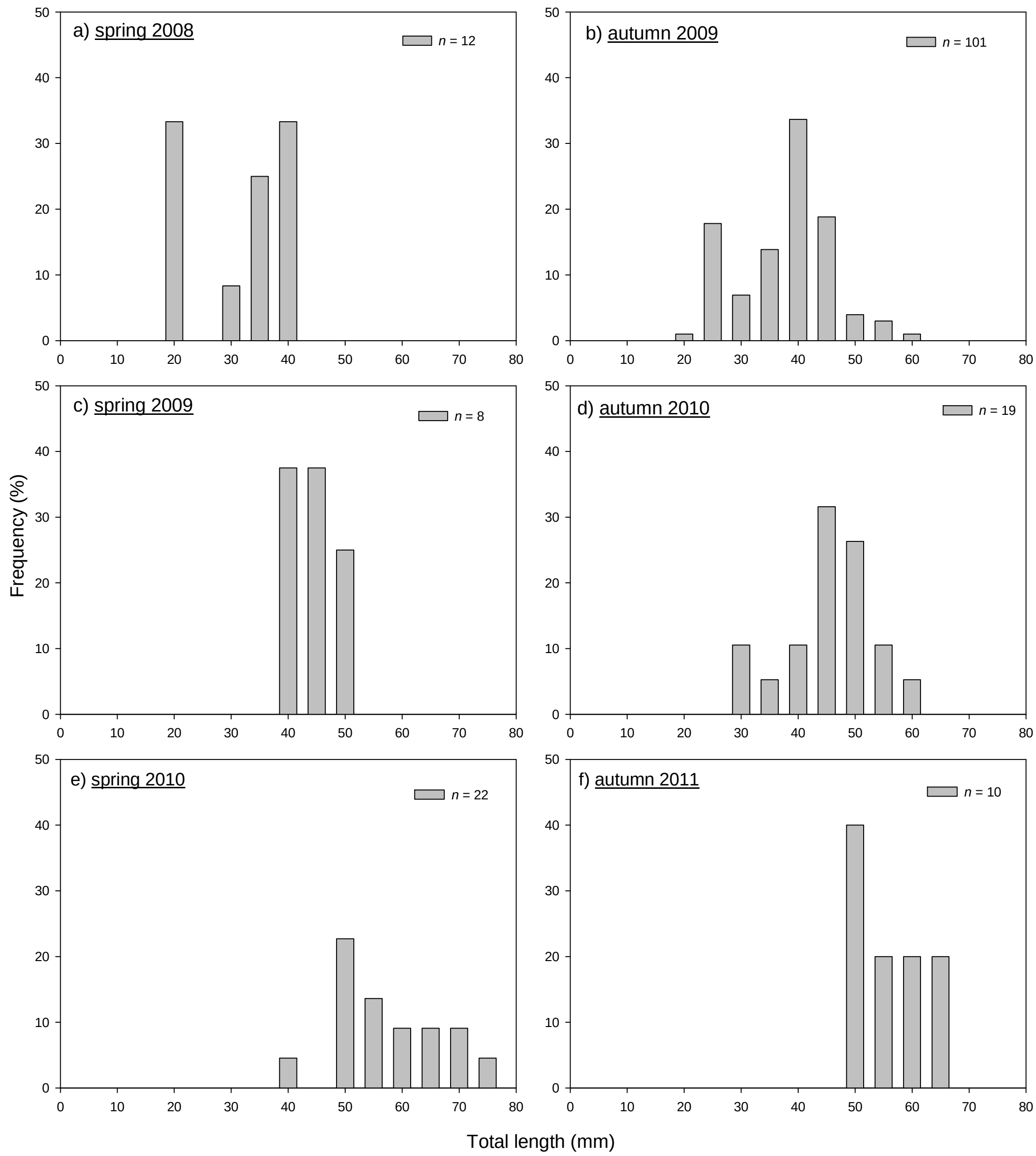


Figure 67. Length frequency distribution of southern pygmy perch from the Inman River site in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010, e) spring 2010 and f) autumn 2011.

Site summary

Southern pygmy perch were sampled in considerable numbers in autumn 2009 but were sampled in consistently low numbers during all other sampling events. Contrasting previous years, recent recruitment was not detected in autumn 2011. This may indicate an absence of significant recruitment in 2010/2011 or high flows and water levels may have resulted in the dispersal of these individuals.

4.18. Currency Creek (Lake Alexandrina: Yarra pygmy perch and Murray hardyhead)

This site is located in Lake Alexandrina, at the junction of Currency Creek with the Goolwa Channel in the game reserve near the town of Goolwa (Figure 69). It is a sheltered lake edge/terminal wetland and was typically characterised by abundant emergent (i.e. *Phragmites australis, Typha domingensis* and *Schoenoplectus validus*) and submerged vegetation (i.e. *Myriophyllum* spp). This site completely dried in summer 2008/09 due to receding water levels in Lake Alexandrina (Figure 68a & b). However, this site was re-inundated in 2009 as a result of raising water levels within the Goolwa Channel (GCWLPM). Water levels then slightly receded before increasing again with increased lake levels in mid-2010 due to increased River Murray flows (Figure 70a). Increased water levels from River Murray inflows in 2010 were accompanied by substantially reduced salinities (Figure 70b). Yarra pygmy perch and Murray hardyhead were recorded at this site in 2007 and 2008 respectively (Hammer 2008b; Hammer 2009).

a) b)

Figure 68a-b. The Currency Creek site; desiccated and disconnected from remaining water in summer 2009.

Fish sampling effort

Spring 2008, spring 2008, autumn 2010, spring 2010 and autumn 2011

- 4 fyke nets set overnight

Autumn 2009

- Not sampled as site had completely dried

2010/11 Photo-point images

Winter 2010


Spring 2010

Summer 2011


Autumn 2011


Figure 69. Photo-point images of the Currency Creek site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

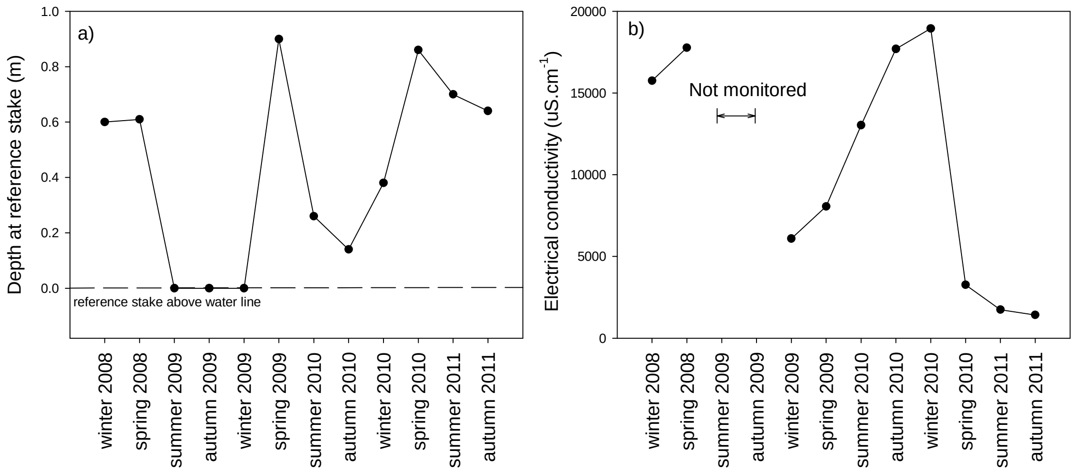


Figure 70. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Currency Creek site between winter 2008 and autumn 2011.

Table 51. Habitat cover measured at Currency Creek during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	20 (algae, *Potamogetan pectinatus, Ruppia*)	10 (*Phragmites,* terrestrial weeds)	0	70
Spring 2010	40 (*Potamogetan pectinatus, Myriophyllum*)	30 (*Typha, Phragmites,Cotula*)	0	30
Summer 2011	20 (*Potamogetan pectinatus*, *Myriophyllum*)	20 (*Typha, Phragmites, Schoenoplectus*)	0	60
Autumn 2011	10 (*Myriophyllum*)	40 (*Typha, Phragmites*, grasses)	0	50

Table 52. Water quality parameters measured at Currency Creek during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	12.1	8.36	8.43	0.5	0.9
Spring 2010	17.4	9.42	9.96	0.8	1.4
Summer 2011	22.6	8.35	8.2	0.4	1
Autumn 2011	18.2	7.64	6.95	0.3	1.2

Catch summary and length-frequency analysis

No Yarra pygmy perch were sampled at this site throughout the duration of the project. Murray hardyhead were present in spring 2008 but the site was completely dry in autumn 2009 and thus no fish were sampled (Table 53). Eleven individuals were sampled in spring 2009 after water levels within the Goolwa Channel were raised; however, no individuals were sampled in autumn 2010. In spring 2010, following naturally increased water levels in Lake Alexandrina, Murray hardyhead were abundant at this site (Figure 71). In contrast, no individuals were sampled in autumn 2010. A diverse assemblage is typically present at this site with a total of 18 other species having been collected (Table 53).

Table 53. Total numbers of fish species collected from the Currency Creek site between spring 2008 and autumn 2011. NS = not sampled.

Species		Sampling trip					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**11**	**NS (dry)**	**11**	**0**	**109**	**0**
Yarra pygmy perch	***Nannoperca australis***	**0**	**NS (dry)**	**0**	**0**	**0**	**0**
Golden perch	*Macquaria ambigua*	0	NS	0	0	0	1
Flat-headed gudgeon	*Philypnodon grandiceps*	76	NS	2	238	368	147
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	3	NS	1	2	6	1
Carp gudgeon	*Hypseleotris* spp.	0	NS	3	2	4	0
Bony herring	*Nematalosa erebi*	0	NS	2	41	3	49
Australian smelt	*Retropinna semoni*	44	NS	2	0	169	14
Congolli	*Pseudaphritis urvillii*	0	NS	0	0	7	8
Common galaxias	*Galaxias maculatus*	2	NS	2	16	12	6
Small-mouthed hardyhead	*Atherinosoma microstoma*	5875	NS	2635	88	1042	43
Tamar goby	*Afurcagobius tamarensis*	137	NS	0	46	69	4
Blue-spot goby	*Pseudogobius olorum*	398	NS	1	65	85	0
Lagoon goby	*Tasmanogobius lasti*	16	NS	13	0	1	2
Bridled goby	*Arenigobius bifrenatus*	22	NS	1	60	56	8
Yellow-eyed mullet	*Aldrichetta forsteri*	0	NS	0	0	1	0
Redfin perch	*Perca fluviatilis*	3	NS	0	0	0	35
Common carp	*Cyprinus carpio*	0	NS	106	1008	19	45
Goldfish	*Carrasius auratus*	0	NS	0	4	2	3
Gambusia	*Gambusia holbrooki*	24	NS	1	63	11	5

Figure 71. Several Murray hardyhead sampled at the Currency Creek site in spring 2010, when the species was abundant.

The population of Murray hardyhead was dominated by large adult fish (48-69 mm TL) in spring 2008 (Figure 72a). Similarly, the population was dominated by adult fish in spring 2009 (Figure 72b), however, the range of lengths was smaller (i.e. 38-60 mm TL). Length distribution was similar again in spring 2010 with fish ranging from 38-61 mm TL, with the majority of individuals 50-55 mm TL (Figure 72c). The length distribution in spring 2010 indicated there had been significant recruitment since spring 2009.

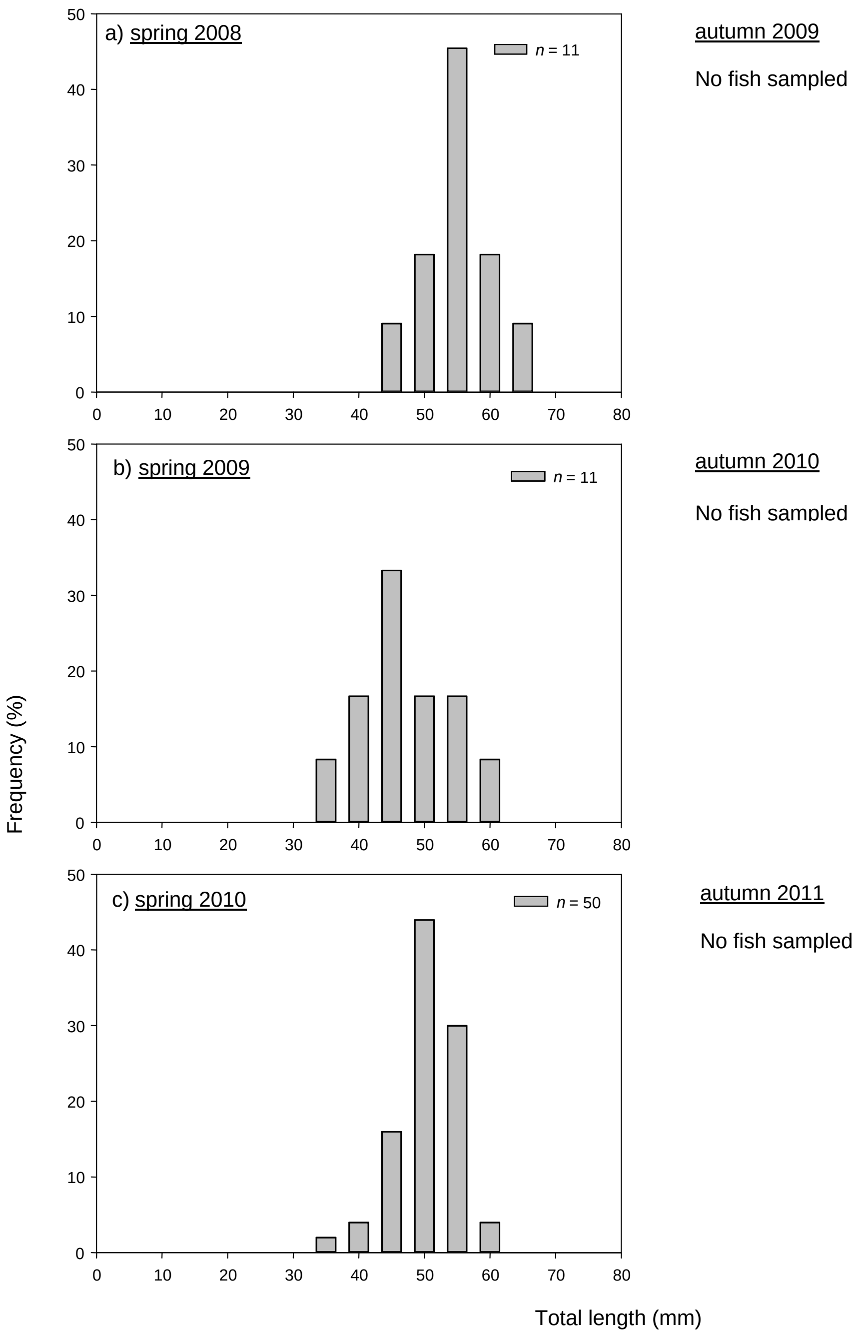


Figure 72. Length frequency distribution of Murray hardyhead from the Currency Creek site in a) spring 2008, b) spring 2009 and c) spring 2010.

Site summary

Yarra pygmy perch have not been sampled throughout the project and have likely been lost from the site. Murray hardyhead, however, re-colonised this site and were captured in low numbers in spring 2009 following the water level rise within the Goolwa Channel but were absent in autumn 2010. Interestingly, after being absent in autumn 2010, the species was captured and abundant at the site in spring 2010 before being absent once more in autumn 2011. It is unclear whether this pattern of spring presence and autumn absence is a regular seasonal pattern at this site (e.g. accessing spawning habitat). Murray hardyhead are highly mobile and subsequent dispersal from this site and re-colonisation is possible given adequate source populations exist.

Yarra pygmy perch from this site have been included in the captive breeding program being undertaken by Aquasave and Cleland Wildlife Park (*n* = 4). The occurrence of significant natural flows and increased water levels in 2010/11 resulted in increased aquatic vegetation and decreased salinity and subsequently the site may become more favourable for re-colonisation (if possible) or re-introduction of Yarra pygmy perch in the future.

4.19. Finniss River Confluence (Lake Alexandrina: Yarra pygmy perch and Murray hardyhead)

This site is located in Lake Alexandrina, at the junction of the Finniss River with the Goolwa Channel (Figure 73). It represents sheltered lake edge habitat and was typically characterised by abundant emergent (i.e. *Phragmites australis, Typha domingensis* and *Schoenoplectus validus*) and submerged vegetation (i.e. *Myriophyllum* spp. and *Vallisneria australis*). This site completely dried in summer 2008/09 due to receding water levels in Lake Alexandrina. However, due to the *Goolwa Channel Water Level Management Plan* and the raising of water levels within the Goolwa Channel, this site was re-inundated in late 2009. Similar to other sites within the Goolwa Channel region, water level again receded in summer 2009/10 before increasing again with Lake Alexandrina levels later in 2010 (Figure 74a). Salinity also decreased dramatically at this site in 2010/11 (Figure 74b) and submerged aquatic vegetation cover has increased (Table 54). Yarra pygmy perch and Murray hardyhead were typically caught in low numbers at this site (Hammer 2008b), and it was a rescue location for 54 Yarra pygmy perch (last records in February 2008; Hammer 2008b).

Fish sampling effort

Spring 2008

- 6 seine net hauls

Autumn 2009

- Not sampled as site had completely dried

Spring 2009 and autumn 2010

- 4 fyke nets set overnight.

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 73. Photo-point images of the Finniss River Confluence site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

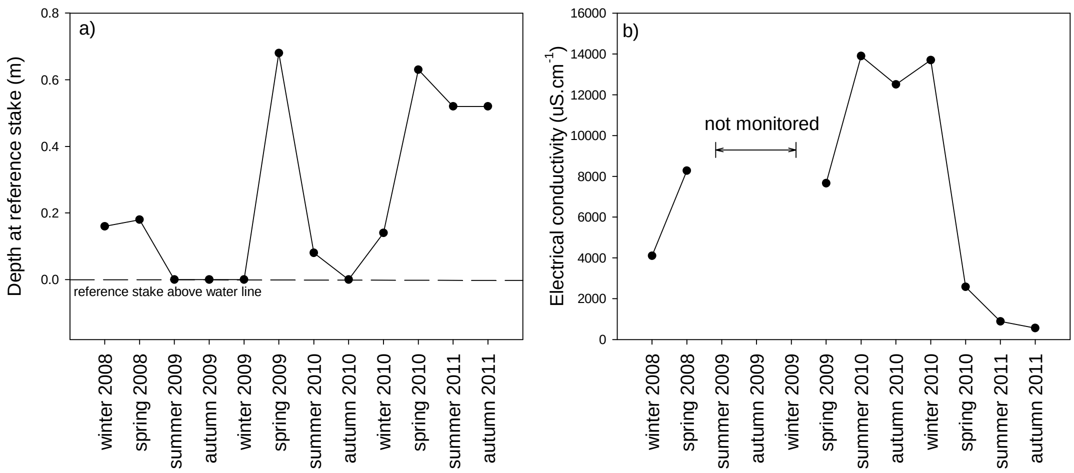


Figure 74. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Finniss River Confluence between winter 2008 and autumn 2011.

Table 54. Habitat cover measured at the Finniss River Confluence during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	1 (algae)	20 (*Phragmites, Schoenoplectus*)	10 (polychaete mounds)	69
Spring 2010	10 (algae)	40 (*Phragmites, Schoenoplectus, Cotula*)	0	50
Summer 2011	10 (*Potamogetan pectinatus, Myriophyllum*)	30 (*Phragmites, Schoenoplectus*)	0	60
Autumn 2011	20 (*Myriophyllum, Potamogetan pectinatus, Vallisneria,* algae)	30 (*Phragmites, Typha, Schoenoplectus*)	0	50

Table 55. Water quality parameters measured at the Finniss River Confluence during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	11.2	8.25	8.29	>0.5	0.5
Spring 2010	15.8	7.64	6.65	0.3	-
Summer 2011	22.4	7.9	9.05	0.2	0.8
Autumn 2011	16.2	7.34	9.5	0.25	0.8

Catch summary and length-frequency analysis

No Yarra pygmy perch were detected throughout the project. Murray hardyhead were sampled in spring 2008 but not for the remainder of sampling through 2009/10 and 2010/11 (Table 56). A total of 17 other fish species have been collected at this site (Table 56). Both Murray hardyhead sampled in spring 2008 were adult fish (Figure 75).

