Inland Waters & Catchment Ecology

Western Mount Lofty Ranges Fish Condition Report 2012-13

Incorporating the Barossa Valley Prescribed Water Resource Area Fish Community Study, the Verification of Water Allocation Science Project (VWASP) and the Western Mount Lofty Ranges Fish Community Monitoring Project

David W. Schmarr, Rupert Mathwin and David L.M. Cheshire

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June 2014

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ACRONYMS

AMLRNRMB	Adelaide and Mount Lofty Ranges Natural Resource Management Board
ANOSIM	Analysis of similarity (statistical test)
BCG	Biological condition gradient
BVFCS	Barossa Valley Prescribed Water Resource Area Fish Community Study
CPUE	Catch per unit of effort
DEWNR	Department of Environment, Water and Natural Resources
DISTLM	Distance based linear model (statistical test)
DO	Dissolved oxygen
FCM	Fish Community Monitoring Project
FHI	Fish health index
GAL BRE	Climbing galaxias (*Galaxias brevipinnis*)
GAL OLI	Mountain galaxias (*Galaxias olidus*)
GAM HOL	Gambusia (*Gambusia holbrooki*)
GIS	Geographic information system
LEBMF	Lake Eyre Basin Ministerial Forum
MDBC	Murray Darling Basin Commission
MLR	Mount Lofty Ranges
NRM	Natural Resource Management
PER FLU	Redfin perch (*Perca fluviatilis*)
PHI GRA	Flathead gudgeon (*Philypnodon grandiceps*)
PIRSA	Primary Industries and Regions South Australia
PWRA	Prescribed water resource area
SAL TRU	Brown trout (*Salmo trutta*)
SARDI	South Australian Research and Development Institute
SIMPER	Similarity percentages test (statistical test)
TL	Total length
VWASP	Verification of Water Allocation Science Project
WMLR	Western Mount Lofty Ranges
WMLRNRM	Western Mount Lofty Ranges Natural Resource Management

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EXECUTIVE SUMMARY

This report presents the cumulative efforts from three projects conducted during the 2012/13 financial year: the Barossa Valley Prescribed Water Resource Area Fish Community Study (BVFCS), baseline monitoring for the Verification of Water Allocation Science Project (VWASP) and monitoring for the Western Mount Lofty Ranges Fish Community Monitoring Project (FCM). This report aligns the common methods and objectives of each project into a single report on the health of the aquatic environment in the Western Mount Lofty Ranges. Separate sections dealing with specific objectives for each project are also presented.

Sites for each project were selected in collaboration with the Department of Environment, Water and Natural Resources (DEWNR) and Adelaide and Mount Lofty Ranges NRM Board (AMLRNRMB) following consistent methodology and exhaustive and methodical process based on criteria outlined in this report. At the conclusion of the surveys, 131 sites had been sampled (between November 2012 and June 2013). The broad spatial extent of sites provided information on the ecological condition of aquatic habitats in the Western Mount Lofty Ranges for the summer of 2012/13. To capitalise on the vast amount of data being collected in this project, the ecosystem health of each site was assessed using two condition indices developed in recent years (Mathwin *et al*., 2014): the biological condition gradient (BCG) and fish health index (FHI). Condition indices and the data underpinning the assessment of each individual site are documented in site summary sheets provided in the accompanying supplementary report. It is envisaged that the supplementary report will be a useful resource for future reference in site specific natural resource management activities.

In total, the three projects sampled at 131 sites, capturing and identifying over 42,500 fish. The distribution and abundance of fish species highlighted three factors contributing to the distribution of healthy fish communities. First, availability of water, through extraction of water resources or variations in rainfall, provided a trajectory of fish community health. Drier, high water extraction areas had poor water quality and were inhabited by species indicative of ecological degradation. Wetter, low water extraction areas had good water quality and species indicative of ecological integrity. Second, loss or alteration of aquatic habitat through poor land and water management practices accompanied sites with low fish abundance, complete absence of fish or sites dominated by exotic fish species. Finally, barriers to fish passage have restricted diadromous fish species to a coastal distribution and a few land-locked populations, resulting in localised depletion or extinction of some species.

A series of species and site specific recommendations are provided to guide and prioritise future management and research efforts.

1. INTRODUCTION

1.1. Background

Communities of aquatic organisms such as fish are a robust indicator for the general condition of aquatic ecosystems (Karr *et al*. 1986). Occupying higher trophic levels, healthy freshwater fish populations reflect positively on the condition of habitat, food-web structure and flow regime, all of which are key components of healthy functioning aquatic ecosystems. Accordingly, many of Australia's largest aquatic monitoring programs, such as the Murray-Darling Basin's Sustainable Rivers Audit and the Lake Eyre Basin Ministerial Forum's Lake Eyre Basin Rivers Assessment, have strong fish monitoring components as an indicator of riverine condition across large spatial and temporal scales (MDBC 2004, LEBMF 2011). Most aquatic ecosystems in good condition support healthy native fish populations and should possess:

- All expected native fish species based on natural range and habitat requirements
- High abundance commensurate with species traits
- Populations with juvenile, adult and long-lived large sized individuals
- Signs of regular recruitment
- Low numbers of exotic species
- Low incidence of disease and parasites

For streams and rivers in the Mount Lofty Ranges (MLR) the majority of this information can be surveyed using well developed rapid assessment methodologies (McNeil and Hammer 2007, McNeil and Cockayne 2011) with findings compared against historic records and known biotic thresholds (McNeil *et al*. 2011, Schmarr *et al*. 2014). Such surveys, especially those that cover a large number of sites across catchments and regions, provide snapshots of aquatic ecosystems that reflect the current condition of those habitats and regions.

These types of data support a range of management prioritisation and assessment activities and provides a useful picture of where important or threatened species are distributed, where key populations exist or are absent, where exotic competitors and/or predators may have been introduced, or where populations may be struggling under the impact of localised or wide-spread threatening processes, anthropogenic and natural impacts. This information can be extremely effective in informing regional Natural Resource Management (NRM) investment decisions and can assist with the development and setting of condition targets and objectives.