Table 56. Total numbers of fish species collected from the Finniss River Confluence between spring 2008 and autumn 2010. NS = not sampled

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Yarra pygmy perch	***Nannoperca obscura***	**0**	**NS (dry)**	**0**	**0**	**0**	**0**
Murray hardyhead	***Craterocephalus fluviatilis***	**2**	**NS (dry)**	**0**	**0**	**0**	**0**
Golden perch	*Macquaria ambigua*	0	NS	0	0	0	4
Australian smelt	*Retropinna semoni*	5	NS	17	51	1820	128
Bony herring	*Nematalosa erebi*	0	NS	6	0	0	832
Flat-headed gudgeon	*Philypnodon grandiceps*	0	NS	8	4	61	107
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	0	NS	0	0	0	1
Carp gudgeon	*Hypseleotris* spp.	0	NS	5	0	1	2
Common galaxias	*Galaxias maculatus*	0	NS	3	1	1	1
Congolli	*Pseudaphritis urvillii*	0	NS	1	0	2	21
Small-mouthed hardyhead	*Atherinosoma microstoma*	47	NS	3240	691	2906	46
Tamar goby	*Afurcagobius tamarensis*	1	NS	2	20	225	1
Blue-spot goby	*Pseudogobius olorum*	5	NS	1	0	5	0
Lagoon goby	*Tasmanogobius lasti*	3	NS	23	10	2	18
Bridled goby	*Arenigobius bifrenatus*	0	NS	2	13	9	4
Redfin perch	*Perca fluviatilis*	0	NS	0	0	0	21
Common carp	*Cyprinus carpio*	0	NS	223	36	64	38
Gold fish	*Carrasius auratus*	0	0	0	0	1	18
Eastern gambusia	*Gambusia holbrooki*	0	NS	0	14	0	0

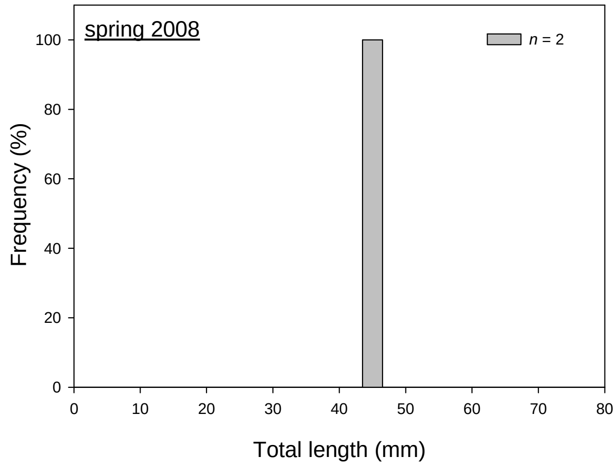


Figure 75. Length frequency distribution of Murray hardyhead from the Finniss River Confluence spring 2008.

Site summary

No Yarra pygmy perch have been sampled at this site throughout the project and have likely been lost. No Murray hardyhead have been sampled since spring 2008. The species was sampled, however, in high abundance at the Currency Creek site in spring 2010, implying that the species may still be present within the local area. The mobile and potentially dispersive nature of Murray hardyhead suggests the site may be re-colonised if favourable habitat (submerged and emergent vegetation) regeneration continues and a potential source populations exist. Yarra pygmy perch from this site have been included in the captive breeding program being undertaken by Aquasave, Cleland Wildlife Park and Flinders University.

4.20. Boggy Creek, Hindmarsh Island (Lake Alexandrina: Murray hardyhead)

Boggy Creek is a small stream/wetland located on Hindmarsh Island in Lake Alexandrina (Figure 76). Yarra pygmy perch were first collected from this site in 2002 (Hammer unpublished). Post drought, a population of Murray Hardyhead at this site was sampled in spring 2008 by researchers from Adelaide University (Wedderburn and Barnes 2009), data from which is presented in this report. Whilst not sampled, Murray hardyhead were likely present at this site historically.

The site is characterised by shallow off-channel stream/wetland habitat with abundant emergent vegetation (i.e. *Typha domingensis, Phragmites australis*). Water is also slightly saline. This site received regular management intervention with environmental water provided on several occasions during low water levels in Lake Alexandrina from 2007-2010, being re-connected to Holmes Creek following naturally increased lake levels in 2010/11 (Figure 77a). Naturally increased water levels and re-connection was accompanied by significantly reduced salinity (Figure 77b).

Fish sampling effort

Spring 2008, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 3 fyke nets set overnight

Autumn 2009

- Not sampled as site had dried

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 76. Photo-point images of the Boggy Creek site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

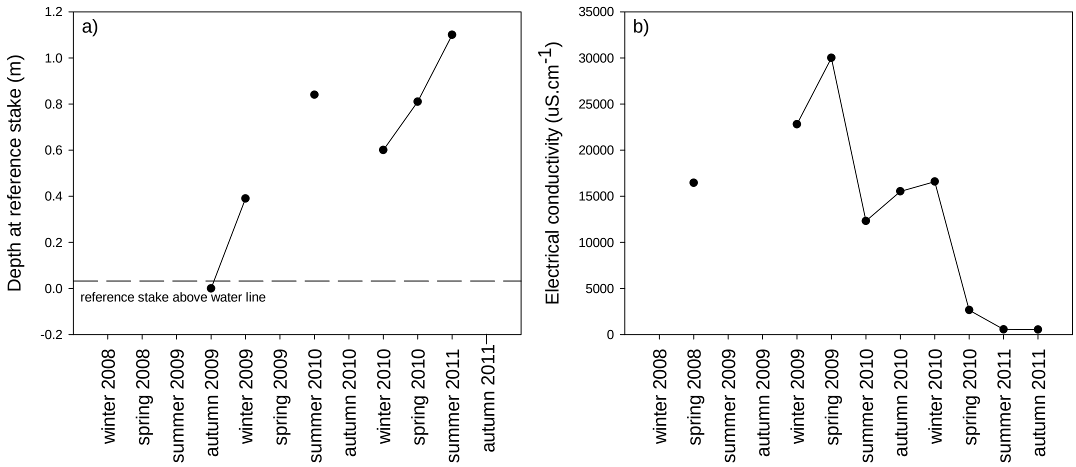


Figure 77. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (μS.cm^{-1}) at the Boggy Creek site between winter 2008 and autumn 2011.

Table 57. Habitat cover measured at Boggy Creek during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	20 (algae)	50 (*Typha, Phragmites,* grasses)	0	30
Spring 2010	60 (total vegetation cover)			40
Summer 2011	10 (*Myriophyllum, Azolla,* algae)	40 (*Typha, Phragmites, Cotula,* grasses)	0	50
Autumn 2011	64 (total vegetation cover)			36

Table 58. Water quality parameters measured at Boggy Creek during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	11.7	7.59	7.59	>0.8	0.8
Spring 2010	19.8	7.26	-	0.66	0.88 (average depth)
Summer 2011	23.7	7.39	5.05	0.3	>1.5
Autumn 2011	18.2	7.18	-	0.3	0.26 (average depth)

Catch summary and length-frequency analysis

A large number of Murray hardyhead were sampled from Boggy Creek, together with six other species, in spring 2008 (Table 59). Water level decreased dramatically over summer/autumn 2008/09 and subsequently, the site was not sampled in autumn 2009. Low numbers of Murray hardyhead were sampled in spring 2009 but they exhibited an increase in abundance in autumn 2010, following the provision of environmental water (Table 59). Following naturally increased water levels and re-connection with Holmes Creek, no Murray hardyhead were sampled in spring 2010 or autumn 2011 (Table 59).

Table 59. Total numbers of fish species collected from Boggy Creek between spring 2008 and autumn 2011. NS = not sampled.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**587**	**NS (dry)**	**16**	**98**	**0**	**0**
Common galaxias	*Galaxias maculatus*	1	NS	0	0	0	0
Flat-headed gudgeon	*Philypnodon grandiceps*	18	NS	0	0	73	2
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	1	NS	0	0	0	0
Carp gudgeon complex	*Hypseleotris* spp.	207	NS	0	0	1	0
Bony herring	*Nematalosa erebi*	0	NS	0	0	0	13
Small-mouthed hardyhead	*Atherinosoma microstoma*	0	NS	0	0	6	0
Tamar River Goby	*Afurcaogobius tamarensis*	0	NS	0	0	2	0
Blue-spot goby	*Pseudogobius olorum*	170	NS	39	1	8	0
Redfin perch	*Perca fluviatilis*	0	NS	0	0	3	1
Gambusia	*Gambusia holbrooki*	6	NS	7	334	4	107
Common carp & goldfish	*Cyprinus carpio & Carrasius auratus*	0	NS	0	0	3214	141

In spring 2008, Murray hardyhead had a broad length distribution from 30-73 mm TL (Figure 78a). This site was dry in autumn 2009 and was not sampled. In spring 2009, the population was dominated by a new YOY cohort (10-14 mm TL) (Figure 78b). In autumn 2010 significant recruitment was evident with the population exhibiting a broad length distribution, ranging from 24-61 mm TL (Figure 78c). Nonetheless, no Murray hardyhead were subsequently sampled in spring 2010 or autumn 2011.

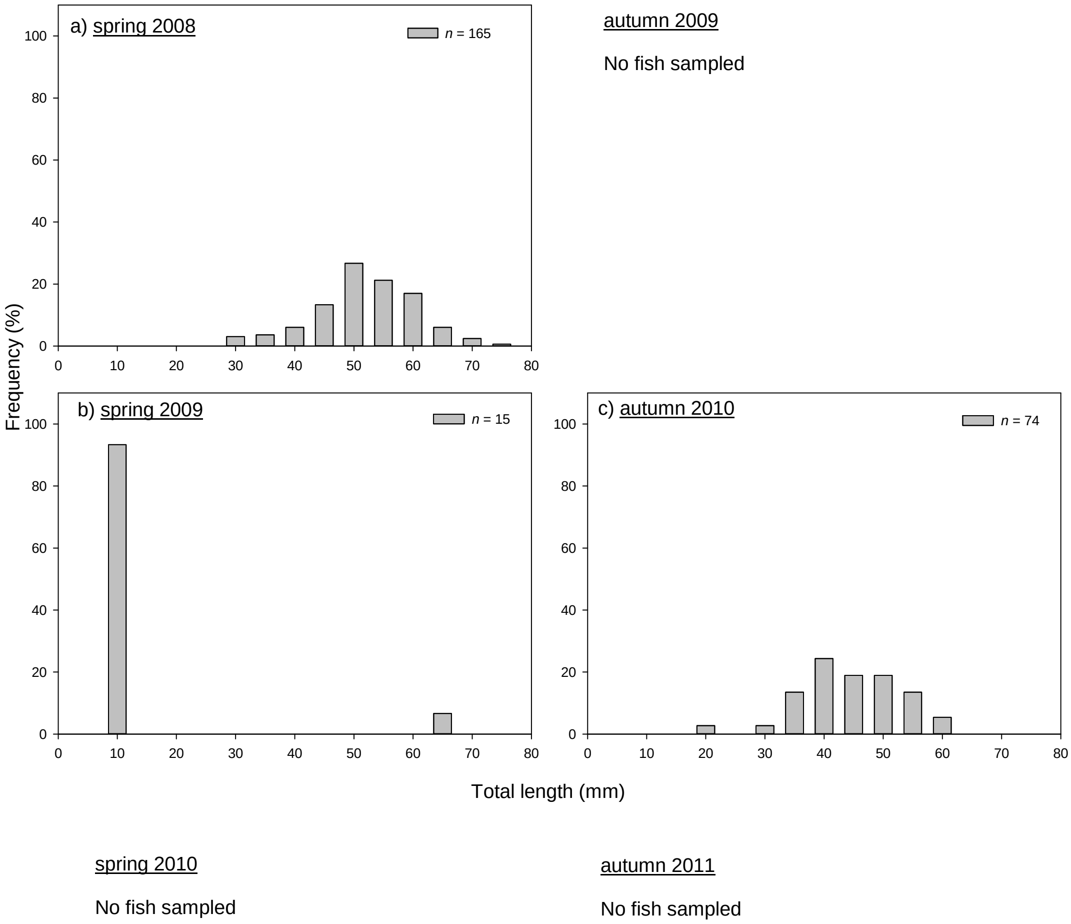


Figure 78. Length frequency distribution of Murray hardyhead from the Boggy Creek in a) spring 2008, b) spring 2009 and c) autumn 2010.

Site summary

Murray hardyhead were sampled in considerable numbers at this site in spring 2008 and in autumn 2010 and significant recent recruitment had been detected. Nonetheless, no Murray hardyhead were detected in 2010/11. The occurrence of increased inflows, raised water levels and re-connection of Boggy Creek with Holmes Creek may have facilitated the movement of Murray hardyhead away from this site. Given the favourable status of habitat at this site, however, re-colonisation may occur.

Individuals from this site were included in a captive breeding program for Murray hardyhead undertaken by the Murray-Darling Basin Freshwater Research Centre (MDFRC), Mildura lab. Spawning and rearing of juveniles was successful and progeny have been released into a surrogate refuge dam in the EMLR (see Munday Dam section 4.32), with the aim of establishing a self-sustaining population for re-introduction upon the re-establishment of favourable 'wild' conditions. These individuals may be re-introduced into Boggy Creek when conditions are deemed favourable.

4.21. Mundoo Drain West, Mundoo Island (Lake Alexandrina: Murray hardyhead, Yarra pygmy perch and southern pygmy perch)

This site is located on Mundoo Island in Lake Alexandrina. It is an irrigation channel that commonly had a high proportion of emergent vegetation (i.e. *Typha domingensis*) and submerged vegetation (Figure 79). Yarra pygmy perch and southern pygmy perch were opportunistically sampled from this site in summer 2007/08 (SARDI unpublished data) and Murray hardyhead were detected by Wedderburn and Barnes (2009) in spring 2008. A total of 50 southern pygmy perch were rescued into captivity from this site in February 2008.

Fish sampling effort

Spring 2008, autumn 2009, spring 2009 and *autumn 2010*

- 3 fyke nets set overnight

Spring 2010 and *autumn 2011*

- Not monitored

This site was not monitored by Adelaide University in 2010/11 to allow greater sampling effort at newly re-inundated and previously high value sites for threatened species in the Wyndgate area (Scotte Wedderburn pers. comm.).

2010/11 Photo-point images

Winter 2010

Spring 2010

No photo

Summer 2011

Autumn 2011

No photo

Figure 79. Photo-point images of the Mundoo Drain West site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

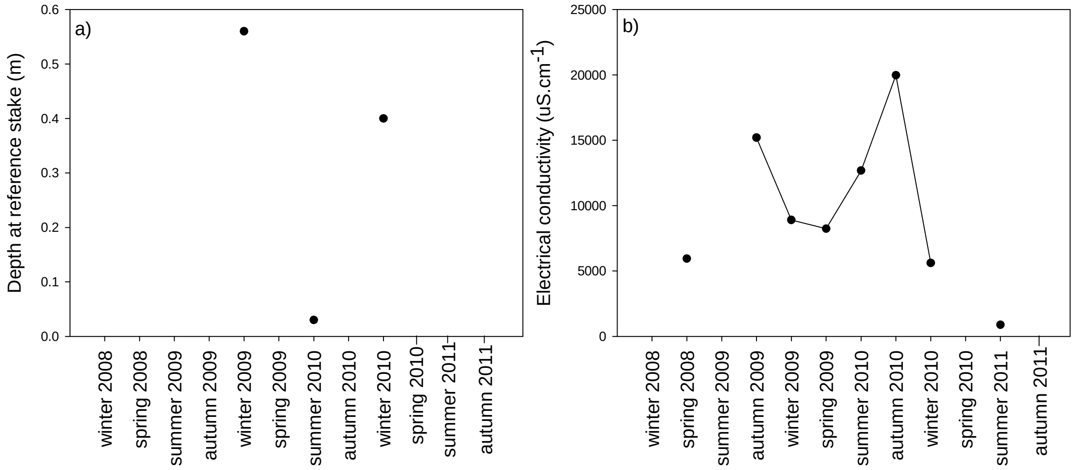


Figure 80. a) depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at Mundoo Drain West between winter 2008 and autumn 2011.

Table 60. Habitat cover measured at Mundoo Drain West during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	50 (*Typha*)	0	50
Spring 2010	Not monitored			
Summer 2011	10 (algae)	40 (*Typha,* grasses)	0	50
Autumn 2011	Not monitored			

Table 61. Water quality parameters measured at Mundoo Drain West during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	11.7	8.05	6.65	>0.7	0.7
Spring 2010	Not monitored				
Summer 2011	24.4	8.54	8.16	0.25	1.5
Autumn 2011	Not monitored				

Catch summary and length-frequency analysis

Low numbers of southern pygmy perch were sampled in spring 2008, autumn 2009 and spring 2009 but none were sampled in autumn 2010 and the site was not sampled in 2010/11 (Table 62). Murray hardyhead were detected in spring 2009 only (Table 62). Eight other species have been sampled at this site but only eastern gambusia was sampled in autumn 2010 and was abundant (Table 62).

Table 62. Total numbers of fish species collected from the Mundoo Drain west between spring 2008 and autumn 2011. NS = not sampled.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**0**	**0**	**14**	**0**	**NS**	**NS**
Southern pygmy perch	***Nannoperca australis***	**6**	**22**	**4**	**0**	**NS**	**NS**
Flat-headed gudgeon	*Philypnodon grandiceps*	40	49	23	0	NS	NS
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	9	3	9	0	NS	NS
Carp gudgeon complex	*Hypseleotris* spp.	460	332	114	0	NS	NS
Common galaxias	*Galaxias maculatus*	3	7	1	0	NS	NS
Congolli	*Pseudaphritus urvillii*	1	0		0	NS	NS
Eastern gambusia	*Gambusia holbrooki*	14	68	41	354	NS	NS
Goldfish	*Carrasius auratus*	29	0	1	0	NS	NS

All southern pygmy perch sampled in spring 2008 were adults (>45 mm TL) (
Figure 81a), however, significant recruitment was detected in autumn 2009 (
Figure 81b). Southern pygmy perch sampled in spring 2009 were again dominated by adult fish (>50 mm TL) (
Figure 81c) and no fish were sampled in autumn 2010.

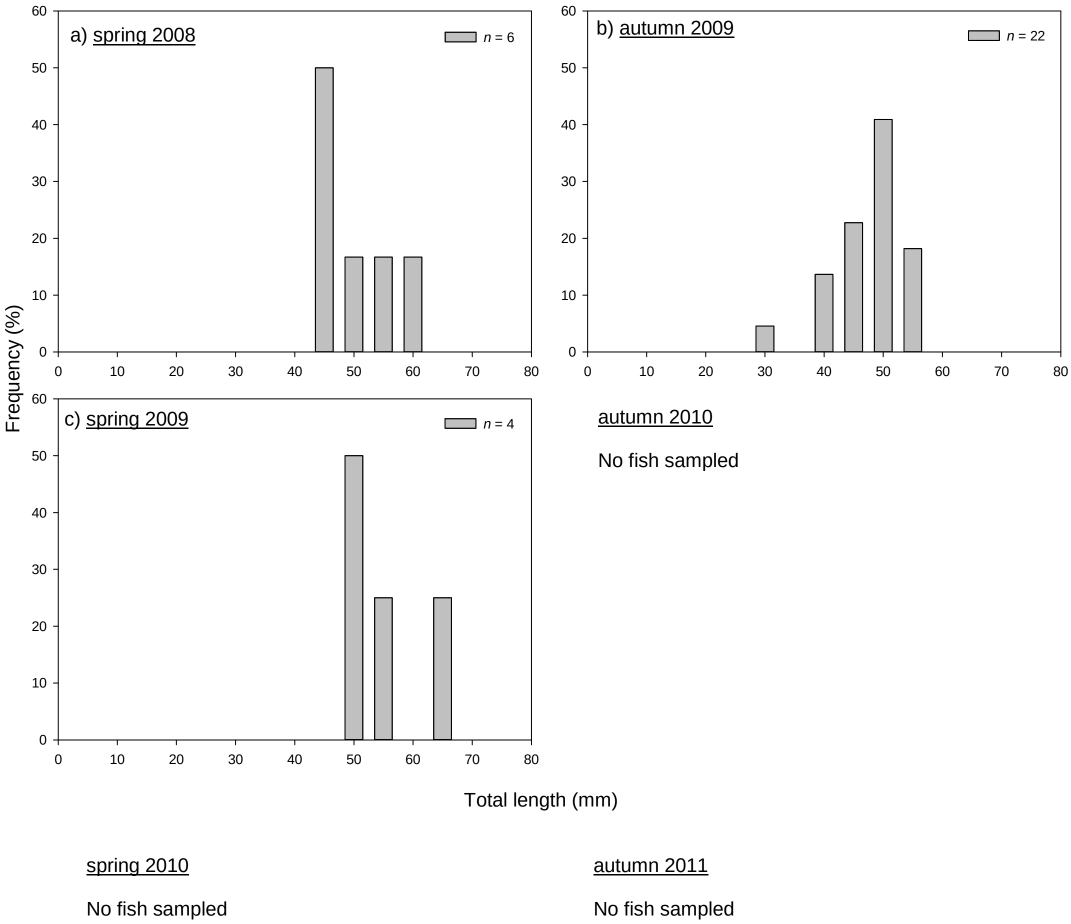


Figure 81. Length frequency distribution of southern pygmy perch from Mundoo Drain West in a) spring 2008, b) autumn 2009 and c) spring 2009.