Consistently collecting data over time in the same locations (sequential data sampling) can result in highly effective monitoring programs that provide relevant biological information with temporal resolution allowing objective analysis of key factors (Power 2007). NRM frameworks for the MLR have a clear requirement for assessing and reporting on the outcomes of NRM investment programs, largely against targets set *a priori* in line with investment priorities and available budgets. As a result, ongoing monitoring programs that utilise consistent methodology at the same sites can be a useful tool for capturing and expressing responses or trajectories in condition that can be measured against desired outcomes or target values.

The Adelaide and Mount Lofty Ranges Natural Resources Management Board (AMLRNRMB) has set clear targets for improving the extent, condition and function of ecosystems and preventing any decline in the conservation status of native species (AMLRNRMB 2009). The Board's biodiversity strategy acknowledges that there is considerable evidence of ongoing loss and declines in freshwater fishes throughout Adelaide and the Mount Lofty Ranges. This assertion is supported by a range of recent projects that have focused on assessing the distribution, population sustainability, habitat, water resource and flow regime requirements of native fish in the region (Hammer 2005, McNeil and Hammer 2007, McNeil *et al.* 2011).

These projects have identified changes in the distribution and diversity of native species, as well as localised depletion or extinction since historical records were published over fifty years ago. These studies have also found that there are a number of exotic species and translocated native species across the region that may raise considerable concern for the sustainability of native fish. Habitat and catchment modifications and changes to flow regime have also been linked to declining distribution and abundances of native fishes, as well as threats to population connectivity presented by barriers to fish movement and migrations (McNeil *et al.* 2011, Schmarr *et al.* 2011).

To inform the management of water resources and aquatic ecosystems in the Western Mount Lofty Ranges Natural Resources Management (WMLRNRM) region, there is a requirement for an understanding of the present distribution and health of native fish populations across the WMLR. The status of these populations will provide a baseline for comparison against future water management regimes. It will also provide data for highlighting and prioritising actions for improving fish population health.

With this goal in mind, three monitoring projects were commissioned by AMLRNRMB to determine the health of fish populations and provide data for water allocation planning: (1) the Barossa Valley Prescribed Water Resource Area (PWRA) Fish Community Study, (2) baseline monitoring for the Verification of Water Allocation Science Project (VWASP) and (3) monitoring for the Western Mount Lofty Ranges Fish Community Monitoring Project (FCM). The first two studies were conceived to provide data directly to water allocation planning; the third provides regional data for assessing aquatic health and highlighting waterways of concern for future management action.

The Barossa Valley PWRA fish study aims to deliver science input to inform the creation of tailored environmental water policies in the Barossa Valley, based on specific ecological conditions and values - an approach which has strong support within the Barossa community. The VWASP study has similar aims, but is tasked with verifying the science of water allocation planning through complementary ecological and hydrological monitoring in specific reaches. This approach requires an understanding of the distribution of ecosystem assets and their water requirements, as well as a site specific understanding of value and condition.

These projects aim to provide the Board with the knowledge required to account for the likely environmental implications of applying varying water policy options in the Barossa and broader Mount Lofty Ranges based on area-specific hydrological and ecological conditions and values. The present component of the project will contribute to this process through surveying the distribution of fish species across the Barossa PWRA and VWASP sites and documenting species presence, population structure, current ecological value and threatening processes.

The fish community monitoring project builds on fish monitoring conducted in 2011 (McNeil *et al.* 2011), as well as the current monitoring conducted for Barossa PWRA fish study and VWASP. These projects have served to provide a comprehensive baseline dataset of fish community health in the WMLR using a consistent sampling methodology.

In addition to the past sampling efforts, an additional method of assessing ecosystem health has been adopted using the Biological Condition Gradient (BCG) developed by Davies *et al.* (2006) and trialled by SARDI using the previous 2011 monitoring data (Mathwin *et al.* 2014).

The following report outlines the results of the three fish surveys and provides data on the distribution and abundance of species at sites across the region, and provides a snapshot of the native and introduced fish population structure. The report presents a classification process for capturing the relative ecological condition of fish communities and populations in order to help provide a simple platform of ecological condition, and assist with prioritisation of NRM investments and progress towards management targets for aquatic biodiversity and condition. Finally, the report will outline management recommendations and provide ideas for the development of monitoring strategies based on the outcomes of the survey.

1.2. Objectives

The combined objectives of this study were to:

- Undertake a survey of fish communities across the WMLR using a consistent and repeatable methodology allowing standardisation of data to support robust multivariate analysis.
- Input raw data into the Biological Database of South Australia (BDBSA).
- Analyse data collected from inside the Barossa Valley prescribed water resource area to identify significant aquatic values and priority catchments and to inform the development of the water allocation plan (WAP).
- Collect baseline data to support the VWASP.
- Revisit key fish communities highlighted under the 2011 Condition of Freshwater Fish Communities Assessment (McNeil *et al*. 2011b).
- Fill spatial knowledge gaps in the range and distribution of the WMLR fish biota.
- Combine fish data from three key WMLR water management projects to create a single region-wide analysis to inform management and guide future research across the region.

2. METHODS

2.1. Study site selection and reach classification

Sites were selected using three sequential steps. The catchments that fell within the Barossa Valley PWRA were visualised using GIS layers provided by DEWNR to identify dry season pools. These were predicted to be the most important refugia for fish survival during periods of low rainfall and/or high extraction. Sites were also identified that held current and future hydrological gauging stations and sites with historic fish data. From these potential locations, study sites were selected with a view of: maximising spatial coverage, reflecting a range of heterogeneous aquatic environments and reach types, and where possible, using previous monitoring sites. These guiding principles were also applied to site selection for the VWASP sites with an additional site placed at, or near, each hydrological monitoring station. Finally, a range of sites were selected for WMLR Fish Community Monitoring that addressed concerns identified in the previous fish community assessment (McNeil *et al.* 2011b), addressed current knowledge gaps in the WMLR fish fauna and enhanced research goals in the VWASP and BVFCS previous two studies. A total of 131 sites were selected for fish sampling for the three projects (Figure 1).