Murray hardyhead sampled in spring 2009 were dominated by large adult fish (>50 mm TL) (Figure 82). No individuals were sampled in autumn 2010.

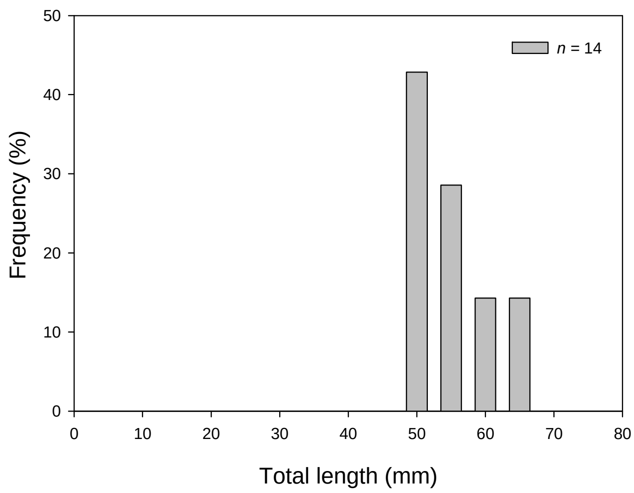


Figure 82. Length frequency distribution of Murray hardyhead from Mundoo Drain west in spring 2009.

Site summary

Water level at this site receded rapidly in summer/autumn 2010 and there was a concurrent increase in salinity (Figure 80a & b). Thus, the quality of remaining habitat was poor. Post sampling in autumn 2010, efforts were made to rescue any remaining southern pygmy perch from this site but none were present. As such, Yarra and southern pygmy perch and Murray hardyhead are likely lost from this site. With increased flows and water levels in Lake Alexandrina in 2010/11, this site was not sampled as part of ‘condition monitoring’ in favour of increasing sampling effort at previously important sites for threatened fish on Hindmarsh Island (around Wyndgate) that were newly inundated.

Southern pygmy perch from this site have been incorporated into a captive breeding program at Flinders University. With improved conditions this site could form a re-introduction location for Yarra pygmy perch, southern pygmy perch and Murray hardyhead from captive stocks.

4.22. Mundoo Drain East, Mundoo Island (Lake Alexandrina: Murray hardyhead)

This site is located on Mundoo Island in Lake Alexandrina. It is an irrigation channel that commonly had a high proportion of emergent vegetation (i.e. *Typha domingensis*) and submerged vegetation (Figure 83). Murray hardyhead were detected at this site by Wedderburn and Barnes (2009) in spring 2008.

Fish sampling effort

Spring 2008, autumn 2009, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 3 fyke nets set overnight
- 3 seine net hauls (~2 m length).

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 83. Photo-point images of the Mundoo Drain East site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

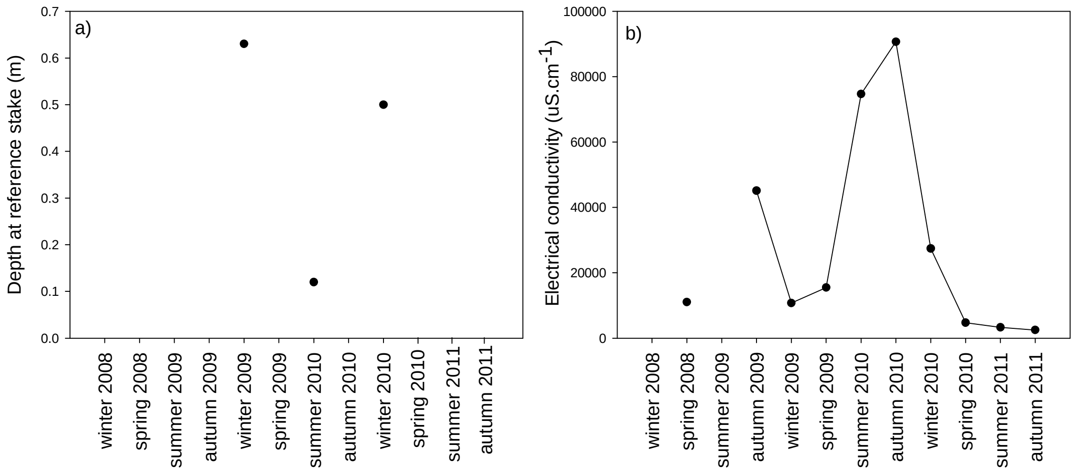


Figure 84. a) depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at Mundoo Drain East between winter 2008 and autumn 2011.

Table 63. Habitat cover measured at Mundoo Drain East during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	50 (*Chara*)	1 (grasses)	0	49
Spring 2010	8 (total aquatic vegetation cover)		0	92
Summer 2011	0	2 (*Typha,* grasses)	0	98
Autumn 2011	48 (total aquatic vegetation cover)		0	52

Table 64. Water quality parameters measured at Mundoo Drain East during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	15.5	8.72	10.81	>0.65	0.65
Spring 2010	20.3	7.68	-	0.63	0.71 (average depth)
Summer 2011	24.4	8.16	8.54	0.25	1.5
Autumn 2011	18.6	8.07	-	0.32	0.62 (average depth)

Catch summary and length-frequency analysis

Murray hardyhead were sampled in considerable numbers in spring 2008, autumn 2009 and spring 2009 but were absent in autumn 2010, spring 2010 and autumn 2011 (Table 65). A total of 10 other species have been sampled from the site (Table 65).

Table 65. Total numbers of fish species collected from the Mundoo Drain east between spring 2008 and autumn 2011.

Species		Sampling trip					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**48**	**273**	**162**	**0**	**0**	**0**
Small-mouthed hardyhead	*Atherinosoma microstoma*	6	301	785	0	110	10
Bony herring	*Nematalosa erebi*	0	0	0	0	0	90
Flat-headed gudgeon	*Philypnodon grandiceps*	1	2	0	0	58	16
Carp gudgeon complex	*Hypseleotris* spp.	0	1	0	0	18	0
Common galaxias	*Galaxias maculatus*	0	0	1	0	0	0
Congolli	*Pseudaphritis urvillii*	0	0	0	0	0	3
Blue-spot goby	*Pseudogobius olorum*	9	32	20	0	0	0
Redfin perch	*Perca fluviatilis*	0	0	0	0	2	32
Eastern gambusia	*Gambusia holbrooki*	40	145	29	0	1	1
Common carp & goldfish	*Cyprinus carpio & Carrasius auratus*	0	0	0	0	233	37

In spring 2008, the Murray hardyhead population was comprised of two cohorts, with an adult cohort >40 mm TL and a cohort of recently recruited YOY fish (<29 mm TL) (Figure 85a). In autumn 2009, growth of the YOY cohort was evident with lengths ranging 29-63 mm TL (Figure 85b). The length-frequency distribution of the population in spring 2009 was different to the previous year with no YOY cohort present (Figure 85a and c). No fish were sampled in autumn 2010, spring 2010 or autumn 2011 and subsequently no recruitment was detected.

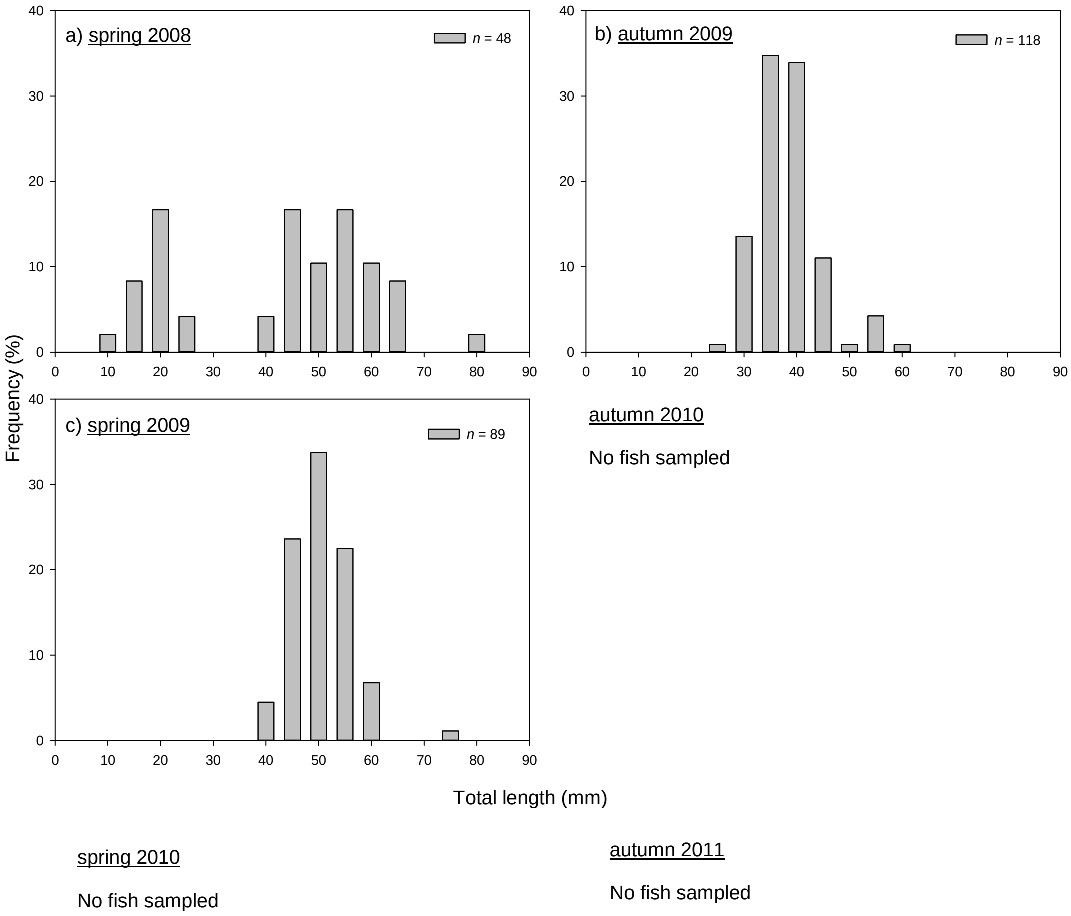


Figure 85. Length frequency distribution of Murray hardyhead from Mundoo Drain east in a) spring 2008, b) autumn 2009 and c) spring 2009.

Site summary

Water level receded rapidly at this site in summer/autumn 2010 and there was a concurrent increase in salinity, with electrical conductivity reaching ~90,000 μS.cm^{-1} (Figure 84a and b). It is likely that Murray hardyhead have been lost from this site over this period. Salinity has been reduced substantially at this site following increased water levels in Lake Alexandrina.

As habitat conditions continue to recover Murray hardyhead may re-colonise this site or this site may represent a potential location for re-introductions if conditions are deemed to be favourable.

4.23. Clayton/Dunn’s Lagoon (Lake Alexandrina: Murray hardyhead)

Dunn’s Lagoon is located near the township of Clayton in the south-west of Lake Alexandrina. It is a large wetland and was typically characterised by abundant emergent (i.e. *Phragmites australis, Typha domingensis* and *Schoenoplectus validus*) and submerged vegetation (i.e. *Myriophyllum* spp.) (Holt *et al.* 2005). Due to receding water levels in Lake Alexandrina, this site completely dried in summer 2008/09 and vegetation was lost, however, Dunn’s Lagoon refilled in 2010 when water levels increased in Lake Alexandrina (Figure 86).

Fish monitoring has occurred at this site since 2003 (Wedderburn and Hammer 2003). Low numbers of Murray hardyhead have consistently been sampled from Dunn’s Lagoon (Wedderburn and Hammer 2003; Higham *et al.* 2005; Bice and Ye 2006; Bice and Ye 2007; Bice *et al.* 2008) along with a single Yarra pygmy perch in 2004 (Holt *et al.* 2005). Due to the low water levels experienced for the majority of the study, sampling for the current project occurred in the area where Dunn’s Lagoon meets the Goolwa Channel whilst other studies have often sampled further into the lagoon.

Fish sampling effort

Spring 2008, autumn 2009, spring 2009

- 6 seine net hauls

Autumn 2009, spring 2010 and autumn 2011

- 4 fyke nets set overnight within Dunn’s Lagoon

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 86. Photo-point images of the Clayton/Dunn's Lagoon site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

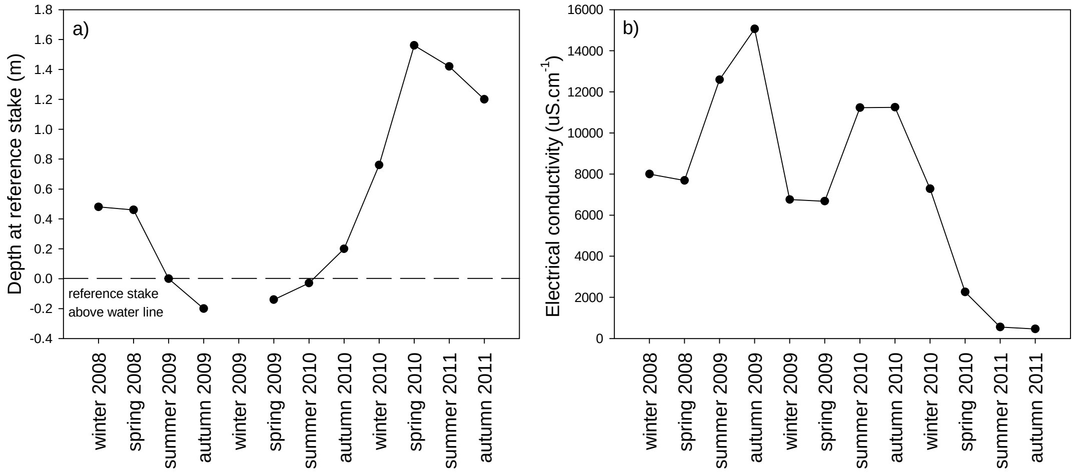


Figure 87. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity ($\mu S.cm^{-1}$) at Clayton/Dunn's Lagoon between winter 2008 and autumn 2011.

Table 66. Habitat cover measured at Clayton/Dunn's Lagoon during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	40 (*Typha, Bolboschoenus, Schoenoplectus, Cotula*)	0	60
Spring 2010	0	40 (*Typha, Triglochin*)	5 (debris)	55
Summer 2011	0	50 (*Typha, Schoenoplectus*)	0	50
Autumn 2011	1 (*Myriophyllum*)	40 (*Typha,* grasses)	4 (debris)	55

Table 67. Water quality parameters measured at Clayton/Dunn's Lagoon during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	12.3	8.5	10.11	-	0.3	-
Spring 2010	21.7	8.83	10.2	9.9	0.4	1.7
Summer 2011	21.8	8.63	9.81	9.45	0.2	>1
Autumn 2011	18	8.64	8.88	7.55	0.18	1.5

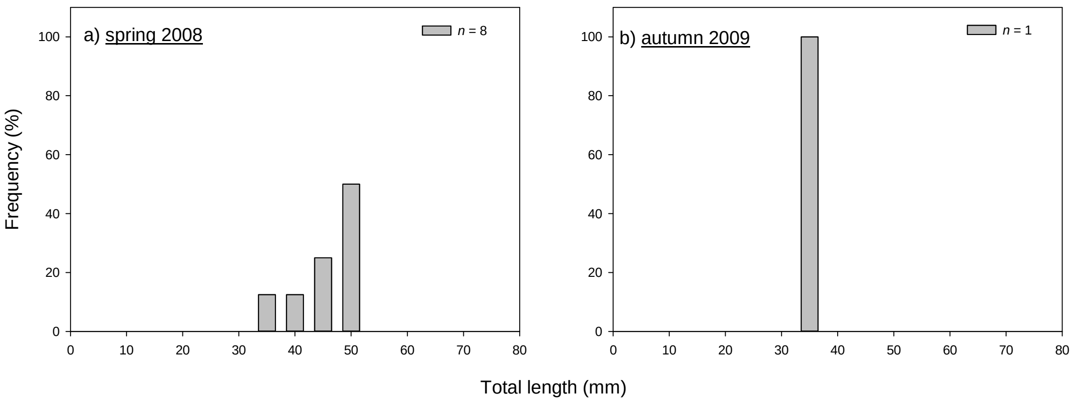
Catch summary and length-frequency analysis

Low numbers of Murray hardyhead were sampled in 2008/09 and no individuals were sampled in 2009/10 or 2010/11 (Table 68). A total of 16 other species have been sampled at this site (Table 68).

All Murray hardyhead sampled in spring 2008 were adults with length ranging from 36-54 mm TL (Figure 88a). Only one individual was captured in autumn 2009 and was likely a new recruit from the most recent spawning season (Figure 88b).

Table 68. Total numbers of fish species collected from Clayton/Dunn's Lagoon between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**8**	**1**	**0**	**0**	**0**	**0**
Golden perch	*Macquaria ambigua*	0	0	0	0	0	5
Australian smelt	*Retropinna semoni*	32	45	86	61	10	3
Bony herring	*Nematalosa erebi*	1	1	0	49		66
Flat-headed gudgeon	*Philypnodon grandiceps*	0	80	0	129	1219	215
Carp gudgeon	*Hypseleotris* spp.	0	0	0	0	21	8
Congolli	*Pseudaphritis urvillii*	0	0	0	0	1	2
Common galaxias	*Galaxias maculatus*	2	1	0	0	4	1
Small-mouthed hardyhead	*Atherinosoma microstoma*	71	90	7	57	0	0
Lagoon goby	*Tasmanogobius lasti*	5	30	38	43	5	0
Tamar goby	*Afurcagobius tamarensis*	9	123	365	12	7	0
Blue-spot goby	*Pseudogobius olorum*	2	1	1	22	19	0
Bridled goby	*Arenogobius bifrenatus*	0	0	0	5	1	0
Redfin perch	*Perca fluviatilis*	0	1	5	1	1	124
Common carp	*Cyprinus carpio*	0	0	0	5	37	21
Gold fish	*Carrasius auratus*	0	0	0	0	0	22
Eastern gambusia	*Gambusia holbrooki*	0	0	0	0	0	2



spring 2009

No fish sampled

autumn 2010

No fish sampled

spring 2010

No fish sampled

autumn 2011

No fish sampled

Figure 88. Length frequency distribution of Murray hardyhead from Clayton/Dunn's Lagoon in a) spring 2008 and b) autumn 2009.

Site summary

Murray hardyhead were again absent from DAP sampling in 2010/11; however, sampling by Wedderburn and Barnes (In Prep.) in spring 2010 detected low numbers within the lagoon (*n* = 6). Nonetheless, sampling of the same site in autumn 2011 failed to detect any individuals. As habitat conditions continue to recover in Dunn's Lagoon, Murray hardyhead may re-colonise this site (assuming there is a source of individuals). Failing this the site may represent a potential location for re-introductions if conditions are deemed to be favourable.

4.24. Milang Jetty (Lake Alexandrina: Murray hardyhead)

This site is a sheltered lake edge located near the township of Milang. Habitat at this site could be characterised as a shallow, sheltered bay with fringing emergent vegetation (Figure 89). Murray hardyhead were sampled at this site in 2003 (Wedderburn and Hammer 2003) and re-sampled in autumn 2008 as part of site selection for the current project (unpublished data). This site dried significantly in 2008/09 but has since been re-inundated 2010/11, with concomitant decreases in salinity (Figure 90a and b).