The classification of reach types within this report are based on the conceptual model developed within the Draft Water Allocation Plan for the Eastern and Western Mount Lofty Ranges PWRA (SAMDBNRMB, 2011). This framework classifies reaches into six distinct types; headwaters, upper pool-riffles, mid pool-riffles, gorges, lowlands and terminal wetlands. The definition of terminal wetland reach types has been altered slightly to include some tidal influenced estuarine systems which flow into the ocean and gulfs.

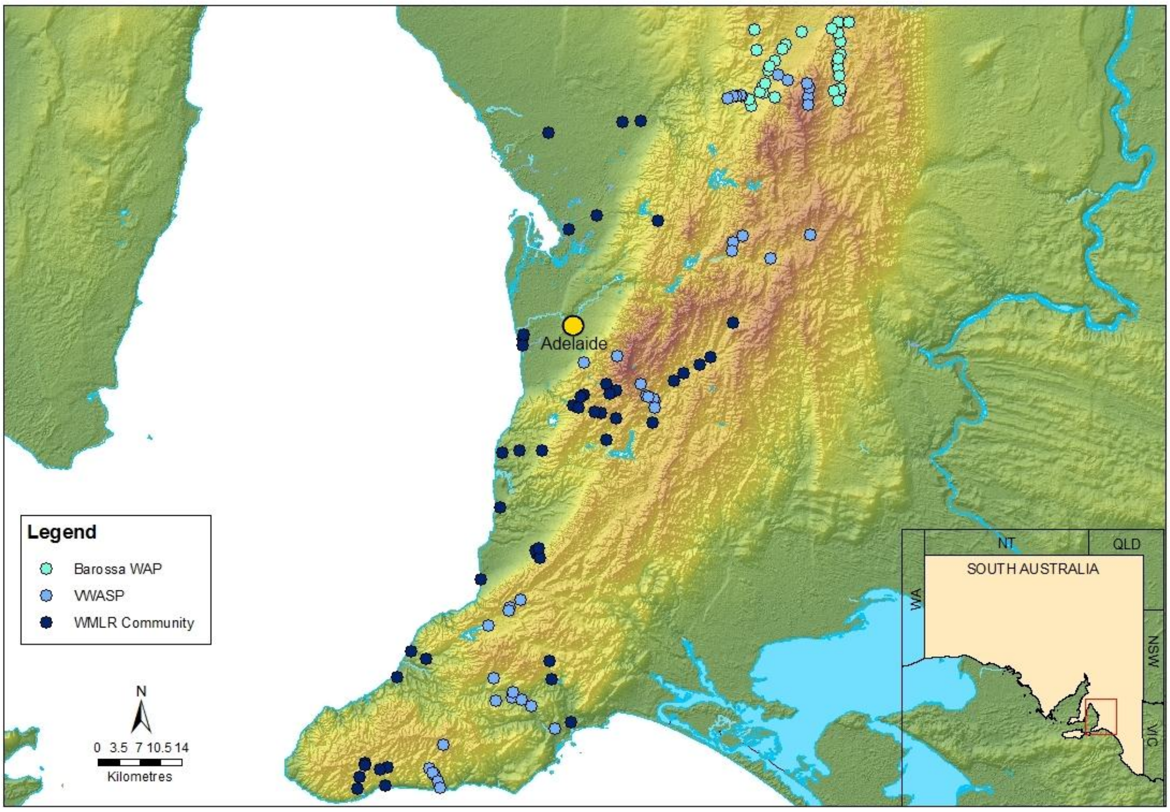

Figure 1. Sites surveyed throughout 2012/13 for the WMLR fish condition surveys. Projects colour coded in legend.

2.2. Timing of sampling

Field sampling took place between November 2012 and June 2013. Sampling for the Barossa Valley PWRA Fish Monitoring project and the VWASP project were carried out during summer 2013 and sampling for the Western Mount Lofty Ranges Fish Community Monitoring Project was carried out during autumn and winter 2013 (Appendix A).

2.3. Habitat assessment and water quality measurement

At each site substrate type, in-stream structure, rate of flow and connectivity to the main channel was assessed and recorded. Percent cover of aquatic, emergent and riparian macrophytes was estimated and the dominant species for each category identified (Sainty and Jacobs 2003).

A point of maximum depth was identified within each site where water quality was recorded. Water Quality parameters, including dissolved oxygen (DO) ($mg.L^{-1}$), water temperature, pH, turbidity (NTU) and salinity (mS/cm), were measured on site using a YSI 6920 Multiparameter Sonde and YSI 650 display system (Figure 2). Measurements were recorded first at the water's surface and then at 50 cm depth intervals concluding at the riverbed. An internal error in the unit failed to record data on two days resulting in the loss of water quality data for 10 sites. These were; Tanunda Railway Crossing, Happy Home Reserve, Willow Glen, Winns Rd, West Beach Rd Bridge, Adelaide Shores Golf Course, Adelaide Shores Skate Park, Hindmarsh Falls, Sawpit Rd and Cootamundra Reserve.

Figure 2. Water quality monitoring (left) and removal of a pacific black duck (*Anas superciliosa*) from a fyke net (right). This duck entered the net overnight and was saved from drowning by the air pocket created between the two polystyrene buoys.

2.4. Standard fish sampling methodology

Pool sampling employed two fyke net designs; 'small fykes' (3 m leader, 2 m funnel, 3 mm mesh) and 'double-wing fykes' (2 x 5 m wings, 3 m funnel, 3 mm mesh). Nets were anchored using heavy gauge chain clipped to the cod and wing ends. Two polystyrene buoys were placed in each net's cod end to force a pocket of net above the water's surface. This created a space where by-catch (turtles, birds or water rats) could take refuge until the net was processed (Figure 2). Two double-wing and four small fykes were deployed at each site with nets positioned to strategically sample the range of microhabitats present at the site. Double-wing fyke nets were deployed together and in opposition with one opening upstream and the second opening downstream. Single fykes were deployed separately within the microhabitats available at the site (e.g. snag, bare bank, submerged vegetation etc). Fyke nets were set before dusk and collected after dawn ensuring that each site was set for a minimum of 14 hours.