Fish sampling effort

Spring 2008, autumn 2009, spring 2009 and autumn 2010

- 6 seine net hauls

Spring 2010 and autumn 2011

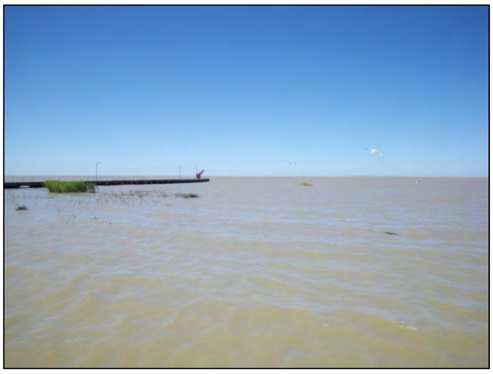
- 4 fyke nets set overnight

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011



Autumn 2011

Figure 89. Photo-point images of the Milang Jetty site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

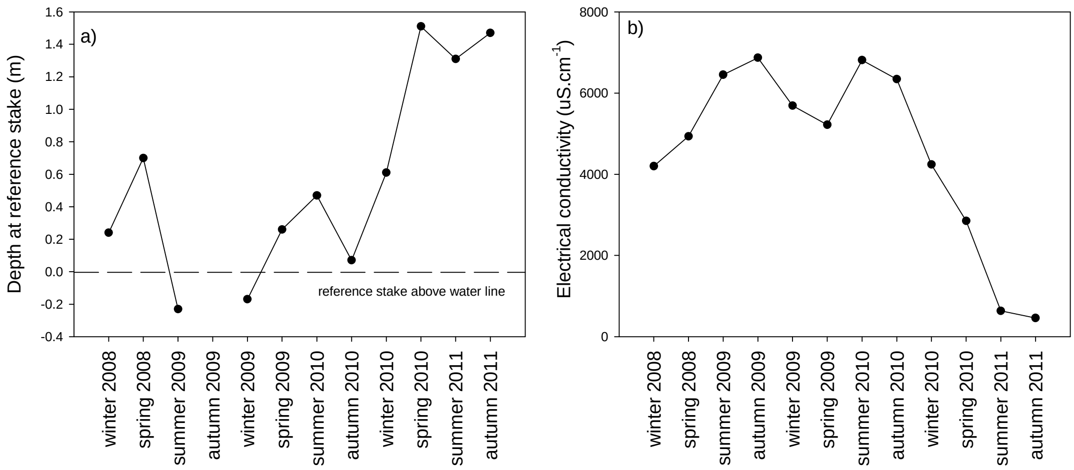


Figure 90. a) depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at Milang Jetty between winter 2008 and autumn 2011.

Table 69. Habitat cover measured at Milang Jetty during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	0	30 (*Cotula,* rye grass, terrestrial weeds)	5 (debris)	65
Spring 2010	0	50 (*Phragmites, Juncus,* terrestrial weeds)	0	50
Summer 2011	0	15 (*Phragmites, Juncus,* grasses)	0	85
Autumn 2011	0	60 (*Phragmites, Typha,* grasses)	0	40

Table 70. Water quality parameters measured at Milang Jetty during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	11.9	8.18	9.23	0.2	0.8
Spring 2010	23.4	8.99	10.25	0.4	0.8
Summer 2011	22.7	8.53	10.57	0.2	>1
Autumn 2011	18.8	8.29	10.01	0.2	1.5

Catch summary and length-frequency analysis

In 2010/11, as in 2009/10, Murray hardyhead were absent from Milang (Table 71). Individuals were only sampled in spring 2008. A total of fifteen other species have been sampled at this site over the project (Table 71).

All Murray hardyhead sampled at this site in spring 2008 were large adults (>45 mm TL) (Figure 91).

Table 71. Total numbers of fish species collected from Milang Jetty between spring 2008 and autumn 2011.

Species		Sampling trip					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**5**	**0**	**0**	**0**	**0**	**0**
Golden perch	*Macquaria ambigua*	0	0	0	0	1	3
Australian smelt	*Retropinna semoni*	120	32	26	12	237	11
Bony herring	*Nematalosa erebi*	16	2	1	23	13	21
Flat-headed gudgeon	*Philypnodon grandiceps*	0	10	22	8	797	58
Carp gudgeon	*Hypseleotris* spp.	0	0	0	0	98	1
Congolli	*Pseudaphritis urvillii*	0	0	0	0	0	1
Common galaxias	*Galaxias maculatus*	1	0	4	0	2	14
Small-mouthed hardyhead	*Atherinosoma microstoma*	15	0	0	9	1	1
Lagoon goby	*Tasmanogobius lasti*	3	15	3	2	146	171
Tamar goby	*Afurcagobius tamarensis*	0	1	0	3	0	0
blue-spot goby	*Pseudogobius olorum*	0	1	0	0	4	1
Common carp	*Cyprinus carpio*	0	0	38	0	123	9
Gold fish	*Carrasius auratus*	0	0	0	0	0	3
Gambusia	*Gambusia holbrooki*	0	1	0	0	0	0
Redfin perch	*Perca fluviatilis*	3	1	0	0	0	2

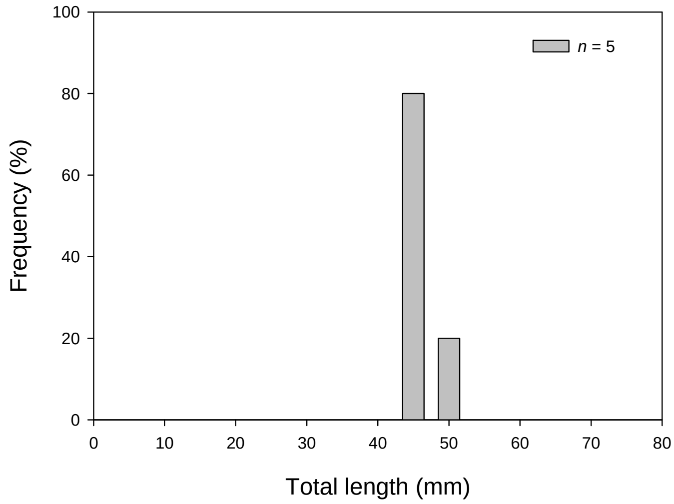


Figure 91. Length frequency distribution of Murray hardyhead from Milang Jetty in spring 2008.

Site summary

Murray hardyhead have potentially been lost from this site. This site was heavily impacted by receding water levels in Lake Alexandrina. Remaining habitat was shallow and poor quality, with little emergent or submerged vegetation. Nevertheless, with increased water level in Lake Alexandrina 2010/11 conditions at this site have improved.

4.25. Bremer Mouth (Lake Alexandrina: Murray hardyhead)

This site is at the mouth of the Bremer River, which flows from the EMLR and discharges into Lake Alexandrina near the town of Milang. Murray hardyhead were first sampled at this site in summer 2008 (Bice *et al.* 2008) and have typically been detected in low abundances. Habitat is similar to that found in the irrigation drain with abundant emergent (e.g. *Typha domingensis, Phragmites australis, Triglochin procerum*) and submerged vegetation (e.g. *Myriophyllum* spp.) (Figure 92).

This site was impacted by reduced water levels in the Lower Lakes through 2007-2010, when it was disconnected from Lake Alexandrina and became desiccated on two occasions (Figure 93a). Increased water levels in 2010 resulted in re-connection with Lake Alexandrina and a marked reduction in salinity at this site (Figure 93a and b).

Fish sampling effort

Spring 2008, spring 2009, spring 2010 and autumn 2011

- 4 fyke nets set overnight

Autumn 2009 and autumn 2010

- not sampled as site had completely dried

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 92. Photo-point images of the Bremer Mouth site from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

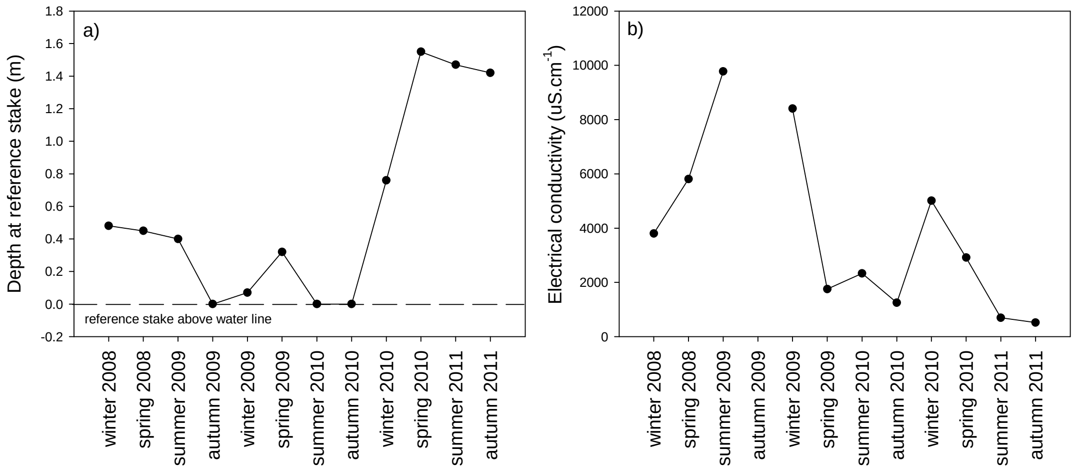


Figure 93. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at the Bremer Mouth between winter 2008 and autumn 2011.

Table 72. Habitat cover measured at the Bremer Mouth during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	1 (*Myriophyllum*)	60 (*Typha, Phragmites, Cotula, Triglochin, Rumex, Lignum*)	0	39
Spring 2010	10 (*Myriophyllum, Potamogetan crispus*)	40 (*Typha, Triglochin, Rumex, Lignum*)	0	50
Summer 2011	10 (*Myriophyllum, Ceratophyllum*)	30 (*Typha, Phragmites, Triglochin, Lignum, Rumex, Persicaria*)	0	60
Autumn 2011	10 (*Myriophyllum, Ceratophyllum*)	40 (*Typha, Triglochin, Rumex, Lignum,* grasses)	5 (debris)	45

Table 73. Water quality parameters measured at the Bremer Mouth during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) Bottom	Secchi (m)	Max depth (m)
Winter 2010	11.6	7.6	6.09		0.5	0.8
Spring 2010	20.1	7.82	3.58	3.04	0.3	1.8
Summer 2011	22.0	7.89	3.83	2.71	0.25	1.7
Autumn 2011	18.1	7.72	2.4	1.53	0.25	2

Catch summary and length-frequency analysis

Murray hardyhead were sampled in low numbers in spring 2008 but were not sampled for the remainder of the study period (Table 74). A total of fifteen other species were sampled at this site from 2008-2011 (Table 74). All Murray hardyhead sampled in spring 2009 were large adult fish (>50 mm TL) (Figure 94).

Table 74. Total numbers of fish species collected from the Finniss River Confluence between spring 2008 and autumn 2011. NS = not sampled.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**9**	**NS (dry)**	**0**	**NS (dry)**	**0**	**0**
Golden perch	*Macquaria ambigua*	0	NS	0	NS	0	2
Australian smelt	*Retropinna semoni*	7	NS	1	NS	20	0
Carp gudgeon complex	*Hypseleotris* spp.	1	NS	1	NS	278	5
Flat-headed gudgeon	*Philypnodon grandiceps*	61	NS	2	NS	992	30
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	0	NS	0	NS	2	1
Bony herring	*Nematalosa erebi*	114	NS	0	NS	1	0
Common galaxias	*Galaxias maculatus*	238	NS	908	NS	1	0
Congolli	*Pseudaphritus urvillii*	1	NS	0	NS	0	0
Small-mouthed hardyhead	*Atherinosoma microstoma*	42	NS	0	NS	3	0
Tamar goby	*Afurcagobius tamarensis*	1	NS	0	NS	0	0
Blue-spot goby	*Pseudogobius olorum*	3	NS	0	NS	0	0
Carp	*Cyprinus carpio*	1	NS	28	NS	0	12
Goldfish	*Carrasius auratus*	0	NS	1	NS	0	1
Tench	*Tinca tinca*	2	NS	0	NS	0	0
Redfin perch	*Perca fluviatilis*	4	NS	0	NS	0	1

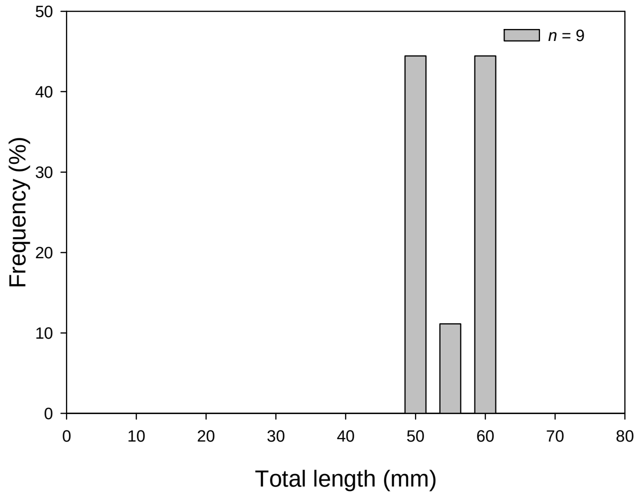


Figure 94. Length frequency distribution of Murray hardyhead from the Bremer Mouth in spring 2008.

Site summary

Murray hardyhead have likely been lost from this site as it completely dried on two occasions and was largely disconnected from Lake Alexandrina at low lake levels. Nonetheless, it is now connected with Lake Alexandrina and given the mobile and dispersive nature of Murray hardyhead re-colonisation may be possible given habitat conditions are favourable and an adequate source population exists.

4.26. Rocky Gully (River Murray: Murray hardyhead)

Rocky Gully is a medium-sized, off-channel wetland of the River Murray below Lock 1 near the town of Murray Bridge below Lock 1 (Figure 95). Rocky Gully was disconnected from the River Murray by a cement structure for the majority of the project, from 2008-2009, in order to hold water at this site whilst River Murray levels were below ~0.3 m AHD (Figure 96a). In winter 2009 in response to very poor conditions and fish numbers in the wetland, an earthen bank was added near the cement structure (height ~0.7m AHD). At times throughout the project salinity was elevated (>50,000 $\mu S.cm^{-1}$) (Figure 96b) and as such, during reduced water levels in the River Murray, this site was provided with environmental water on several occasions to reduce salinity and mitigate other water quality issues (i.e. algal bloom). Increased flows and water levels, and subsequent re-connection with the River Murray in 2010, resulted in substantially reduced salinities at this site (Figure 96a and b).

Habitat at Rocky Gully is typically dominated by algae and fringing terrestrial grasses. Prior to reduced water levels in the lower River Murray, Smith (2006) sampled a diverse assemblage of 16 species in 2005, including Murray hardyhead.

Fish sampling effort

Spring 2008, autumn 2009, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 4 fyke nets set overnight

2010/11 Photo-point images

Winter 2010

Spring 2010

Summer 2011

Autumn 2011

Figure 95. Photo-point images of Rocky Gully from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

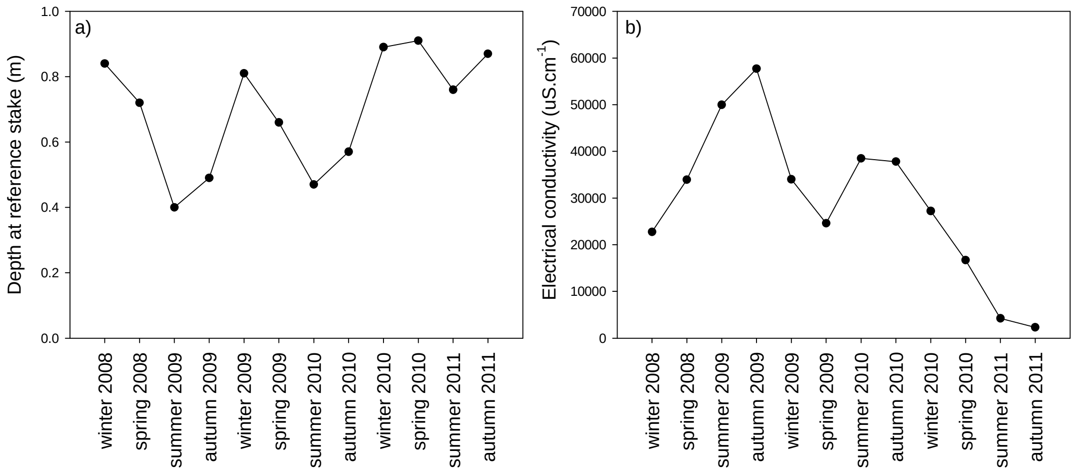


Figure 96. a) depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (μS.cm^{-1}) at Rocky Gully between winter 2008 and autumn 2011.

Table 75. Habitat cover measured at Rocky Gully during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	5 (algae)	10 (grasses)	1 (rock)	84
Spring 2010	10 (algae)	10 (grasses, *Bolboschoenus,* samphire)	1 (rock)	79
Summer 2011	1 (algae)	20 (grasses, *Bolboschoenus, Phragmites,* samphire)	0	79
Autumn 2011	0	20 (*Phragmites,* grasses)	10 (rock)	70

Table 76. Water quality parameters measured at Rocky Gully during each site visit.

Season	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	11.2	9.87	11.5	8.38	0.65	1.3
Spring 2010	22.6	8.31	7.83	2.2	0.7	1.5
Summer 2011	25.0	8.9	3.62	3.69	0.35	1.5
Autumn 2011	17.2	8.74	9.65	4.44	0.36	1.5

Catch summary and length-frequency analysis

Murray hardyhead were sampled in large numbers in spring 2009 (Table 77). However in autumn 2009 they had shown a significant decrease in abundance and were not detected in subsequent sampling in spring 2009 (Table 77). In autumn 2010, however, Murray hardyhead were captured in considerable abundance (Table

77). The species was captured in low-moderate abundance in both spring 2010 and autumn 2011 (Table 77). A total of thirteen other species were sampled at this site throughout the project including six species only sampled in autumn 2011 following significant reductions in salinity (Table 77).

Table 77. Total numbers of fish species collected from Rocky Gully between spring 2008 and autumn 2010.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**760**	**3**	**0**	**103**	**26**	**14**
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	0	0	0	0	0	184
Small-mouthed hardyhead	*Atherinosoma microstoma*	7606	0	7	612	132	3
Murray rainbowfish	*Melanotaenia fluviatilis*	0	0	0	0	0	17
Freshwater catfish	*Tandanus tandanus*	0	0	0	0	0	38
Flat-headed gudgeon	*Philypnodon grandiceps*	0	0	73	179	231	1072
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	0	0	5	2	14	2
Australian smelt	*Retropinna semoni*	0	0	0	0	0	1
Carp gudgeon complex	*Hypseleotris spp*	0	0	1	0	42	26
Lagoon goby	*Tasmanogobius lasti*	29	0	0	0	0	0
blue-spot goby	*Pseudogobius olorum*	314	0	0	0	0	0
Common carp	*Cyprinus carpio*	0	0	0	0	0	32
Goldfish	*Carrasius auratus*	0	0	0	0	0	13
Gambusia	*Gambusia holbrooki*	38	65	20	151	4	45

All Murray hardyhead sampled in spring 2008 appeared to be adults from the previous spawning season (i.e. spring/summer 2007/08; >30 mm TL) (Figure 97a). The fish collected in autumn 2009 were likely to be recruits from spawning in spring/summer 2008 (Figure 97b). Whilst no fish were sampled in spring 2009, juvenile Murray hardyhead were observed (pers. obs.). In autumn 2010, Murray hardyhead exhibited a broad length distribution with fish ranging from 35-69 mm TL and recent recruitment was evident (Figure 97c). In spring 2010, the Murray hardyhead population was again dominated by adult individuals, which exhibited a broad length distribution ranging from 48-74 mm TL (Figure 97d). All individuals sampled in autumn 2010 were likely to be newly recruited YOY, with all fish <50 mm TL (Figure 97e and 98).

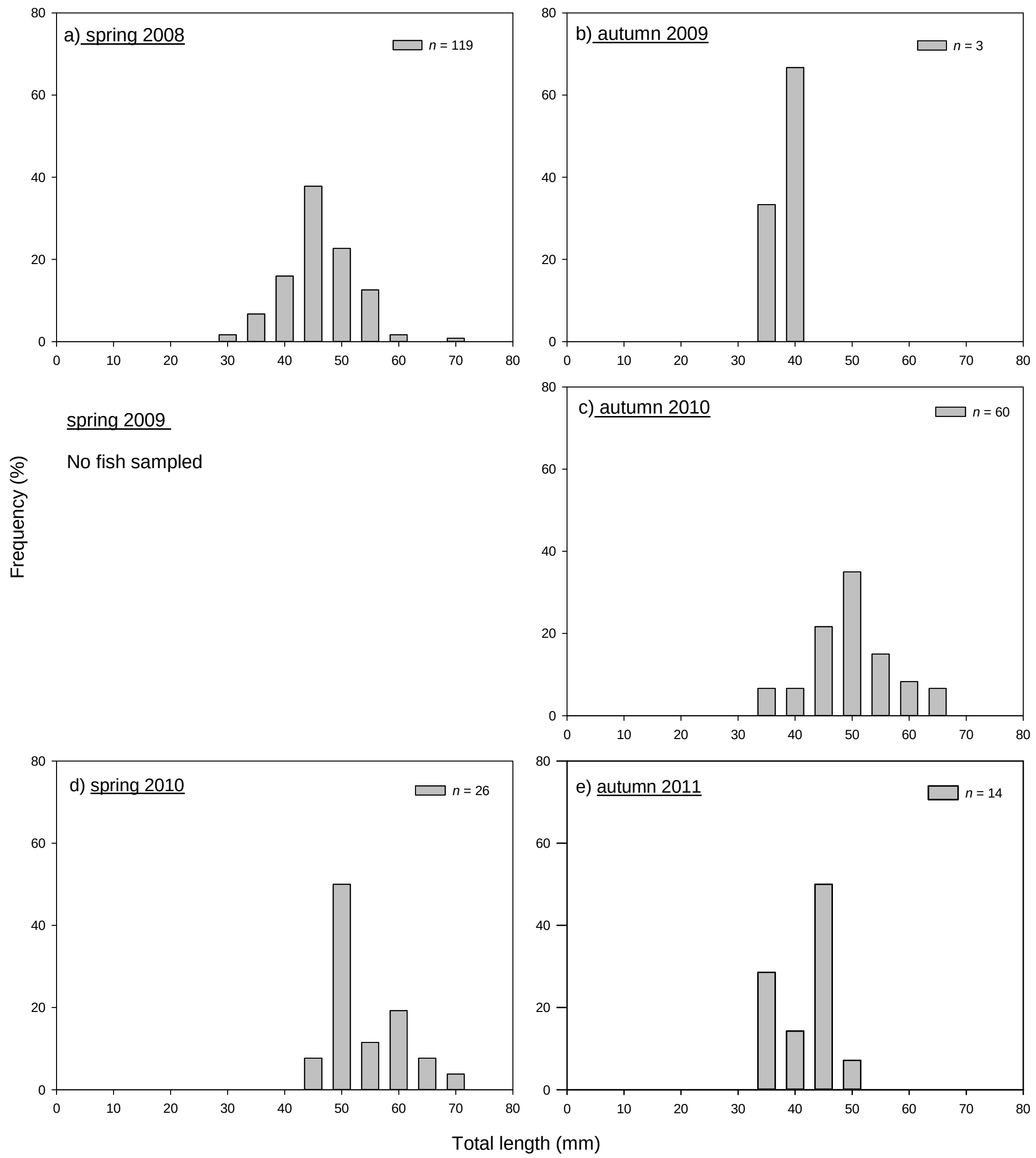


Figure 97. Length frequency distribution of Murray hardyhead from Rocky Gully in a) spring 2008, b) autumn 2009, c) autumn 2010, d) spring 2010 and e) autumn 2011.

Figure 98. YOY Murray hardyhead sampled from Rock Gully in autumn 2011.

Site summary

Murray hardyhead underwent a severe decline in abundance in 2008/09. This was likely due to the combination of a severe algal bloom and elevated salinity, which reached ~55,000 µS.cm^{-1} in autumn 2009 (Figure 96b). Further sampling at this site, after autumn 2009, in an attempt to rescue fish for captive maintenance yielded just two individuals. An environmental water allocation was provided to this site in winter 2009. This action appears to have been favourable for Murray hardyhead with an increase in abundance and recruitment detected in autumn 2010. Furthermore, the species persisted through 2010/11 and recent recruitment was evident. Murray hardyhead are, however, believed to favour slightly-moderately saline conditions and reduced salinity at Rocky Gully may indeed favour species adapted to 'fresher' conditions that may ultimately compete with Murray hardyhead (Wedderburn *et al.* 2008). A number of fish (n = 50) were taken into captive breeding at MDFRC during a time of higher abundance (autumn 2010) as a proactive measure for broader conservation of the Lower Lakes conservation unit.

4.27. Riverglades (River Murray: Murray hardyhead)

Riverglades is a medium-large off-channel wetland of the River Murray below Lock 1 near the town of Murray Bridge (Figure 99). Riverglades was disconnected from the River Murray and became desiccated in 2008. The site was re-inundated during winter/spring 2010 due to increased River Murray flows and water levels. Prior to disconnection the wetland was typically characterised by abundant submerged and emergent vegetation and Murray hardyhead were last detected in 2004/05 (Wedderburn *et al.* 2007).

Fish sampling effort

Spring 2008

- 5 seine net hauls

Autumn 2009, spring 2009 and autumn 2010

- Not sampled - dry

Spring 2010 and autumn 2011

- 4 fyke nets set overnight

2010/11 Photo-point images

Winter 2010

Not monitored

Spring 2010


Summer 2011


Autumn 2011


Figure 99. Photo-point images of Riverglades from spring 2010, summer 2011 and autumn 2011.

Environmental conditions

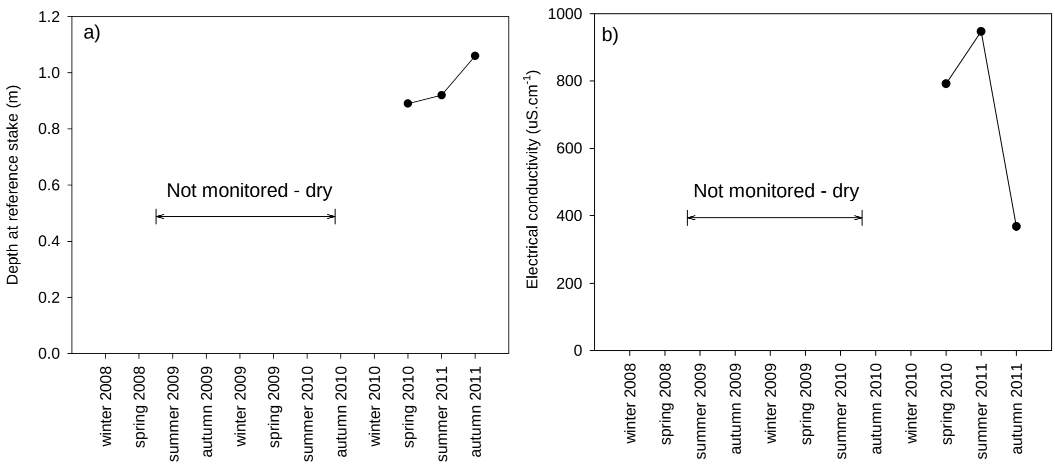


Figure 100. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at Riverglades between winter 2008 and autumn 2011.

Table 78. Habitat cover measured at Riverglades during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	Not monitored			
Spring 2010	5 (algae)	50 (*Ludwigia, Triglochin, Phragmites*)	0	45
Summer 2011	19 (*Ceratophyllum, Azolla, Lemna*)	80 (*Phragmites, Ludwigia*)	0	1
Autumn 2011	50 (*Ceratophyllum*)	40 (*Persicaria,* grasses)	5	5

Table 79. Water quality parameters measured at Riverglades during each site visit.

Season	Temp (°C)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Winter 2010	Not monitored					
Spring 2010	22.9	7.05	1.99	0.6	0.2	1.2
Summer 2011	23.9	7.77	1.82	1.72	0.4	1.5
Autumn 2011	16.3	7.91	3.01	0.11	1.2	1.8

Catch summary and length-frequency analysis

No Murray hardyhead were sampled at Riverglages in spring 2008, spring 2010 or autumn 2011 (Table 80). A total of nine other fish species were sampled over the study period (Table 80).

Table 80. Total numbers of fish species collected from Riverglades between spring 2008 and autumn 2011.

Species		Sampling trip					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**0**	**NS (dry)**	**NS (dry)**	**NS (dry)**	**0**	**0**
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	4	NS	NS	NS	0	3
Golden perch	*Macquaria ambigua*	0	NS	NS	NS	4	
Flat-headed gudgeon	*Philypnodon grandiceps*	21	NS	NS	NS	8	1
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	1	NS	NS	NS	5	1
Carp gudgeon complex	*Hypseleotris* spp.	9	NS	NS	NS	66	8
Australian smelt	*Retropinna semoni*	29	NS	NS	NS	0	0
Bony herring	*Nematalosa erebi*	0	NS	NS	NS	1	0
Common carp	*Cyprinus carpio*	0	NS	NS	NS	546	0
Eastern gambusia	*Gambusia holbrooki*	0	NS	NS	NS	0	332

Site summary

Riverglades was heavily impacted by low water levels in the River Murray below Lock 1 from 2007-2010. The site was disconnected from the River Murray and desiccated through this period but was re-inundated and re-connected in 2010. The return of Murray hardyhead to this site is thus dependent upon dispersal and colonisation from other sites (e.g. Rocky Gully). Habitat conditions (e.g. aquatic vegetation cover) at the site have improved substantially with re-inundation in 2010/11.

4.28. Disher Creek (River Murray: Murray hardyhead)

Disher creek is a saline water disposal basin near the town of Renmark in the Riverland. This wetland is fed by water from the Renmark Area Drainage Disposal Scheme (RADDS). The site is shallow and often has abundant submerged vegetation (i.e. *Lepilaena*) and elevated salinities (Figure 101).

This site traditionally harboured a large population of Murray hardyhead across the whole wetland (Lloyd and Walker 1986; Wedderburn 2000). However, lack of flooding and decreased volumes of ‘drainage disposal’ flows led to increased salinities throughout much of the wetland. As such the distribution of Murray hardyhead within the wetland has significantly contracted and the species was confined to the immediate area around the drainage disposal outflow (DAP site selection, Wilson and Wedderburn unpublished data). Over the project period water levels remained low and salinity remained elevated during the period 2008-2010 but from mid 2010-2011 water levels rose sharply and salinity decreased substantially upon increased River Murray flows and flooding (Figure 102a and b).

Fish sampling effort

Spring 2008, autumn 2009, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 4 fyke nets set overnight

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 101. Photo-point images of Disher Creek from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

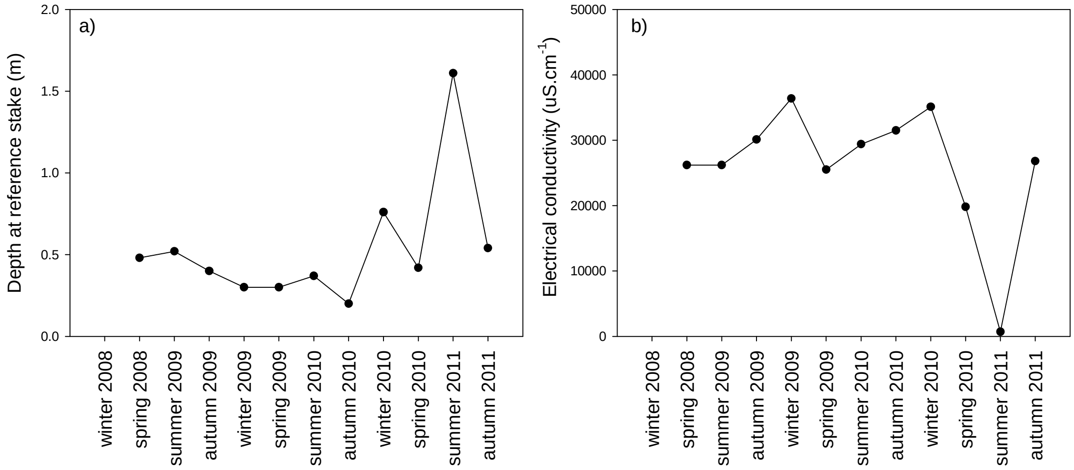


Figure 102. a) Depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (µS.cm^{-1}) at Disher Creek between winter 2008 and autumn 2011.

Table 81. Habitat cover measured at Disher Creek during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	60 (*Lepilaena*, algae)	10 (Lignum, *Triglochin*)	0	30
Spring 2010	80 (*Lepilaena*, algae)	10 (Lignum, *Triglochin, Bolboschoenus*)	0	10
Summer 2011	20 (*Lemna, Azolla*)	20 (Lignum, samphire)	5 (dead bushes)	55
Autumn 2011	0	10 (*Lignum*)	5 (debris)	85

Table 82. Water quality parameters measured at Disher Creek during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	14.4	8.06	8.73	>0.5	0.5
Spring 2010	21.6	7.78	13.49	>0.55	0.55
Summer 2011	25.8	7.38	1.58	0.3	>1.2
Autumn 2011	17	8.71	8.69	>0.6	0.6

Catch summary and length-frequency analysis

Murray hardyhead were sampled in low numbers in spring 2008 but exhibited an increase in abundance in autumn 2009 (Table 83). Considerable numbers were also sampled in spring 2009 (Figure 103) but a substantial decline was evident in autumn 2010 (Table 83). Murray hardyhead were again sampled in low abundance in spring 2010 and were absent in autumn 2011. Eastern gambusia was the only other species sampled at this site between spring 2008 and spring 2010, and was highly abundant. Seven additional species were sampled following re-connection with the River Murray in autumn 2011 (Table 83).

Table 83. Total numbers of fish species collected from Disher Creek between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	*Craterocephalus fluviatilis*	**3**	**174**	**52**	**4**	**15**	**0**
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	0	0	0	0	0	120
Bony herring	*Nematalosa erebi*	0	0	0	0	0	14
Flat-headed gudgeon	*Philypnodon grandiceps*	0	0	0	0	0	13
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	0	0	0	0	0	5
Carp gudgeon	*Hypseleotris* spp.	0	0	0	0	0	569
Common carp	*Cyprinus carpio*	0	0	0	0	0	25
Goldfish	*Carrasius auratus*	0	0	0	0	0	3
Gambusia	*Gambusia holbrooki*	2650	9687	3470	15490	8907	23651

Figure 103. Adult Murray hardyhead sampled from Disher Creek in spring 2009.

All Murray hardyhead sampled in spring 2008 were large adult fish (56-72 mm TL) (Figure 104a). Significant recruitment was observed in autumn 2009 with the majority of the population likely to be YOY individuals (Figure 104b). The population exhibited a broad range of lengths in spring 2009 (39-71 mm TL) but few individuals were sampled in autumn 2010 (Figure 104c & d). Nonetheless, fish <50 mm TL were likely to be YOY (Figure 104d). In spring 2010, length frequency distribution was similar to the previous spring with the adult population exhibiting a broad range of lengths from 42-75 mm TL (Figure 104e).

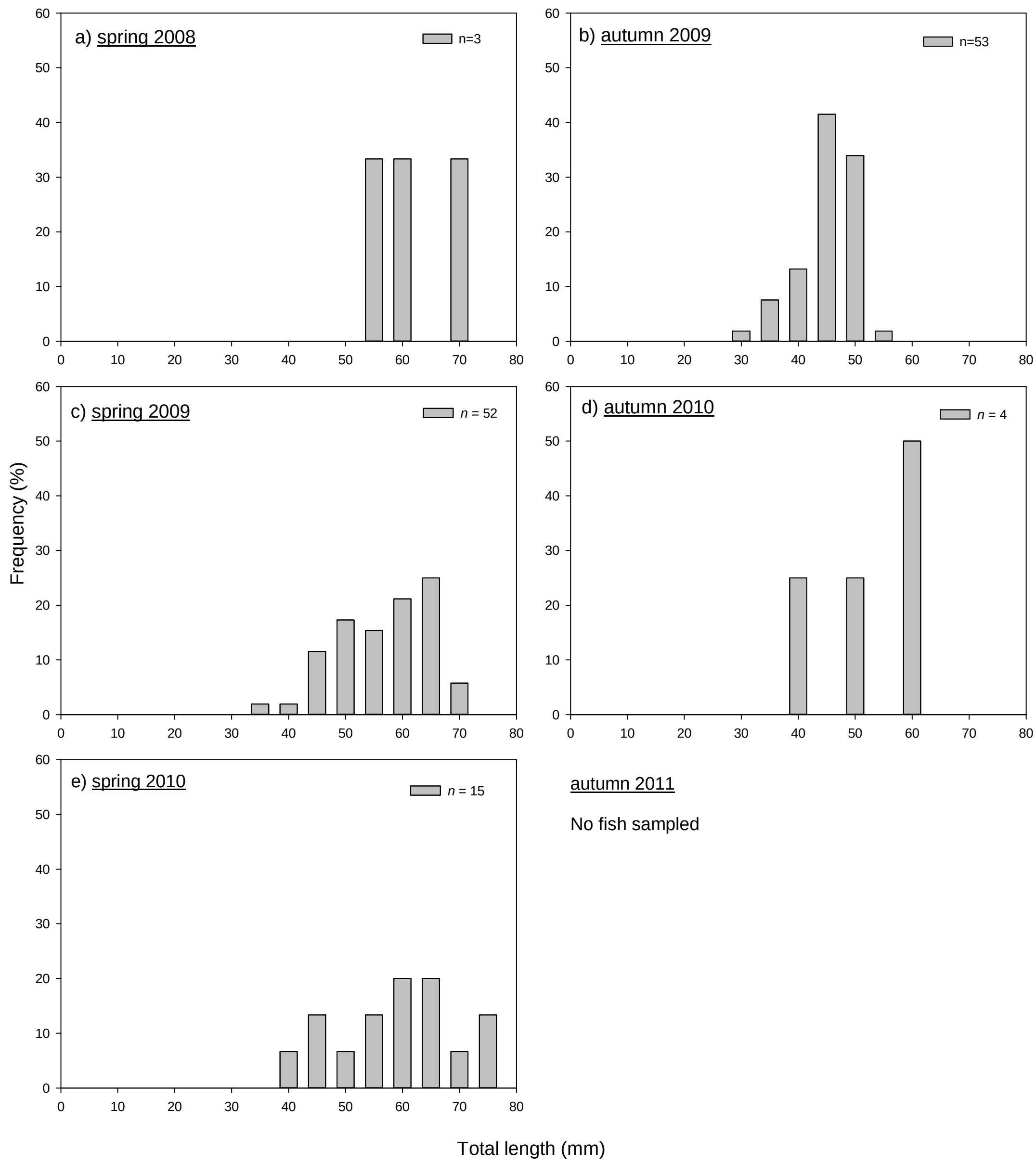


Figure 104. Length frequency distribution of Murray hardyhead from Disher Creek in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010 and e) spring 2010.

Site summary

Water level and salinity at this site (Figure 102a & b) remained relatively stable over the period spring 2008 – autumn 2010, however, increased River Murray flows and flooding in the region resulted in elevated water levels and dramatically reduced salinities. Murray hardyhead were typically present, albeit in fluctuating numbers and recruitment was often evident. Nonetheless, following increased water levels, connectivity with the River Murray and reduced salinity within Disher Creek, Murray hardyhead were not detected at the site. Murray hardyhead are a highly mobile species and with connectivity with the River Murray and regional flooding, individuals may have dispersed from the site. Furthermore, under flood conditions, the area of available habitat for the species was exponentially greater than was previously the case and thus the sampling efficiency of this species would have been dramatically reduced. Sampling following the recession of the River Murray to 'pool level' would provide greater insight to the fate of Murray hardyhead at this site.

Individuals from this site have been included in the captive breeding program being undertaken by the MDFRC Mildura lab. As such, there may be capacity to re-introduce individuals to this site if they are determined to have been locally extirpated and habitat is suitable (e.g. measured by cover availability and abundance of alien species).

4.29. Berri Evaporation Basin (River Murray: Murray hardyhead)

Berri Evaporation Basin is a saline water disposal basin near the town of Berri in the Riverland. The site could be described as a creek or billabong with abundant emergent vegetation (i.e. *Typha domingensis* and *Phragmites australis*) (Figure 105). Murray hardyhead were typically abundant at this site but have decreased in abundance in recent years (cf. Wedderburn *et al.* 2008; DAP site selection autumn 2008, Wilson and Wedderburn unpublished data). Salinity at this site has been gradually decreasing (Figure 106b) which may favour common small-bodied freshwater species at the expense of Murray hardyhead.

In 2010/11, increased River Murray flows and regional flooding resulted in significantly increased water levels at this site (Figure 106a) and connection with the River Murray.

Fish sampling effort

Spring 2008, autumn 2009, spring 2009, autumn 2010, spring 2010 and autumn 2011

- 8 fyke nets set overnight

2010/11 Photo-point images

Winter 2010


Spring 2010


Summer 2011


Autumn 2011


Figure 105. Photo-point images of Berri evaporation basin from winter 2010, spring 2010, summer 2011 and autumn 2011.