A subset of nets was deployed at sites when conditions were inappropriate for a complete complement of nets. At two sites on Callawonga Creek, stream depth was insufficient to support fyke netting, here a combination of backpack electrofishing and box style bait traps were used.

2.4.1. Electrofishing

A Smith-Root LR-24 backpack electrofisher was used to undertake focused sampling in marginal habitats and riffles at two sites (Figure 3). Sampling was undertaken by two trained staff who fished for a total of 2,000 seconds at each site. Frequency, voltage and duty cycle settings varied between sites and were matched to local conditions. All fish were collected and processed using the fyke net fish methodology.

Figure 3. Demonstration of electrofishing operation.

2.4.2. Fish processing

At each site, captured fish were identified to species. The only exception were carp gudgeon (*Hypseleotris*), which exist in the WMLR as a species complex and were identified to genus. Fish species were considered to be either native (endemic to the catchment with historic data to confirm this), translocated (an Australian native fish species that is not considered endemic to the catchment per McNeil and Hammer 2007) or exotic (a fish species that is not endemic to Australia). For each species, total length (TL) was recorded for the first 100 fish collected. This was considered a representative subset to create reliable length frequency distributions. Where the 100^{th} fish of a species was measured part way through processing a net, measurements continued for this species until completion of the net to eliminate within-net selection bias. The only exception to this process was gambusia (*Gambusia holbrooki*). This species may be gravid for ten months of the year and produce up to nine broods during this time (Milton and Arthington 1983). Length frequency distributions for this species fail to inform on key ecological questions and so only the first 50 fish of this species were measured and sexed to contribute data towards verifying biological characteristics for this species in the WMLR. In addition to length, fish were visually assessed for the presence of fungal infection, subcutaneous endoparasites, spawning condition and congenital abnormalities. These data were used to inform condition assessments presented in (Schmarr *et al*., 2014).

The species and maximum carapace length (MCL) of any turtles caught in nets were also recorded, as well as the number of yabby (*Cherax destructor*) and marron (*Cherax cainii*). Presence of freshwater shrimp of the genus *Paratya* and *Macrobrachium* was recorded, as well as the presence of tadpoles.

2.5. Data analysis

2.5.1. Standardisation of site data across the WMLR

To standardise fish sampling results to a catch per unit of effort (CPUE), the total catch data for each net from every SARDI WMLR sampling event since autumn 2006 was compiled noting set and pull times for each event. This dataset was reviewed and events with missing data points such as unrecorded set or pulled times were eliminated along with gear types that were not used in the current study. This process created a dataset tailored to compare the efficiency of double-wing and single fyke nets and effort ratios. Analysis in this study considered three gear types; single fyke nets, upstream facing double-wing fyke nets and downstream facing double-wing fyke nets.

Total catch per hour was calculated for each net and a $\log_{10}$ transformation was applied to normalise the entire dataset. Average catch for each net type was then calculated using small fyke nets as the base unit producing a gear effort score for each net type. In this way a small fyke net set for one hour produced one unit of effort.

Total catch for each sampling event in the study was divided by the total gear effort (sum of all gear effort at the site) and divided by the number of hours that nets were set to produce a CPUE value for each site.

2.5.2. Data analysis for the fish community of the Barossa Valley Prescribed Water Resource Area

Multivariate analysis of fish communities provides an objective method of profiling similarities across multiple sites. Significant correlation between fish communities may be used to observe the geographic distribution of common threats and strengths and may be used as a framework for the development of regional management priorities.

Due to the specific management outcomes required from this project an individual set of results was created for the 43 sites that fell within the Barossa PWRA. The Primer 6 statistical package (with Permanova Add-on) (Clarke and Gorley 2006) was used to perform all multivariate analysis. Fish community data was analysed using CPUE values transformed using Log(x+1). A Similarity Percentages analysis (SIMPER) and distance based linear model (DISTLM) (Dufrene and Legendre 1997) were used to examine relationships within fish community compositions. To assess and compare fish community composition data, a non-parametric analysis of similarity (ANOSIM) using the Bray Curtis resemblance matrix was performed. Data were visualised using a cluster analysis dendrogram. Environmental data considering six water quality parameters (average temperature, salinity, pH, turbidity, and maximum and minimum DO) were transformed using Log(x+1) and normalised. These data were related to fish community data using distance base linear models to determine significant water quality correlates. This relationship was visualised as a multi-dimensional scale (MDS) plot. For presentation purposes, sites without fish were considered as outliers and excluded from the plot. Fish sites were presented based on the cluster groupings that separated at a 50% similarity.

2.5.3. Multivariate analysis of the 2012-13 Western Mount Lofty Ranges fish communities

For each site in each of the three projects, raw abundance of the fish community was standardised to CPUE and transformed using a Log(x+1). Four sites were unsuitable for inclusion in the analysis, three due to non-standard gear types (dab netting and electrofishing) and one from destruction of nets due to high flow conditions. A total of 127 sites from across the three projects were considered together. A SIMPER analysis and distance based linear model (Dufrene and Legendre 1997) were used to examine relationships within fish community compositions. Bray-Curtis (1957) similarity was used to calculate a resemblance matrix for the cluster analysis which was visualised as a dendrogram.

Environmental data (mean water temperature, salinity, pH and turbidity, minimum and maximum DO) for each site were transformed using Log(x+1) and then normalised. A total of 117 sites from across the three projects had sufficient data to include in this analysis. Two environmental data sets were created and analysed, one containing average yearly rainfall, FHI and BCG scores, the second containing water quality data. These data were related to fish community data using distance based linear models (DISTLM) to determine the significance of site condition and water quality parameters. This relationship was visualised as distance based linear models plots. Fish sites were represented in these plots corresponding to five geographic distributions within the study area. Geographic areas were defined as sites within the MLR above -34.647679°S (Northern MLR), sites within the MLR between -34.647679°S and -34.879627°S (Mid North MLR), sites located within metropolitan areas on the Adelaide plains (Metropolitan), sites located within the MLR between -34.879627°S and -35.227819°S (Mid South MLR) and those sites within the MLR located below -35.227819°S.

2.5.4. Site health assessments

Two techniques were used to characterise site 'health' to inform management. The Biological Condition Gradient (BCG) uses a ten step approach to score biotic communities and ecological assets in a landscape context (Davies and Jackson 2006). Details for the application of BCG scoring in the WMLR may be found in (Mathwin *et al.* 2014). The second approach used was the Fish Health Index (FHI). This approach scores the size and composition of fish communities to assess the stability of native fish populations. Methods for this approach may be found in (McNeil *et al.* 2011b). To best inform management, it was decided that a combined BCG and FHI approach would provide the most robust representation of fish health.

2.5.5. Site characterisation

The data collected and generated were used to create a site characterisation summary for each site. The collated site characterisations for each of the three studies are presented in Schmarr *et al.* (2014).

3. RESULTS

3.1. General results

A total of 131 sites were sampled throughout the three projects. Fish were present at 112 of the 131 sites. In total, 42,504 fish were caught comprising twelve native, three translocated and six exotic fish specie. Of these, 13,278 were native fish and 29,223 exotic. Only three individual translocated fish were identified (Table 1).

The most abundant native fishes were flathead gudgeon (*Philypnodon grandiceps,* n= 6,029 individuals), mountain galaxias (*Galaxias olidus,* n = 3,404 individuals) and common galaxias (*Galaxias maculatus*, n= 1,454 individuals). The most commonly recorded native species were mountain galaxias (30 occasions), flathead gudgeon (29 occasions), climbing galaxias (*Galaxias brevipinnis*, 17 occasions) and common galaxias (16 occasions). All remaining endemic native species were recorded on fewer than 10 occasions (Table 1).

Gambusia (*Gambusia holbrooki*) was the most abundant exotic species recorded accounting for 52% (n = 21,964 individuals) of total fish caught. Redfin perch (*Perca fluviatilis*), was the second most abundant exotic species at 16.5% (n = 6,998 individuals). The four remaining exotic species (goldfish, brown trout, tench and European carp) contributed fewer than 200 individuals. The most commonly encountered exotic species were gambusia (46 occasions), redfin perch (33 occasions), tench (*Tinca tinca*, 11 occasions) and brown trout (*Salmo trutta*, 10 occasions) (Table 1).

Four species of fish endemic to the Murray-Darling Basin were recorded. These were; silver perch (*Bidyanus bidyanus*) in the Little Para, Murray River catfish (*Tandanus tandanus*) in Sturt Creek, carp gudgeon (*Hypseleotris* spp.) in the North Para River and dwarf flathead gudgeon (*Philypnodon macrostomus*) in the Torrens. Both silver perch and carp gudgeon were first records in their respective catchments.

3.2. Fish results within the Barossa Prescribed Water Resource Area

In total 44 sites were sampled within the Barossa Valley PWRA during February 2013 (Appendix A). A total of 32,099 fish were collected including three native, five exotic and one translocated fish species (Table 1). The most abundant native species was flathead gudgeon (5,873 fish) followed by western blue spot goby (*Pseudogobius olorum*, 1,264 fish) and mountain galaxias (559 fish). The most widespread native fish species were located at 19 sites (flathead gudgeon), 6 sites (western blue spot goby) and 3 sites (mountain galaxias).

Table 1. Total abundance of black bream (*Acanthopagrus butcheri*), Tamar goby (*Afurcagobius tamarensis*), climbing galaxias (*Galaxias brevipinnis*), common galaxias (*Galaxias maculatus*), mountain galaxias (*Galaxias olidus*), carp gudgeon (*Hypseleotris spp.*), southern pygmy perch (*Nanaoperca australis*), flathead gudgeon (*Philypnodon grandiceps*), dwarf flathead gudgeon (*Philypnodon macrostomus*), western bluespot goby (*Pseudogobius olorum*), congolli (*Pseudaphritisurvilli*), silver perch (*Bidyanus bidyanus*), Murray River catfish (*Tandanus tandanus*), goldfish (*Carassius auratus*), European carp (*Cyprinus carpio*), Gambusia (*Gambusia holbrooki*), redfin perch (*Perca fluviatilis*), brown trout (*Salmo trutta*) and tench (*Tinca tinca*). Native records are highlighted green, translocated records in blue and exotic records red.

Catchment	Reach	Site Name	Black Bream	Tamar Goby	Climbing Galaxias	Common Galaxias	Mountain Galaxias	Carp Gudgeon	Southern Pygmy Perch	Flathead Gudgeon	Dwarf Flathead Gudgeon	Western Bluespot Goby	Congolli	Carp Gudgeon	Silver Perch	Murray River Catfish	Goldfish	European Carp	Gambusia	Redfin Perch	Brown Trout	Tench
Gawler River	Duck Ponds Creek	Rex's Place																				
		US Duck Ponds Pool																				
		DS Duck Ponds Pool																				
	Greenock Creek	Seppeltsfield Weir																	806			
		Owen's Grange																				
		Owen's Culvert																				
	Tanunda Creek	DS Kaiser Stuhl																	58			
		US Tanunda Creek Rd																	16			
		DS Tanunda Creek Rd																	2396			
		Tanunda Railway Crossing																				
	Jacobs Creek	Jacobs Creek Old Gauge					508															
		Jacobs Creek Crossing					50													1		
		Jacobs Creek Visitors Centre					1			230												
	Little Para River	One Tree Hill Crossing								7				1								
		Happy Home Reserve																				