Environmental conditions

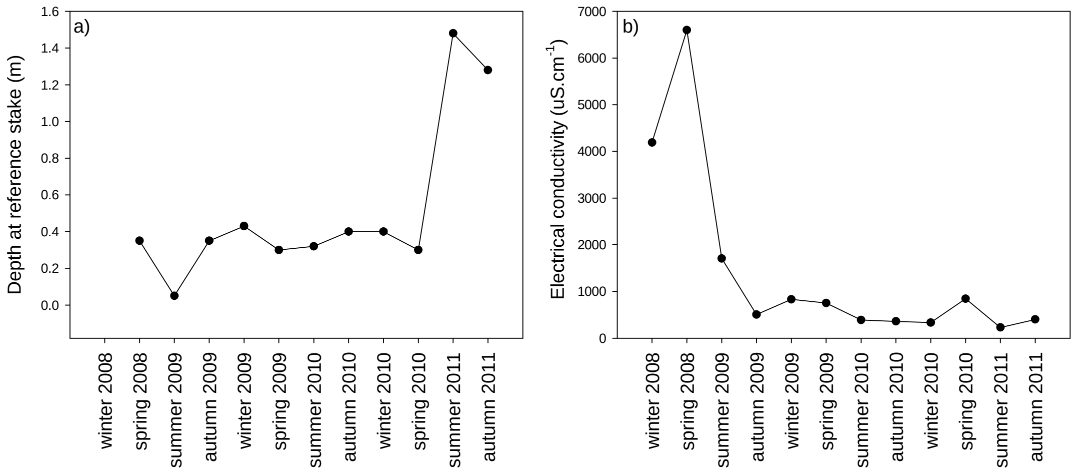


Figure 106. a) depth at reference stake (m, i.e. water level variability) and b) electrical conductivity (μS.cm^{-1}) at Berri evaporation basin between winter 2008 and autumn 2011.

Table 84. Habitat cover measured at Berri evaporation basin during each site visit. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Winter 2010	20 (algae)	20 (*Typha, Phragmites*)	1 (snag)	59
Spring 2010	5 (algae)	35 (*Typha, Phragmites*)	0	60
Summer 2011	5 (*Azolla*)	50 (*Typha, Phragmites*)	0	45
Autumn 2011	0	30 (*Lignum*)	5 (snag)	65

Table 85. Water quality parameters measured at Berri evaporation basin during each site visit.

Season	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Winter 2010	7.5	9.79	5.03	>0.6	0.6
Spring 2010	24.4	7.2	5.83	>0.6	0.6
Summer 2011	26.1	7.28	0.47	0.35	1.6
Autumn 2011	16.6	8.31	1.08	0.25	1.4

Catch summary and length-frequency analysis

Murray hardyhead were sampled in moderate abundance from spring 2008 to autumn 2010 but were sampled in low abundance in spring 2010 and were not detected in autumn 2011 (Table 86). A total of ten other species have been collected from this site over the study period with five new species recorded in autumn 2011 (Table 86).

Table 86. Total numbers of fish species collected from Berri Evaporation Basin between spring 2008 and autumn 2011.

Species		**Sampling trip**					
Common name	**Scientific name**	**Spring 2008**	**Autumn 2009**	**Spring 2009**	**Autumn 2010**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	***Craterocephalus fluviatilis***	**37**	**84**	**16**	**41**	**3**	**0**
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	0	0	0	0	0	5
Bony herring	*Nematalosa erebi*	0	0	0	0	0	5
Australian smelt	*Retropinna semoni*	39	91	9	10	6	0
Carp gudgeon complex	*Hypseleotris* spp.	4585	3146	3386	3869	1652	279
Flat-headed gudgeon	*Philypnodon grandiceps*	518	355	214	374	58	0
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	24	32	11	38	40	0
Murray rainbowfish	*Melanotaenia fluviatilis*	0	0	0	0	0	2
Common carp	*Cyprinus carpio*	0	0	0	0	0	257
Goldfish	*Carrasius auratus*	0	0	0	1	0	102
Gambusia	*Gambusia holbrooki*	860	4284	1619	472	101	2065

Two distinct cohorts of Murray hardyhead were present in spring 2008, representing adults (45-65 mm TL) likely spawned in 2007 and YOY (21-25 mm TL) likely from recent spawning in 2008 (Figure 107a). This YOY cohort had progressed in length in autumn and spring 2009 and represented the majority of the population (Figure 107b and c). Further growth of this cohort was evident in autumn 2010 (Figure 107d). However the length-frequency distribution in autumn 2010 was dissimilar to the previous year, with what appears to be a comparatively lesser level of recruitment (Figure 107d). The three individuals sampled in spring 2010 were all large adult fish (>50 mm TL) (Figure 107e and 108).

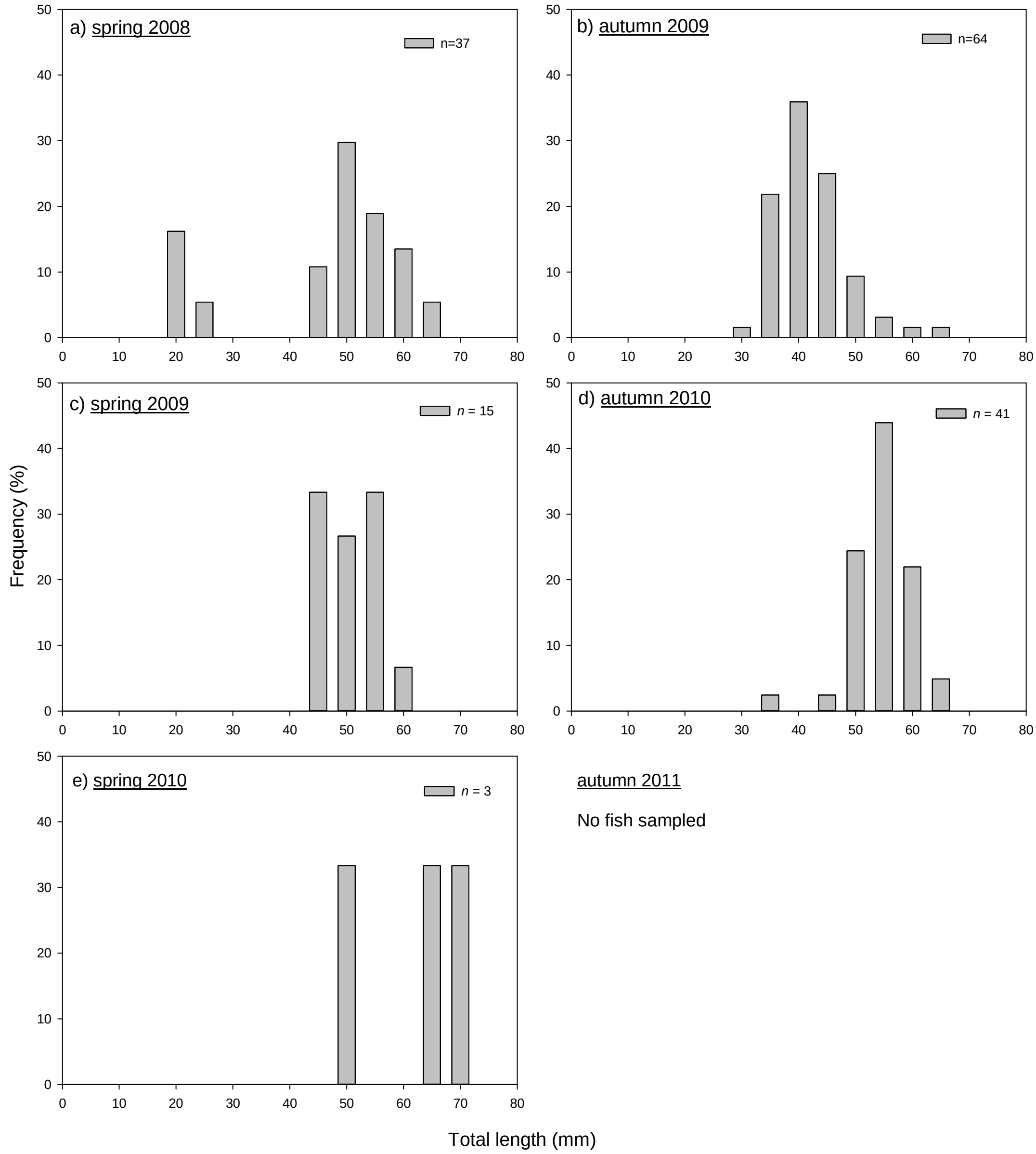


Figure 107. Length frequency distribution of Murray hardyhead from Berri evaporation basin in a) spring 2008, b) autumn 2009, c) spring 2009, d) autumn 2010 and e) spring 2010.

Figure 108. Large adult Murray hardyhead sampled at the Berri Evaporation Basin site in spring 2010.

Site summary

Murray hardyhead were present at this site in low to moderate numbers throughout the project until autumn 2011 when the species was not detected. Similar to observations for Disher Creek, flooding and subsequent connectivity with the River Murray may have facilitated the dispersal of remaining individuals from this site. Additionally, dramatically increased area of available habitat may have reduced sampling efficiency for this species. Sampling following the return of the River Murray to 'pool level' may determine the fate of individuals from this site.

Individuals from this site have also been included in the captive breeding program being undertaken by the MDFRC Mildura lab. As such, there may be capacity to re-introduce individuals to this site if they are determined to have been locally extirpated.

4.30. Oster Dam Surrogate Refuge (Yarra pygmy perch)

Following a significant decline of Yarra pygmy perch in the Lower Lakes, a number (*n* = 132) of the few remaining individuals were removed from the wild in 2007 to be included in a captive breeding program, with the aim of releasing fish into surrogate refuges and ‘wild’ sites on the return of favourable conditions (Hammer 2007; Hammer 2008b). Suitable surrogate refuge sites were identified through a rigorous assessment process carried out by Aquasave (Hammer *et al.* 2009a), with the Oster Dam identified as a favourable surrogate refuge (Figure 109). Subsequently, a total of 70 captively bred juvenile Yarra pygmy perch (20-35 mm TL) were released into the dam over two releases in November 2008 (50 fish) and December 2008 (20 fish). The site was then monitored in alignment with wild site fish monitoring in 2009/10 and 2010/11 (not sampled during ‘wild site’ environmental assessment monitoring in winter and summer).

Fish sampling effort

Spring 2009, autumn 2010 and spring 2010

- 4 short-winged fyke nets set overnight
- 2 long-winged fyke nets set overnight

Autumn 2011

- 4 long-winged fyke nets set overnight

Sampling was reduced in autumn 2011 as fewer nets were required to determine population status. Fish numbers are presented with relative abundance (i.e. fish.net^{-1})

2010/11 Photo-point images

Spring 2009


Autumn 2010


Spring 2010

Autumn 2011


Figure 109. Photo-point images of the Oster Dam from spring 2009, autumn 2010, spring 2010 and autumn 2011.

Environmental conditions

Table 87. Habitat cover measured at the Oster Dam surrogate refuge during fish sampling. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Spring 2009	0	70	0	30
Autumn 2010	0	50	2	48
Spring 2010	0	55	2	43
Autumn 2011	2 (*Chara*)	50 (*Myriophyllum, Typha, Baumea, Gahnia,* grass)	0	48

Table 88. Water quality parameters measured at the Oster Dam surrogate refuge during fish sampling.

Season	EC ($\mu S.cm^{-1}$)	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Spring 2019	527	15.7	7.29	-	-	0.38	2.5
Autumn 2010	712	20	7.47	-	-	0.2	2
Spring 2010	599	22.5	6.77	7.66	1.02	0.2	2
Autumn 2011	650	11.1	6.82	3.86	1.72	0.45	>1.5

Catch summary and length-frequency analysis

Yarra pygmy perch were sampled in low-moderate abundance in spring 2009 but abundance had increased substantially by autumn 2010 (Table 89). Abundance was similar in spring 2010 before another increase in autumn 2011, when the species was highly abundant (Table 89).

Table 89. Total numbers and relative abundance ($fish.net^{-1}$, in brackets) of Yarra pygmy perch collected from the Oster Dam surrogate refuge between spring 2009 and autumn 2011.

Species		Sampling trip			
Common name	Scientific name	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Yarra pygmy perch	*Nannoperca obscura*	15 (2.5)	220 (36.7)	186 (31)	297 (74.3)

The Yarra pygmy perch population at the Oster Dam was dominated by large adult fish (45 mm TL) in spring 2009, likely representing the individuals released in November and December 2008 (Figure 110a). Significant recruitment had occurred by autumn 2010, with the majority of the population comprised of YOY <50 mm TL (~80%) (Figure 110b). Two cohorts were present in spring 2010, one cohort ranged from 37-68 mm TL indicating the growth of the YOY cohort present in autumn 2010 and recent recruitment was indicated by the presence of a cohort measuring 15-22 mm TL (Figure 110c). In autumn 2011, the population exhibited a broad length distribution with fish ranging from 19-69 mm TL (Figure 111), with a dominant YOY cohort ranging from 19-38 mm TL, indicating protracted spawning and recruitment in 2010/11 (Figure 110d).

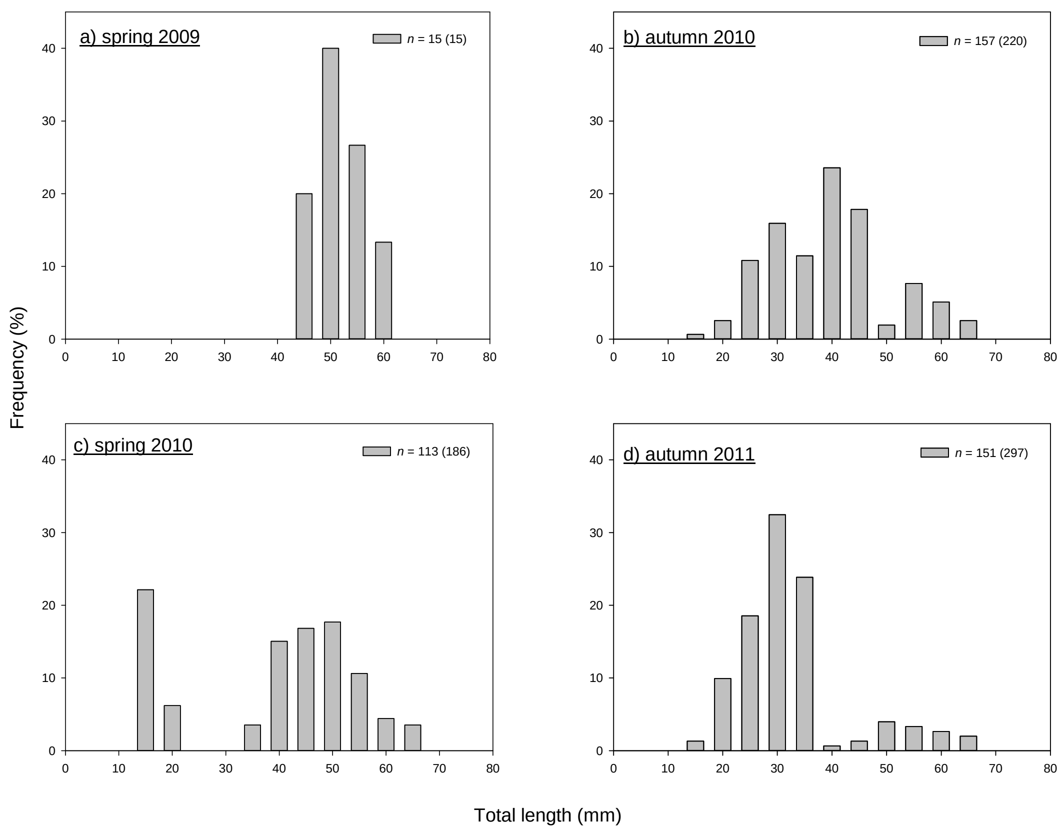


Figure 110. Length frequency distribution of Yarra pygmy perch from the Oster Dam surrogate refuge from a) spring 2009, b) autumn 2010 c) spring 2010 and d) autumn 2011.

Figure 111. A sub-sample of Yarra pygmy perch, representing the broad range of length/age individuals at the Oster Dam in autumn 2011.

Site summary

The population of Yarra pygmy perch in the Oster Dam surrogate refuge has become well established since juveniles were released in late 2008. This species is now abundant at this site and protracted spawning and significant recruitment was evident in both autumn 2010 and 2011 resulting in a broad and complex length/age structure. As such, the population will likely be favourable for sourcing individuals for re-introductions to former wild sites.

4.31. Crouch Dam Surrogate Refuge (Yarra pygmy perch)

Similar to the Oster Dam (see previous section), the Crouch Dam was identified as a favourable surrogate refuge location for captively bred juvenile Yarra pygmy perch by Hammer *et al.* (2009a) (Figure 112). Subsequently, a total of 90 captively bred juvenile Yarra pygmy perch (20-35 mm TL) were released into the dam on two occasions in December 2008 (70 fish) and April 2009 (20 fish). The site was subsequently monitored in alignment with wild site fish monitoring in 2009/10 and 2010/11 (not sampled during 'wild site' site assessment monitoring in winter and summer).

Fish sampling effort

Spring 2009, autumn 2010 and spring 2010

- 4 short-winged fyke nets set overnight
- 4 long-winged fyke nets set overnight

Autumn 2011

- 4 long-winged fyke nets set overnight

Sampling was reduced in autumn 2011 as fewer nets were required to determine population status. Fish numbers are presented with relative abundance (i.e. fish.net^{-1})

2010/11 Photo-point images

Spring 2009


Autumn 2010


Spring 2010


Autumn 2011


Figure 112. Photo-point images of the Crouch Dam from spring 2009, autumn 2010, spring 2010 and autumn 2011.

Environmental conditions

Table 90. Habitat cover measured at the Crouch Dam surrogate refuge during fish sampling. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Spring 2009	30	20	10	40
Autumn 2010	40	25	2	33
Spring 2010	10	10	5	75
Autumn 2011	40 (*Chara, Otellia, Nymphaea, Potamogetan ochreatus*)	10 (*Typha, Eleocharis*)	0	50

Table 91. Water quality parameters measured at the Crouch Dam surrogate refuge during fish sampling.

Season	EC (µS.cm^{-1})	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Spring 2009	304	18.1	8.3	9.4	2.4	0.75	>3
Autumn 2010	585	21.3	7.45	-	-	0.4	>3
Spring 2010	407	19.9	7.27	7.9	7.5	0.45	>3
Autumn 2011	574	13.7	7.77	8.95	2.61	0.6	~4

Catch summary and length-frequency analysis

Following releases in December 2008 and April 2009, Yarra pygmy perch were moderately abundant in spring 2009 (Table 92). In autumn 2010, the population had substantially increased in abundance and continued to do so, with the species being highly abundant in spring 2010 and autumn 2011 (Table 92).

Table 92. Total numbers and relative abundance (fish.net^{-1}, in brackets) of Yarra pygmy perch collected from the Crouch Dam surrogate refuge between spring 2009 and autumn 2011.

Species		Sampling trip			
Common name	Scientific name	Spring 2009	Autumn 2010	Spring 2010	Autumn 2011
Yarra pygmy perch	*Nannoperca obscura*	54 (6.8)	1062 (132.8)	2338 (292.3)	1138 (284.5)

In spring 2009, the population was dominated by adult fish (>40 mm TL) (Figure 113a), which likely represent both original ‘release’ fish and potentially some recruitment following the first release (i.e. December 2008). In autumn 2010, abundance increased dramatically due to significant recruitment of YOY (Figure 113b). Spawning in this year was likely protracted, with high growth rates of YOY, indicated by the domination of individuals 35-49 mm TL and presence of recently spawned cohort ranging from 16-18 mm TL. The population again exhibited a broad length distribution in spring 2010 (16-70 mm TL), with significant recruitment evident (i.e. individuals <35 mm TL) (Figure 113c). Significant recruitment of YOY was again exhibited in autumn 2011, with >80% of the population comprised of likely YOY individuals <40 mm TL (Figure 113d and 114).