Catchment	Reach	Site Name	Black Bream	Tamar Goby	Climbing Galaxias	Common Galaxias	Mountain Galaxias	Carp Gudgeon	Southern Pygmy Perch	Flathead Gudgeon	Dwarf Flathead Gudgeon	Western Bluespot Goby	Congolli	Carp Gudgeon	Silver Perch	Murray River Catfish	Goldfish	European Carp	Gambusia	Redfin Perch	Brown Trout	Tench
Gawler River		Whites Road Wetland																	106			
	North Para River	North Para Old Gauge																	585	51		
		Brooks Property																	41	985		
		US Cornerstone Stud																	34			
		Cornerstone Stud																	8	794		
		US Evan's Weir																	218	189		
		DS Evans Weir																	316	682		
		Third Evan's Weir																	10	2		
		US McEvoy Weir																	334	303		
		US Thorne-Clarke																		126		5
		Thorne-Clarke Ford								3									4	256		3
		Gumhill								38									349	211		2
		Old Moculta Bridge								708										113		
		Penrice Quarry 2								21									600	1		
		Penrice Quarry								295									1061			
		Nuritootpa Caravan Park																	360			
		DS Nuritoopta Caravan Park																	1515			
		Smythe St Crossing								514							8		98			1
		Hahn's paddock								355									28			
		DS Matchos								358							28	1	531			
		Tanunda Township								335							1					1
		Heinemann Guage								7									16			
		Barossa Novotel								1149		551			1				267	3		2

Catchment	Reach	Site Name	Black Bream	Tamar Goby	Climbing Galaxias	Common Galaxias	Mountain Galaxias	Carp Gudgeon	Southern Pygmy Perch	Flathead Gudgeon	Dwarf Flathead Gudgeon	Western Bluespot Goby	Congolli	Carp Gudgeon	Silver Perch	Murray River Catfish	Goldfish	European Carp	Gambusia	Redfin Perch	Brown Trout	Tench
Gawler River	North Para River	St Hallets Bike Path								390									2306			
		St Hallets Crossing								572							1		168			
		US Landcare Reserve								177							1		140	27		2
		DS Landcare Reserve								13									1	221		3
		Kochs								155		314							2323			
		US Chattertons										12							328			1
		DS Chattertons								329		164							2143	8		3
		US Yaldara weir										26					146		2221			
		Yaldara Weir								224		197					1		938			
	Gawler River	Pony Club				15							1				1		23			
		Gawler Flood Pool				1																
		Old Port Wakefield Road				14				62			3						2			
Torrens River	Upper Torrens	Mount Pleasant Golf Dam																				
		Mount Pleasant Cottage																				
		Talunga Park Bridge																	342			
		Mt Pleasant Crash Repair																	760			
		US Mount Pleasant Pipeline					6			11									40			
		Cromer Rd Bridge					2			2	1							1	1			
	Millers Creek	Winton Rd					222															
		Alexander Forest Road					80															
		Martin Hill Rd																				
Torrens River	First Creek	Chinaman's Hut					239															
		Waterfall Gully					48															

Catchment	Reach	Site Name	Black Bream	Tamar Goby	Climbing Galaxias	Common Galaxias	Mountain Galaxias	Carp Gudgeon	Southern Pygmy Perch	Flathead Gudgeon	Dwarf Flathead Gudgeon	Western Bluespot Goby	Congolli	Carp Gudgeon	Silver Perch	Murray River Catfish	Goldfish	European Carp	Gambusia	Redfin Perch	Brown Trout	Tench
		US Chinaman's Hut					26															
Patawalonga River	Brownhill Creek	Brownhill Ford					443															
		DS Caravan Park					38															
	Sturt Creek	Cherry Plantation					85															
		Star & Arrow Rd																				
		Weymouth Horse Trail					100															
		Weymouth Reserve					58															
		Riverglen Place					4													7		
		Winns Rd																			4	
		Frank Smith Park														1				5		1
		Willow Glen																			4	
		Sturt Valley Rd																				
	Patawalonga	West Beach Road Bridge				30													321			
		Adelaide Shores Golf Course				11													124			
		Adelaide Shores Skate Park	46	1		4						8										
Christie's Creek	Christie's Creek	Thaxted Park Golf Course																				
		Galloway Rd				4													7			
		Christie Wetland															1					
Onkaparinga River	Aldgate Creek	Aldgate Bridge					64															
		Nurrutti Reserve					225															
		Dixons			2		264															
		Mylor Bridge			90		397															

Catchment	Reach	Site Name	Black Bream	Tamar Goby	Climbing Galaxias	Common Galaxias	Mountain Galaxias	Carp Gudgeon	Southern Pygmy Perch	Flathead Gudgeon	Dwarf Flathead Gudgeon	Western Bluespot Goby	Congolli	Carp Gudgeon	Silver Perch	Murray River Catfish	Goldfish	European Carp	Gambusia	Redfin Perch	Brown Trout	Tench
Onkaparinga River		Mylor Dam					18													2468		
	Scott Creek	Scott Creek					11															
		Scott Creek Gauge																	1			
	Onkaparinga River	Charleston					241															
		Clisby Rd					13													18		
		Oakwood Rd								11										8		
		Spoehrs Rd								4	1									43		
		Verdun																	1	67		
		Silverlakes																		2		
Pedler Creek	Pedler Creek	DS Pedler Footbridge				249	4															
Washpool Creek	Washpool Creek	Washpool								1												
Wirra Creek	Wirra Creek	Wirra Creek Bridge					17															
Willunga Creek	Willunga Creek	St. Johns Rd																				
		Methodist St																				
		Norman Road (Giles Rd)																				
Myponga River	Myponga River	DS Myponga River Gauge					222															
		Rogers Rd Culvert			141															2		
		Roger's Property			56																	
		Myponga Township			146															385		
Carrickalinga Creek	Carrickalinga Creek	Rose Cottage			1	1	1													1		
		Riverview Drive			3	42	13						1									
Yankalilla	Yankalilla	Yankalilla River Bridge					4			14			2									

Catchment	Reach	Site Name	Black Bream	Tamar Goby	Climbing Galaxias	Common Galaxias	Mountain Galaxias	Carp Gudgeon	Southern Pygmy Perch	Flathead Gudgeon	Dwarf Flathead Gudgeon	Western Bluespot Goby	Congolli	Carp Gudgeon	Silver Perch	Murray River Catfish	Goldfish	European Carp	Gambusia	Redfin Perch	Brown Trout	Tench
River	River	DS Yankalilla Crossing				37				30			18									
Deep Creek	Deep Creek	Dog Trap Creek																				
		Deep Creek Crossing																			4	
		Rangers Pump																			5	
		Deep Creek Waterfall			13																	
		Deep Creek WF Below			13																1	
Boat Harbour Creek	Boat Harbour Creek	Boat Harbour Guage			3																	
		Boat Harbour Gate 42			19																	
		Boat Harbour Beach				126																
Callawonga Creek	Callawonga Creek	Callawonga Dam																				
		Walker's Waterfall			16																	
		Walker's Place																			4	
		Callawonga			5																7	
		Callawonga Guage																			3	
		Balquhidder				40															4	
		Callawonga Beach				480							109									
Inman River	Inman River	Teague Property			52				208										14			
		Forest Dam																				
		Inman Gauge			20															2		
		Hay Bales																		6		
		White's Property						2										4	3	2		
		Gunter's																4		5		
Inman River	Inman River	Swains Rd Crossing						40					1							4		
Hindmarsh	Hindmarsh	Hindmarsh Falls			72																3	

Catchment	Reach	Site Name	Black Bream	Tamar Goby	Climbing Galaxias	Common Galaxias	Mountain Galaxias	Carp Gudgeon	Southern Pygmy Perch	Flathead Gudgeon	Dwarf Flathead Gudgeon	Western Bluespot Goby	Congolli	Carp Gudgeon	Silver Perch	Murray River Catfish	Goldfish	European Carp	Gambusia	Redfin Perch	Brown Trout	Tench
River	River	Sawpit Rd			14	16							1									
		Cootamundra Reserve	2			384				14			16									
Total			48	1	666	1454	3404	42	208	6029	2	1272	152	1	1	1	188	10	21964	6998	39	24

The most abundant exotic species in the Barossa PWRA were gambusia (20,219 fish), redfin perch (3,972 fish) and goldfish (*Carassius auratus*, 186 fish). The most commonly recorded exotic fish species were gambusia (found on 32 of 44 sampling events), redfin perch (found on 17 occasions) and tench (found on 10 occasions) (Table 1). A single translocated silver perch was caught at the Barossa Novotel site. This constitutes a first record in this catchment.

For the purposes of reporting, the main branch of the North Para River was considered as three distinct reaches, the upper, middle and lower North Para. The tributaries; Greenock Creek, Duck-Pond Creek, Tanunda Creek and Jacobs Creek were also considered as separate reaches. The upper North Para begins in the headwaters near Mount McKenzie at the US Cornerstone Stud site and flows downstream to Penrice Quarry. The middle North Para commences below this site and extends downstream to the St Hallets Bike Path. The lower North Para commences below this with the furthest downstream site being Yaldara Weir.

3.2.1. Duck Ponds Creek

Duck Ponds Creek was sampled at three locations during February 2013 (Rex's Place, US Duck Ponds Pool and DS Duck Ponds Pool). All sites were within a mid pool-riffle reach. This reach is a narrow channel surrounded by pastoral and cropping activities. No fish were caught in Duck Ponds Creek. This was most likely a result of the very low DO levels recorded with maximum DO not exceeding 2.7 $mg.L^{-1}$ and minimum DO no higher than 0.5 $mg.L^{-1}$(Appendix C). All pools were dominated by emergents bulrush (*Typha domingensis*) and common reed (*Phragmites australis*) with no submerged macrophytes observed. Eucalypts (*Eucalyptus sp.*) dominated the riparian zones at all sites (Appendix B). Substrates were predominantly of fine sediment. No flows were observed during sampling.

3.2.2. Jacobs Creek

Jacobs Creek was sampled at three locations during February 2013. The Jacobs Creek Old Gauge site was the furthest upstream and was considered an upper pool-riffle reach while the Jacobs Creek Crossing and Jacobs Creek Visitors Centre sites were within a mid pool-riffle reach. Three fish species (mountain galaxias, flathead gudgeon and redfin perch) were identified within Jacobs Creek. The native mountain galaxias were recorded at all three sites on Jacobs Creek and were in particularly high abundance at the upstream site which appeared to be a source population for the catchment. This was the only reach found to contain mountain galaxias in the Barossa PWRA. The Jacobs Creek Visitors Centre site contained a second native species (flathead gudgeon) in high abundance. A single large redfin perch was recorded at Jacobs Creek Crossing.

Emergent macrophytes varied between sites with common rush (*Juncus usitatus*), bulrush and common reed dominating. Exotic ash (*Fraxinus angustifolia*) and native redgum (*Eucalyptus camaldulensis*) dominated the riparian vegetation and chara (*Chara sp.*) and filamentous algae were the only submerged macrophytes observed. Flow was recorded at the uppermost site (Jacobs Creek Old Gauge) (Appendix B). The landholder stated that this site was spring fed and flows year round. No flow was recorded at either downstream site. Maximum DO recorded at Jacobs Creek Old Gauge was 1.31 $mg.L^{-1}$; much lower that the average recorded within the greater WMLR. Salinity was slightly elevated (3.2 ppt) at the downstream visitors centre, however, parameters were still within suitable levels for the persistence of native fish.

3.2.3. Greenock Creek

Greenock Creek was sampled at two sites during February 2013 (Seppeltsfield Weir and Owen's Grange) with both sites in a mid pool-riffle reach. This tributary was narrow and scoured with little riparian vegetation securing the banks. The emergent macrophyte common reed was present however no submerged macrophytes were observed (Appendix B). Substrates were largely dominated by fine sediments. No flow was present at the time of sampling.

The exotic gambusia was the only fish species recorded in Greenock Creek. The upstream site, Seppeltsfield Weir, contained high abundances of gambusia while the downstream site Owen's Grange contained no fish. Greenock Creek had the highest average salinity (6.14 ppt at Seppeltsfield Weir and 8.65 ppt at Owens Grange) recorded within the Barossa and the highest non-estuarine salinity in the WMLR (Appendix C).