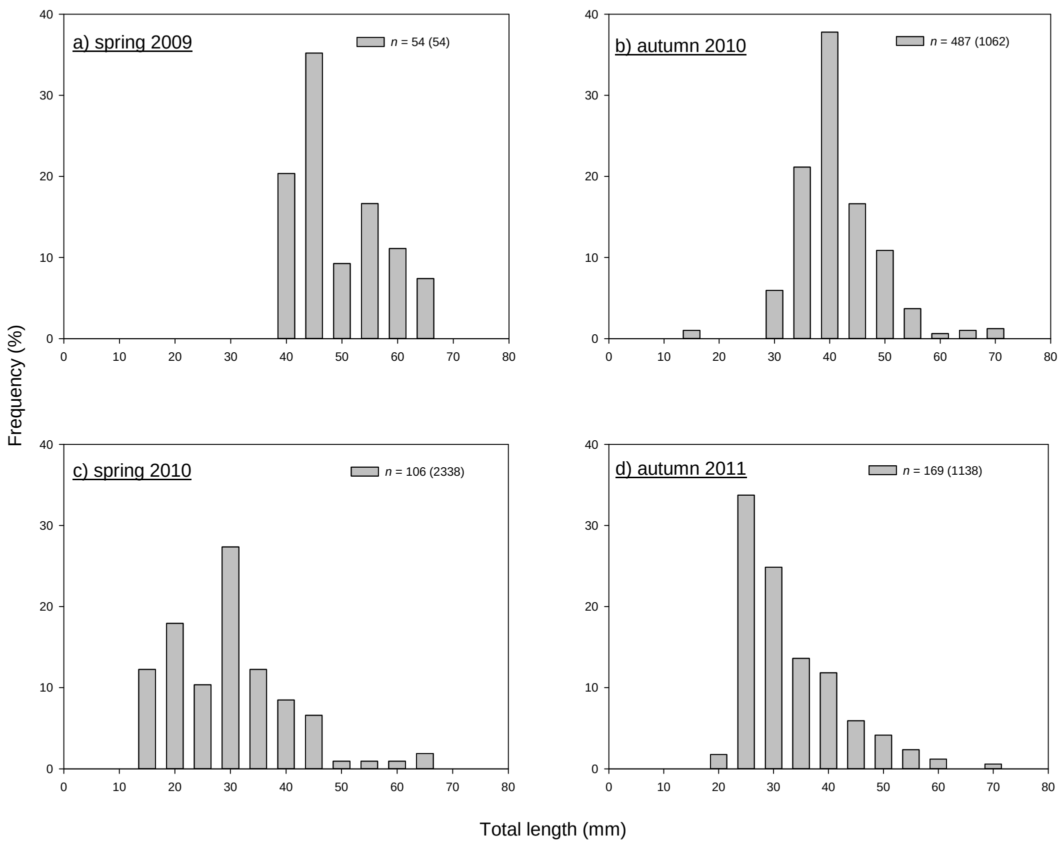


Figure 113. Length frequency distribution of Yarra pygmy perch from the Crouch Dam surrogate refuge from a) spring 2009, b) autumn 2010 c) spring 2010 and d) autumn 2011.

Figure 114. A large adult and YOY Yarra pygmy perch sampled from the Crouch Dam surrogate refuge in autumn 2011.

Site summary

Following juvenile releases in December 2008 and April 2009, this population has become well established and is now highly abundant. Furthermore, protracted spawning and consistent recruitment was evident throughout sampling, resulting in a population with a broad and complex length/age structure. This dam is of medium size (~3000 m^2) and is characterised by dense and diverse submerged aquatic vegetation in the littoral zone, and subsequently is likely to harbour a large population of Yarra pygmy perch. This population is thus highly suited as a source of individuals for re-introductions to former wild sites.

4.32. Munday Dam Surrogate Refuge (Murray hardyhead)

The Munday Dam is a medium-sized dam (~2000 m^2) (Figure 115) in the upper Reedy Creek catchment, that was identified as a favourable surrogate refuge location for wild and captively bred Murray hardyhead by Hammer *et al.* (2009a). The dam is characterised by moderate salinity (~4500 $\mu S.cm^{-1}$) and abundant submerged vegetation (i.e. *Vallisneria* and filamentous algae). Subsequently, 100 Murray hardyhead, mostly captively bred juveniles from the Boggy Creek population (bred at the MDFRC Mildura lab) together with a small number of the original adult breeders, were released in May 2010. The site was subsequently monitored in alignment with wild site fish monitoring in 2009/10 and 2010/11 (not sampled during 'wild site' site assessment monitoring in winter and summer). Following the sampling detailed in this section, a further 141 individuals were released into the dam in May 2011, comprising 48 captively bred juveniles from the Boggy Creek population, 7 adults from Boggy Creek and 86 adults from Rocky Gully.

Fish sampling effort

Spring 2009, autumn 2010 and spring 2010

- 4 short-winged fyke nets set overnight
- 4 long-winged fyke nets set overnight

Autumn 2011

- 4 long-winged fyke nets set overnight

Sampling was reduced in autumn 2011 as fewer nets were required to determine population status. Fish numbers are presented with relative abundance (i.e. $fish.net^{-1}$)

2010/11 Photo-point images

Spring 2010

Autumn 2010

Figure 115. Photo-point images of the Munday Dam from spring 2010 and autumn 2010.

Environmental conditions

Table 93. Habitat cover measured at the Munday Dam surrogate refuge during fish sampling. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Spring 2010	50 (*Vallisneria*, filamentous algae)	5 (*Phragmites, Typha, Schoenoplectus pungens*)	20	25
Autumn 2011	50 (*Vallisneria*, filamentous algae)	10 (*Phragmites, Typha, Schoenoplectus pungens*)	0	40

Table 94. Water quality parameters measured the Munday Dam Surrogate Refuge during fish sampling.

Season	EC ($\mu S.cm^{-1}$)	Temp (ºC)	pH	DO (ppm) surface	DO (ppm) bottom	Secchi (m)	Max depth (m)
Spring 2010	3530	21.2	7.2	9.1	10.3	0.5	>2
Autumn 2011	4000	14.5	7.75	11.18	7.95	1.5	>2

Catch summary and length-frequency analysis

Following a release in May 2010, Murray hardyhead were sampled in moderate numbers in spring 2010 and again in similar numbers but greater relative abundance in autumn 2011 (Table 95). Schools of small juveniles were observed in shallows on both sampling occasions.

Table 95. Total numbers and relative abundance (fish.net^{-1}, in brackets) of Yarra pygmy perch collected from the Munday Dam surrogate refuge between spring 2009 and autumn 2011.

Species		Sampling trip	
Common name	**Scientific name**	**Spring 2010**	**Autumn 2011**
Murray hardyhead	*Craterocephalus fluviatilis*	35 (5.8)	31 (7.75)

The population exhibited bi-modality in spring 2010, with the larger cohort (>50 mm TL) representing released fish and the smaller cohort (17-35 mm TL) likely representing newly recruited YOY (Figure 116a). In autumn 2011, growth of this cohort was evident and there was likely further YOY recruitment, with the population exhibiting a broad length distribution ranging 27-66 mm TL (Figure 116b and 117).

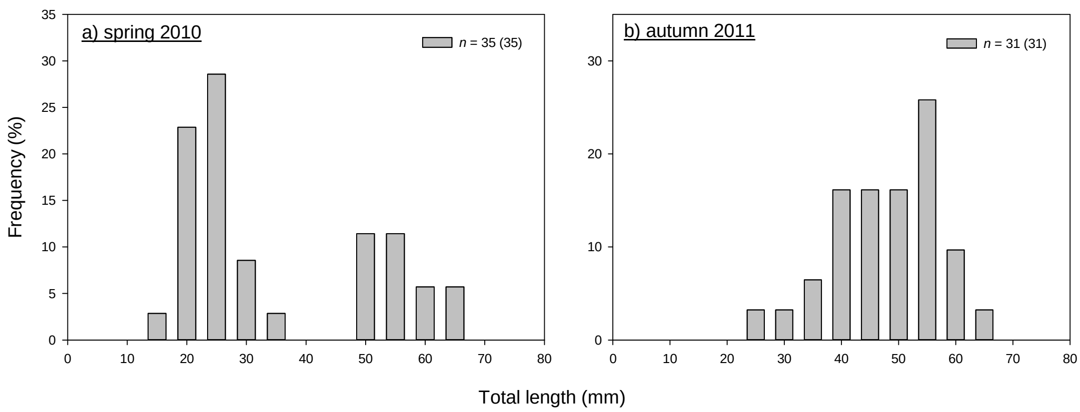


Figure 116. Length frequency distribution of Murray hardyhead from the Munday Dam surrogate refuge from a) spring 2010 and b) autumn 2011.

Figure 117. Murray hardyhead sampled from the Munday Dam surrogate refuge in autumn 2011.

Site summary

Murray hardyhead have become established at this site and are low-moderately abundant. Nonetheless, this dam is of moderate size and thus is likely to currently harbour a substantial population of the species. The population has shown indications of recent recruitment and exhibited a broad and complex length/age structure. The release of another 141 individuals in May 2011 will increase the population size and potentially facilitate greater recruitment in 2011/12 (as well as improving genetic diversity). As such, this population may be favourable for sourcing individuals for re-introductions at wild sites.

4.33. Paiwalla Wetland Refuge (Southern purple-spotted gudgeon)

Paiwalla is a managed off-channel wetland (Figure 118) (managed by the SA MDB NRMB and the Wetlands Habitat Trust) approximately 2 km upstream of the River Murray from Jury Swamp (see section 4.2). Paiwalla was one of the only wetlands associated with the River Murray below Lock 1 that received water and maintained aquatic habitat over the period of low water from 2007-2010 (Hammer *et al.* 2009a). Site inspections indicated aquatic habitat was adequate and there were high abundances of food resources (i.e. zooplankton) and thus was chosen as a release site for southern purple-spotted gudgeon (Hammer *et al.* 2009a). Subsequently, a total of 271 captively bred juvenile southern purple-spotted gudgeon (40-80 mm TL), bred and reared by Native Fish Australia (SA) and Aquasave, along with Alberton Primary School and Urrbrae Agricultural High School, were released into the wetland over three releases in March 2010 (113 fish), November 2010 (83 fish) and May 2011 (75 fish). The site was monitored in alignment with wild site fish monitoring in 2010/11 (not sampled during 'wild site' site assessment monitoring in winter and summer). Monitoring was conducted prior to releases in November 2010 and May 2011.

Fish were marked with calcein, a non-lethal chemical tag for marking fish otoliths and calcified structures, via osmotic induction, prior to release (Crook *et al.* 2009). Individuals were first immersed in a hyperosmotic solution (~50g.L^{-1}) before being immersed in a 'calcein' solution for staining. This potentially enables the differentiation of 'released' fish and naturally recruited individuals by analysing the level of fluorescence from a fish's calcified structures. Fish were monitored for fluorescence during the autumn sampling event.

Fish sampling effort

Spring 2010 and autumn 2011

- 4 short-winged fyke nets set overnight
- 5 long-winged fyke nets set overnight

2010/11 Photo-point images

Spring 2010

Autumn 2011

Figure 118. Photo-point images of Paiwalla Wetland from spring 2010 and autumn 2011.

Environmental conditions

Table 96. Habitat cover measured at the Paiwalla Wetland during fish sampling. Habitat cover is measured as the proportion (percent (%) cover) of aquatic habitat area comprised of submerged and emergent vegetation, physical structure or open water.

Season	Submergent vegetation	Emergent vegetation	Physical	Open water
Spring 2010	50 (*Chara*)	10	30	10
Autumn 2011	35 (*Chara*)	10	20	35

Table 97. Water quality parameters measured at Paiwalla Wetland during fish sampling.

Season	EC (µS.cm^{-1})	Temp (ºC)	pH	DO (ppm)	Secchi (m)	Max depth (m)
Spring 2010	2220	22.3	9.41	4.3	>1.2	1.3
Autumn 2011	5090	22.7	8.37	9.44	0.2	1.3

Catch summary and length-frequency analysis

Southern purple-spotted gudgeon were sampled in low-moderate abundance in spring 2010 and moderate abundance in autumn 2011 (Table 98). A total of six other species were sampled from this site (Table 98).

Table 98. Total numbers and relative abundance (fish.net^{-1}, in brackets) of southern purple-spotted gudgeon and total numbers of other fish species collected from Paiwalla Wetland in spring 2010 and autumn 2011.

Species		**Sampling trip**	
Common name	**Scientific name**	**Spring 2010**	**Autumn 2011**
Southern purple-spotted gudgeon	***Mogurnda adspersa***	**19 (2.0)**	**54 (6.0)**
Carp gudgeon	*Hypseleotris* spp.	166	288
Flat-headed gudgeon	*Philypnodon grandiceps*	284	30
Dwarf flat-headed gudgeon	*Philypnodon macrostomus*	12	8
Unspecked hardyhead	*Craterocephalus stercusmuscarum fulvus*	0	13
Freshwater catfish	*Tandanus tandanus*	0	17
Bony herring	*Nematalosa erebi*	1	0

Individuals sampled in spring 2010 ranged from 60-89 mm TL and are likely to represent the individuals released in March 2010 (Figure 119a). In autumn 2011 there were three distinct cohorts ranging from 25-36 mm, 56-57 mm and 76-110 mm TL (Figure 119b and 120a and b). Results from the fluorescence readings taken from fish in the field (due to calcein staining), suggest that the largest cohort represents a mix of fish from releases in March 2010 and November 2010, whilst both of the smaller cohorts represent newly recruited YOY individuals (Figure 121). A fluorescence reading of over 300 units is considered to indicate calcein staining. By autumn 2011, fish from the first release had been at liberty for approximately one year and initial results suggest that fluorescence has either degraded by this time or 'stained' body parts have been covered in new tissue. Fish from the release in November 2010, were at liberty for approximately six months and are hypothesized to comprise individuals >80 mm TL that exhibit significant fluorescence (Figure 121). The smaller cohort exhibited no sign of fluorescence and are therefore likely to be wild spawned.

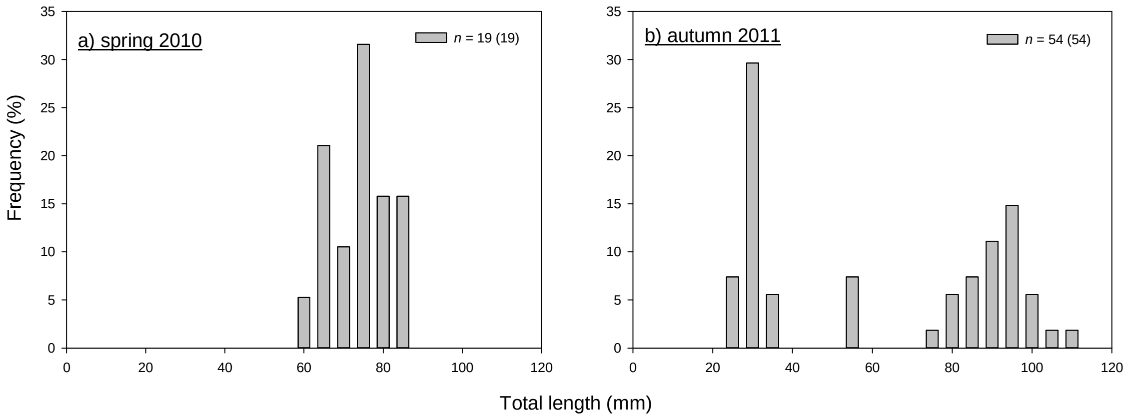


Figure 119. Length frequency distribution of southern purple-spotted gudgeon from Paiwalla Wetland from a) spring 2010 and b) autumn 2011.

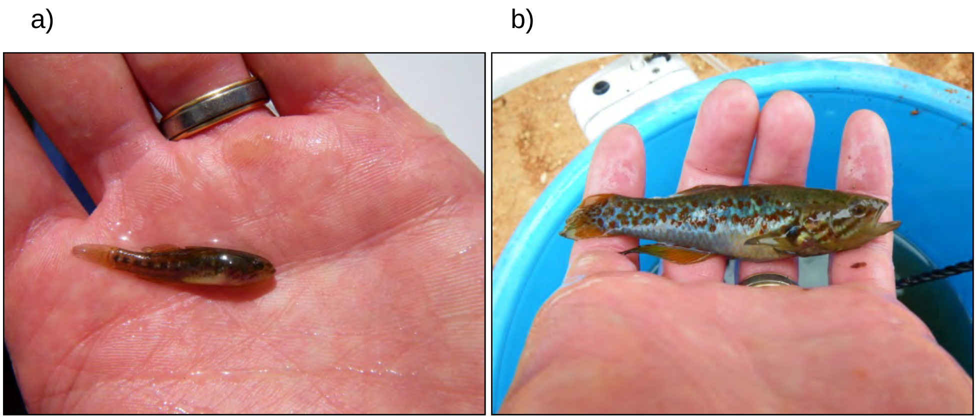


Figure 120. a) YOY and likely 'wild' spawned southern purple-spotted gudgeon and b) adult and likely 'original' release fish from Paiwalla Wetland in autumn 2011.

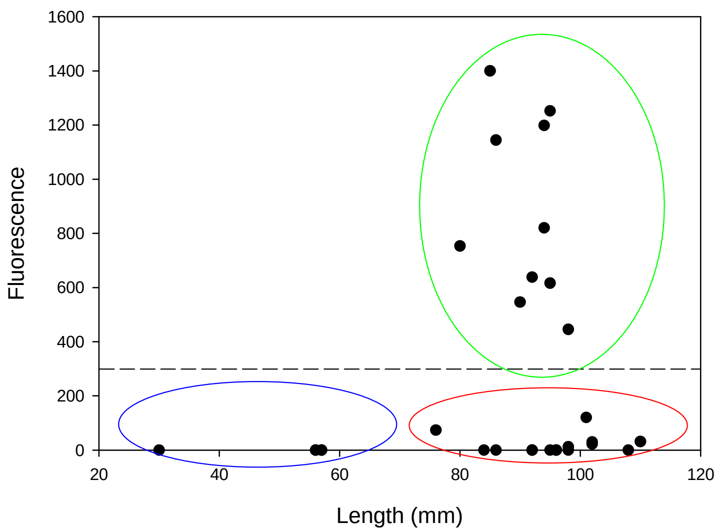


Figure 121. Fluorescence readings against fish length for southern purple-spotted gudgeon sampled at the Paiwalla Wetland in autumn 2011. The red ellipse indicates individuals

hypothesized to have been released in March 2010, the green ellipse those released in November 2010 and the blue ellipse represents recently 'wild' spawned individuals.

Site summary

Following releases of captively bred fish into the Paiwalla Wetland, southern purple-spotted gudgeon have exhibited high levels of survival and are present in low-moderate abundance. Importantly recent recruitment was observed in autumn 2011 suggesting this population is likely to become firmly established should suitable environmental conditions continue to be provided.

Initial results from calcein marking of released fish indicate that using the current osmotic induction method (5 min immersion in 50 $g.L^{-1}$ and 5 min immersion in 10 $g.L^{-1}$ calcein solution) (sensu Crook *et al.* 2009) may result in detectable 'chemical tags' for a period of 6-12 months. Whilst such longevity of mark retention is insightful when differentiating released and wild spawned fish in the short-term following a release, greater mark retention is desired. A laboratory trial to determine the effectiveness and longevity of calcein staining using an adapted method is currently being undertaken by SARDI Aquatic Sciences.

5. DISCUSSION

5.1. Species' 'wild' population status

The hydrological conditions experienced in catchments across South Australia in 2010/11, were vastly different from those experienced over the last five years. Following an extended period of below average rainfall, above average temperatures and subsequently dramatically reduced inflows to the Murray-Darling Basin (MDB) (Murphy and Timbal 2008), significant rainfall and inflows in 2010, resulted in dramatically increased River Murray flows, increased flows in the tributaries of the eastern Mount Lofty Ranges (EMLR) and the return of typical water levels in the Lower Lakes (~0.75 m AHD). Nonetheless, variation in hydrological conditions and the subsequent influence on several abiotic (e.g. salinity, connectivity) and biotic (e.g. aquatic vegetation regeneration) factors differed spatially between catchments and sites. When coupled with variation in species' life history traits (e.g. dispersive v sedentary), physico-chemical tolerances/preferences and preceding population status, this resulted in different species and populations exhibiting varying responses to conditions in 2010/11. One over-arching commonality between most catchments and sites was hydrological restoration and the gradual restoration/enhancement of aquatic habitat (e.g. submerged vegetation, particularly in the Lower Lakes). However, positive responses from fish populations were often not observed and may be due to the absence of individuals prior to increased flow and water level in 2010/11, or absence of nearby sources of individuals (i.e. low resilience due to the very harsh preceding drought conditions). Highly mobile species may also have dispersed from the sites following re-inundation and re-connectivity and it is also possible that fish were not detected as increased area of available habitat due to higher water levels may have reduced sampling efficiency. Further monitoring following the return of 'typical' water levels may better determine the fate of individual species.

The data presented in this report are used to summarize the status of each population and site in 2010/11 (i.e. abundance, recruitment, site condition) and to develop risk factors for the loss of each of these populations (Table 99). A 'traffic light' system was applied to visually represent the risk to each population. Levels of risk are defined as follows,

- Low risk (green) – moderate-high abundance in 2010/11, evidence of recent recruitment and favourable/improved habitat conditions.
- Moderate risk (orange) – moderate abundance in 2010/11, lack of recruitment in 2010/11 (river blackfish) and/or diminished habitat quality.
- High risk (red) – substantial declines in abundance (between spring 2010 and autumn 2011 or relative to 2008/09 and 2009/10), lack of recruitment (pygmy

perch species, southern purple-spotted gudgeon and Murray hardyhead), extended lack of recruitment (i.e. >3 years, river blackfish) and/or severely diminished habitat quality.

- Population potentially lost (purple) - not detected in 2010/11

Jury Swamp, an off-channel wetland of the River Murray below Lock 1, is the only 'wild' site monitored for southern purple-spotted gudgeon and this population is either present in very low numbers or is likely to have been lost. With increased flows and water levels in the River Murray in 2010/11, the wetland has been re-inundated and habitat conditions (i.e. aquatic vegetation cover and diversity) have improved dramatically. Further vegetation response is required to reach conditions that last supported this species prior to drying (i.e. rooted submerged vegetation and rushes), however should the vegetation condition continue to improve the site is likely to be favourable for re-colonisation (assuming individuals still remain in the area) or for re-introductions of captively bred individuals.

As of autumn 2011, river blackfish were present at all five monitoring sites for this species. Populations within the Tookayerta catchment (i.e. Willowburn Road and Deep Creek Road) and the population within the Angas River (i.e. Angas River Gauge site) were sampled in moderate-high abundances, with significant recent recruitment observed and are subsequently at low risk of loss. The Willowburn Road population exhibited a YOY recruitment event of a magnitude never previously recorded in South Australia (Hammer 2006; Hammer 2009), undoubtedly in response to improved flow conditions in 2010/11. Additionally, Rodwell Creek, a river blackfish population considered at high risk of loss in 2008/09 and 2009/10 (Bice *et al.* 2009; Bice *et al.* 2010a), exhibited significant YOY recruitment and an expansion in population size and local distribution. This population is now considered to be at a moderate risk of loss due to the continued threat posed by hydrological alteration in the catchment. Conversely, the remaining river blackfish population in the Marne River remains at a critically high risk of loss. This population is overwhelmingly dominated by large adult fish and recruitment has now not been observed for 9 years. Without changes to the management of the Marne River catchment or external management intervention, this population has a high likelihood of local extirpation in the immediate future

A total of 13 sites were monitored for southern pygmy perch, including eight where this species was present together with other threatened species. Southern pygmy perch were found at both Tookayerta catchment sites together with river blackfish and the populations at Willowburn Road and Deep Creek Road are at low risk of loss. The Meadows Creek population exhibited positive trends in both recruitment and abundance in 2010/11, and aquatic habitat was also favourable, but this site remains at moderate risk due to hydrological alteration within the catchment and potential for this site to rapidly dry and fragment with extended hot and dry conditions. The Inman River population also remains at medium risk of loss as current abundances are similar to 2009/10. Two populations/sites were deemed to be at high risk of loss, namely Black Swamp and Turvey's Drain. Low numbers of southern pygmy perch were detected at Black Swamp in spring 2010 but they were absent in autumn 2011. Water levels in 2010/11 at Black Swamp have improved however a positive response in presence and absence of submerged aquatic vegetation was not observed. Southern pygmy perch at Turvey's Drain have been consistently declining and the absence of this species in autumn 2011 was preceded by recruitment failure and subsequently the species may have been lost from the site. Individuals from this site, however, are being held in captivity for later reintroduction.

The remaining six populations/sites sampled have potentially been lost, which includes the Finniss Waterfalls site where the species was formerly abundant (Hammer 2005; Hammer 2009). Large individual adults were sampled in 2009/10 and recruitment was not detected, with subsequent absence throughout 2010/11. Individuals are persisting further downstream, as indicated by supplementary sampling, however, natural re-colonisation is unlikely due to a natural barrier to upstream movements. The remaining populations that have been potentially lost are all located within the Lower Lakes and most were desiccated or became severely degraded (e.g. increased salinity, lack of vegetated habitat) at some point between 2007 and 2010. With the return of typical water levels in the Lower Lakes, habitat conditions at these sites are continuing to improve and sites may become favourable for re-colonisation, if an adequate source of individuals exists. Southern pygmy perch are not a highly dispersive species (Hammer 2001) however, so natural re-colonisation is unlikely and re-introductions to some of these sites may be required.

As in 2009/10, Yarra pygmy perch were not collected from any of the six sites sampled for this species in 2010/11. All of these sites are in the Lower Lakes and most were desiccated or became severely degraded (e.g. increased salinity, isolation from littoral habitats, lack of vegetation) at some point between 2007 and 2010. Furthermore, no Yarra pygmy perch were collected by Wedderburn and Barnes (2009), Wedderburn and Hillyard (2010) or Wedderburn and Barnes (In Prep) from broader surveys of sites in the Lower Lakes in 2008/2009, 2009/10 and 2010/11 as part of *The Living Murray* 'condition monitoring'. Yarra pygmy perch were last collected in the region in February 2008 near the mouth of Eastick Creek (Hammer 2008b) and its continued absence, despite extensive sampling, indicates the likely wild extirpation of this species from the region. The future of Yarra pygmy perch in the Lower Lakes is thus likely to be dependent upon the reintroduction of a small population of captively bred individuals.

In autumn 2011, Murray hardyhead were detected at just 1 of 16 sites sampled for this species. Murray hardyhead is the most widely yet patchily distributed species under investigation and is represented by two separate conservation units: (a) the Lower Lakes unit, which is known from wetlands, irrigation drains and sheltered lake edges in the Lower Lakes and off-channel wetlands below Lock 1, and (b) the Riverland unit, known from off-channel evaporation basins in the upper reaches of the South Australian MDB (Adams *et al.* 2011). The only population where individuals were detected in autumn 2011 was at Rocky Gully. The species had declined at this site relative to autumn 2010 and spring 2010 and was deemed to be at a high risk of loss.

No Murray hardyhead were detected at either of the Riverland sites (i.e. Disher Creek and Berri Evaporation Basin) or in the Lower Lakes in autumn 2011 during DAP monitoring or *The Living Murray* 'condition monitoring' (Wedderburn and Barnes In Prep). The Riverland sites were subject to significant flooding and thus connectivity with the River Murray in 2010/11. Murray hardyhead are a highly mobile species and connectivity with the River Murray may have facilitated dispersal away from these sites. Conversely, the high water levels at these sites and subsequent dramatic increases in available habitat area may have 'diluted' individuals, increasing the difficulty in sampling the species. Monitoring of these sites following the recession of the River Murray back to 'pool level' may determine the presence/absence of Murray hardyhead. Furthermore, if individuals have dispersed from these sites, monitoring of potentially new sites, that were inundated and reconnected during flood conditions in 2010/11, may yield Murray hardyhead. Determining the current distribution and status of Murray hardyhead in the South Australian Riverland is a priority.

Similar to the situation in the Riverland, increased water level, available habitat and potential dispersal of individuals may have resulted in the failure to detect Murray hardyhead in the Lower Lakes in autumn 2011. Two individuals were sampled by Bice and Zampatti (2011) in autumn 2011, immediately upstream of Goolwa Barrage. Additionally, individuals were detected in the Lower Lakes in spring 2010 (i.e. Currency Creek and Dunn's Lagoon (Wedderburn and Barnes In Prep)) and thus, it is likely that the species is still present in the area but in low abundance. Future monitoring will determine the presence/absence of Murray hardyhead in the region and re-introductions from a surrogate refuge may be required.

Table 99. The population status of threatened fish species (abundance, recruitment and site conditions) at each site monitored under the Drought Action Plan and associated risk level to the persistence of the population in 2010/11 (colours: green – low risk, orange – medium risk, red – high risk, purple – population lost). NS = not sampled.

Site Name	DAP Site Number	Target species	No. caught spring 2010	No. caught autumn 2011	Recruitment within the last 12 months (Y/N)	Water level (Rising, stable, falling, dry)	Site comments
Jury Swamp	1.1.1	Southern purple spotted gudgeon	0	0	Yes	Stable	Likely lost but if still present abundance probably very low
Rodwell Creek	2.1.1	River blackfish	4	4	Yes	Variable (pumping)	Pool was maintained by watering prior to significant flows. Significant recruitment in 2010/11
Marne	2.2.1	River blackfish	3	1	No	Stable	No recruitment detected within last 4 years and may not have occurred for ≥9 years. Pool in poor condition (i.e. presence of unknown white plume on bottom of pool)
Angas Gauge	2.3.1	River blackfish	11	25	Yes	Seasonally variable	Pool in good condition, consistent abundances and recent recruitment evident.
Willowburn Road	2.4.1a	River blackfish	8	58	Yes	Seasonally variable	Pools in good condition (i.e. consistent cool base flow). High abundance and substantial recent recruitment in autumn 2011.
	3.4.1a	Southern pygmy perch	45	38	Yes	Seasonally variable	Pools in good condition (i.e. consistent cool base flow). High abundance and recent recruitment in autumn 2011.
Deep Creek Road	2.4.1b	River blackfish	1	8	Yes	Seasonally variable	Pool in good condition (i.e. consistent cool base flow). Consistent abundance and recent recruitment evident.
	3.4.1b	Southern pygmy perch	22	12	Yes	Seasonally variable	As above
Middle Creek Junction	3.1.1	Southern pygmy perch	69	15	Yes	Seasonally variable	Increase in abundance from 2010/11, improved habitat quality.
Boundary Creek Drain	3.2.1a	Southern pygmy perch	0	0	-	Stable	Population probably lost.
	4.1.1a	Yarra pygmy perch	0	0	-	Stable	Population probably lost. Potential re-introduction site?
	5.1.1a	Murray hardyhead	0	0	-	Stable	Population probably lost. Potential re-introduction site?
Eastick	3.2.1b	Southern pygmy perch	0	0	-	Stable	Population probably lost.
	4.1.1b	Yarra pygmy perch	0	0	-	Stable	Population probably lost. Potential re-introduction site?
	5.1.1b	Murray hardyhead	0	0	-	Stable	Population probably lost. Potential re-introduction site?
Steamer Drain	3.2.1c	Southern pygmy perch	0	0	-	Stable	Population probably lost.
	4.1.1c	Yarra pygmy perch	0	0	-	Stable	Population probably lost. Potential re-introduction site?
	5.1.1c	Murray hardyhead	0	0	-	Stable	Population probably lost. Potential re-introduction site?

Table 96 continued.

Site Name	DAP Site Number	Target species	No. caught spring 2010	No. caught autumn 2011	Recruitment within the last 12 months (Y/N)	Water level summer-autumn (Rising, stable, falling, dry)	Site comments
Black Swamp	3.2.2a	Southern pygmy perch	2	0	No	Stable	Population likely to be small. No individuals detected in autumn 2010. Conditions in the area may be favourable for this species with continued higher water levels and habitat regeneration.
	4.1.3	Yarra pygmy perch	0	0	-	Stable	Population probably lost
Black Swamp Drain	3.2.2	Southern pygmy perch	0	0	No	Stable	Potentially present given presence at Black Swamp but may be absent. Conditions in the area may be favourable for this species with continued higher water levels and habitat regeneration.
Turvey's Drain	3.2.3	Southern pygmy perch	2	0	No	Stable	Despite environmental watering, marked decrease in abundance from 2008/09 and 2009/10 and no recruitment detected.
	5.1.3a	Murray hardyhead	0	0	No	Stable	As above
Meadows	3.3.1	Southern pygmy perch	28	48	Yes	Seasonally variable	Consistent or marginally increased numbers and significant recruitment, albeit restricted distribution within the site and potential for drying and fragmentation with extended periods of hot, dry weather.
Waterfalls	3.3.3	Southern pygmy perch	0	0	No	Seasonally variable	Following extended recruitment failure (>3 years) – population lost. Present further downstream
Inman	3.5.1	Southern pygmy perch	16	10	Yes	Seasonally variable	Abundance similar to 2009/10. Recruitment evident
Currency Creek	4.1.2A	Yarra pygmy perch	0	0	-	Stable	Population probably lost
	-	Murray hardyhead	109	0	No	Stable	Sampled in high abundance in spring but absent in autumn 2011. The species is highly mobile and dispersive and may have moved away from the site. Individuals may be present in local area.
Finniss River Confluence	4.1.2	Yarra pygmy perch	0	0	No	Stable	Population probably lost
	-	Murray hardyhead	0	0	No	Stable	Population lost from the site but may be present in local area.
Boggy Creek	5.1.1d	Murray hardyhead	0	0	No	Stable	Not detected throughout 2010/11. Likely moved or dispersed from site with increased water level and connectivity. Individuals may be present in local area.
Mundoo Drain West		Murray hardyhead	NS	NS	No	Stable	Population was likely lost but requires further sampling to determine status.
		Southern pygmy perch	NS	NS	No	Stable	Population was likely lost but requires further sampling to determine status.

Table 96 continued.

Site Name	DAP Site Number	Target species	No. caught spring 2010	No. caught autumn 2011	Recruitment within the last 12 months (Y/N)	Water level summer-autumn (Rising, stable, falling, dry)	Site comments
Mundoo Drain East		Murray hardyhead	0	0	No	Stable	Population likely lost. Pools previously dried or very shallow. With increased water level, individuals may re-colonise or may be a favourable reintroduction site.
Clayton	5.1.2	Murray hardyhead	0	0	No	Stable	Individuals were sampled further within Dunn's Lagoon by Wedderburn and Barnes (In Prep) in spring 2010. Likely some individuals present in the local area.
Milang Jetty	5.1.3b	Murray hardyhead	0	0	No	Stable	Not sampled since spring 2010, population likely lost. However, water levels have now risen and as such conditions may become favourable for Murray hardyhead and the species may re-colonise the site if an appropriate source population exists.
Bremer River Mouth	5.1.3c	Murray hardyhead	0	0	No	Stable	Population likely lost. Habitat conditions have improved and the species may recolonise the site if an appropriate source population exists.
Rocky Gully	5.1.4	Murray hardyhead	26	14	Yes	Stable	This population has declined since autumn 2010, with increased water levels and connection with the River Murray. Individuals may have dispersed into the River Murray or increased water levels in Rocky Gully may have diluted individuals decreasing catch efficiency. Furthermore, decreased salinity at this site may favour less salt tolerant species that may compete with Murray hardyhead.
Riverglades	5.1.5	Murray hardyhead	0	0	-	Stable	Population was lost following desiccation. With increased water levels and reinundation, site may become favourable for recolonisation or reintroduction.
Disher Creek	5.2.1	Murray hardyhead	15	0	No	Stable	Decreasing abundance and then absence in autumn 2011. High water levels and connectivity may have resulted in dispersal and/or dilution of individuals decreasing catch efficiency. Follow up sampling required to determine status. Very high abundance of gambusia may be impacting Murray hardyhead
Berri	5.2.1	Murray hardyhead	3	0	No	Stable	Decreasing abundance and then absence in autumn 2011. High water levels and connectivity may have resulted in dispersal and/or dilution of individuals decreasing catch efficiency. Continued increase in non salt-tolerant species that may compete with Murray hardyhead

5.2. In situ population maintenance

Several actions have been undertaken throughout the duration of the DAP in an attempt to protect wild habitats/populations, primarily involving the delivery of environmental water. In 2010/11, however management interventions at most of sites were minimal in comparison to preceding years (Bice *et al.* 2010a) as a result of broadly improved hydrological conditions in the South Australian MDB. Indeed, most sites were subject to flooding or increased water levels and habitat and/or populations were maintained through natural means. More specific information on in-situ maintenance is provided in site summaries, but key highlights are summarised below.

In response to low water levels and low dissolved oxygen concentrations since autumn 2008, Rodwell Creek continued to be filled with environmental water in early 2010, prior to the onset of significant natural flows. Furthermore, the aerator installed in 2009/10 continued to operate and regular checks (monthly to weekly) of water quality and depth were undertaken at the monitoring pool, and extended to other recently recolonised pools nearby.

Conversely, several at risk populations/sites have received little management intervention over the course of the project, either due to resource limitation or low feasibility. At one such site, the Finniss Waterfalls, the southern pygmy perch population has unfortunately been lost whilst the Marne River river blackfish population remains potentially the most ‘at risk’ population monitored as part of the DAP.

5.3. Captive breeding and surrogate refuges

There are currently captive breeding programs established through the DAP of at least one population for each of the five threatened species (involving multiple agencies, see site summaries for specifics). The primary goal of these programs is to spread risk from imperilled ‘wild’ populations (providing a ‘back up’ population) and to then produce juveniles for introduction into surrogate refuges, and ultimately into ‘wild’ sites. Juvenile Yarra pygmy perch, Murray hardyhead and southern purple-spotted gudgeon have already been released into surrogate refuges and initial survey results suggest that releases have been successful with the establishment of self-sustaining populations.

Releases of juvenile Yarra pygmy perch into two surrogate refuge dams (i.e. Oster and Crouch Dams) have been highly successful. Populations at both sites, particularly at the Crouch Dam, are highly abundant and have complex length/age structures indicating the presence of several different age classes of individuals. As such, in their current state these populations are excellent candidates for sourcing individuals for wild re-introductions.

Releases of Murray hardyhead into the Munday Dam surrogate refuge in 2010/11 have had moderate success. As of autumn 2011, this species was present in low-moderate abundance however recent recruitment was observed. Nonetheless, this population has been at liberty in the dam for approximately one year and further expansion of the population is likely to continue in the second year, as was observed with Yarra pygmy perch surrogate refuge sites. The release of another group of individuals into the dam in May 2011 is likely to increase the adult population prior to spawning in spring/summer 2011/12.

A number of juvenile southern purple-spotted gudgeon have been released into a restored wild refuge at the Paiwalla wetland near Jury Swamp, over a series of events. This was undertaken over a series of releases and the population is now considered to be in low-moderate abundance (autumn 2011) and encouragingly, recent recruitment was observed. Captive rearing of southern purple-spotted gudgeon continues to be successful and thus, in combination with the new wild population at Paiwalla, there are likely to be adequate numbers of individuals for future reintroductions to the original wild site at Jury Swamp.

Further rescues of Murray hardyhead and southern pygmy perch were made in winter 2010. These were undertaken to either take advantage of peaks in abundance, in a proactive attempt to improve genetic resources and capacity within captive breeding programs (Rocky Gully) or in a risk management response to the uncertainty over site management and site condition prior to the return of better conditions (e.g. watering failure, ongoing poor conditions: Turvey's Drain) and with rewetting (e.g. acid sulfate soils, predator invasion: Boggy Creek).

5.4. Conclusion

With significantly improved hydrology in 2010/11, relative to preceding years, the focus of the DAP has now shifted from monitoring and determining sites at risk of loss and the need for applying urgent conservation management actions, towards facilitating the recovery and continued persistence of populations of threatened fish post-drought. This is an important step in the process of conserving threatened fish species and should build upon successes from the preceding four years. The return of favourable hydrological conditions has generally not been immediately accompanied by positive responses of threatened species (with the exception of a small number of populations), highlighting the fundamental importance of incorporating a ‘recovery phase’ into the DAP to ensure its objectives are achieved.

The status of populations at several sites and indeed across entire regions (e.g. the Lower Lakes), is unclear following increased flows and flooding in 2010/11. The presence and location of core populations, at higher water levels, remains unknown for several species. Thus, an integrated approach that allows determination of the status of wild populations and subsequent utilisation of captive populations to facilitate recovery and long-term persistence of populations should be adopted. Captive bred populations are currently being held (i.e. aquaria/ponds) or maintained in surrogate refuges for four of the five threatened species; namely Yarra pygmy perch, southern pygmy perch, Murray hardyhead and southern purple-spotted gudgeon. Prior to the re-introduction of these individuals into former habitats (or to bolster reduced wild populations), a rigorous, scientifically defensible framework must be developed to guide re-introductions (see George *et al.* 2009). This would include assessments of receiving environments against pre-determined criteria (e.g. water quality, habitat, species composition and water security) based on scientific data prior to re-introductions, and, implementation of techniques to determine the success of re-introductions (i.e. calcein staining of stocked fish as a mark-recapture method). As such, re-introductions would occur in a structured and transparent manner and the objective of subsequent long-term species persistence would have a greater chance of being achieved.

Monitoring and subsequent management actions as part of the DAP in the last 4 years have generated significant knowledge on the conservation of threatened fish species and their ability to persist through both human-induced and natural disturbances. The low abundance and fragmented nature of threatened fish populations necessitated that management was focused on targeted small-scale interventions (i.e. site-scale) to increase the ‘resistance’ of individual populations to perturbations (e.g. receding water levels and increased salinity). However, future management of threatened species rather should focus on increasing the abundance, distribution and connectivity between threatened fish populations and hence build greater ‘resilience’ and capacity of populations to withstand future droughts and other disturbance.

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