3.2.4. Tanunda Creek

Tanunda Creek was sampled at four locations during February 2013. The three upstream sites (DS Kaiserstuhl, US Tanunda Creek Rd, and DS Tanunda Creek Rd) were upper pool-riffle habitats and the downstream site (Tanunda Railway Crossing) was a mid pool-riffle habitat. All the sites were isolated, with no flow present during the time of sampling. The channel was a narrow, shallow channel, with some erosion present. Fish refuges were limited to a few small still pools with poor habitat qualities. The dominant riparian vegetation were eucalypts with no record of any emergent or submerged vegetation (Appendix B). The dominant substrate at all sites was fine sediment.

Only a single species of fish was observed on Tanunda Creek, the exotic gambusia. This species was in very high abundances at US Tanunda Creek Rd, but at lower abundances at DS Kaiserstuhl and DS Tanunda Creek Rd. The Tanunda Railway Crossing contained no fish.

Maximum dissolved oxygen was low at US Tanunda Creek Rd and DS Kaiserstuhl (2.44 $mg.L^{-1}$). Salinity levels on Tanunda Creek were high at 3.18 ppt (Appendix C).

3.2.5. Upper North Para River

The upper North Para River contained 14 sites, sampled during February 2013. All sites were within a mid pool-riffle reach characterised by moderately wide channels, higher elevation with gradual sloping gradient and scattered pool habitats between reaches of dense emergent macrophyte cover. Emergent macrophytes along this reach were dominated by bulrush and common reed, submerged macrophytes observed included water ribbons (*Triglochin procerum)* and water milfoil (*Myriophyllum amphibium*). Riparian vegetation was dominated by eucalypts and the exotics ash and birch (*Betula* sp.) (Appendix B). Substrates were dominated by very fine sediment. No flow was observed at the time of sampling.

Four fish species were identified within the upper North Para River, one native fish species (flathead gudgeon) and three exotic fish species (gambusia, redfin perch and tench). The native flathead gudgeon was recorded in moderate to high abundances at five sites of the reach between Thorne-Clark Ford and Penrice Quarry. The exotic gambusia and redfin perch were recorded in high abundances throughout the upper North Para reach; Tench was restricted to the lower section of this reach and in low abundance.

Maximum DO levels within the upper North Para River were relatively low compared to most catchments across the WMLR. US Evans Weir was a notable exception with a maximum DO of 24.20 $mg.L^{-1}$. This site was in algal bloom at the time of sampling. Minimum DO across the upper North Para sites was on average, two times lower than the average recorded in the WMLR. Salinity at most sites along this reach was two to four times higher than the WMLR average (Appendix C).

3.2.6. Mid North Para River

The mid North Para River was sampled at nine locations during February 2013. All sites were within mid pool-riffle habitats and characterised by moderately wide channels lined with dense macrophytes. Substrates were dominated by fine sediments.

Five fish species were recorded within the mid North Para River, one native (flathead gudgeon) and four exotic (goldfish, European carp (*Cyprinus carpio)*, gambusia, and tench). Along the reach flathead gudgeon and gambusia were recorded in very high abundances. The remaining species goldfish, European carp and tench were present in low abundances and with patchy distributions. The absence of redfin perch in this reach is notable as they were present in both the upper and lower reaches of the North Para River.

Emergent macrophytes were dominated by bulrush and common reed. Riparian vegetation was predominantly comprised of *Eucalyptus* species and ash. The only submerged macrophyte observed was curled pondweed (*Potamogeton crispus*) (Appendix B). No flow was present at the time of sampling. Maximum DO was, on average, significantly lower than other WMLR catchments. Salinity was typically elevated, being between 2 and 5 ppt at most sites. Water quality parameters including, temperature, salinity, pH and turbidity were within suitable levels required for the persistence of native fish (Appendix C).

3.2.7. Lower North Para River

The lower North Para River was sampled at eight locations during February 2013. All sites were within a mid pool-riffle reach characterised by high, often steep, valley walls and rocky creek beds lined with bedrock and large boulders. The lower North Para reach contained the greatest richness of fish species observed in the Barossa PWRA. This included two native species (flathead gudgeon and western blue spot goby), four exotic fish species (goldfish, gambusia, redfin perch and tench) and one translocated Murray-Darling fish species, silver perch (*Bidyanus bidyanus*). Both species of native fish were found in high abundance at most sites. A single translocated silver perch was caught at the Barossa Novotel site. This was a first record of this species in this catchment and the only instance of this species in the current study. The exotic gambusia was recorded in high abundance at most sites in this reach. Exotic goldfish, redfin perch and tench were distributed patchily and in varying abundance within the reach.

Emergent macrophytes were dominated by bulrush. Riparian vegetation was dominated by exotic plants such as ash and giant cane (*Arundo donax*) (Appendix B). No submerged vegetation was observed in this reach. Substrates were a mixture of cobble, gravel and bedrock (10+ mm). Maximum DO was relatively high across all sites within the lower North Para, with each site above 10 $mg.L^{-1}$. DS Landcare Reserve had the highest maximum recorded DO reading of 24 $mg.L^{-1}$, more than three times the average maximum DO recorded throughout the WMLR. Salinities were elevated and ranged between 2 and 5 ppt (Appendix C).

3.3. Multivariate analysis of the Barossa Prescribed Water Resource Area

SIMPER analysis and distance based linear models indicated that mountain galaxias ($p < 0.001$), gambusia ($p < 0.001$), redfin perch ($p < 0.001$), flathead gudgeon ($p < 0.001$) and sites where no fish were caught ($p < 0.001$) were the significant factors separating the sites. Cluster analysis of the normalised CPUE data found only a single significant grouping (Figure 4). This distinguished sites with fish as being significantly different from sites without fish. Although not significant, six clusters are distinguishable when a 50% level of similarity is considered. These are presented in descending order:

- **Group 1**: Contained 14 sites that all contained flathead gudgeon in their composition
- **Group 2**: Contained 10 sites that were all dominated by gambusia.
- **Group 3**: Contained four sites with gambusia present at each site, but in comparatively low abundance.
- **Group 4**: Contained seven sites that all contained redfin perch.
- **Group 5**: Was comprised of two sites that both contained more than a single mountain galaxias.
- **Group 6**: Was significantly different to the other sites within the Barossa PWRA and was composed of the six sites where nets were set, but no fish were caught.

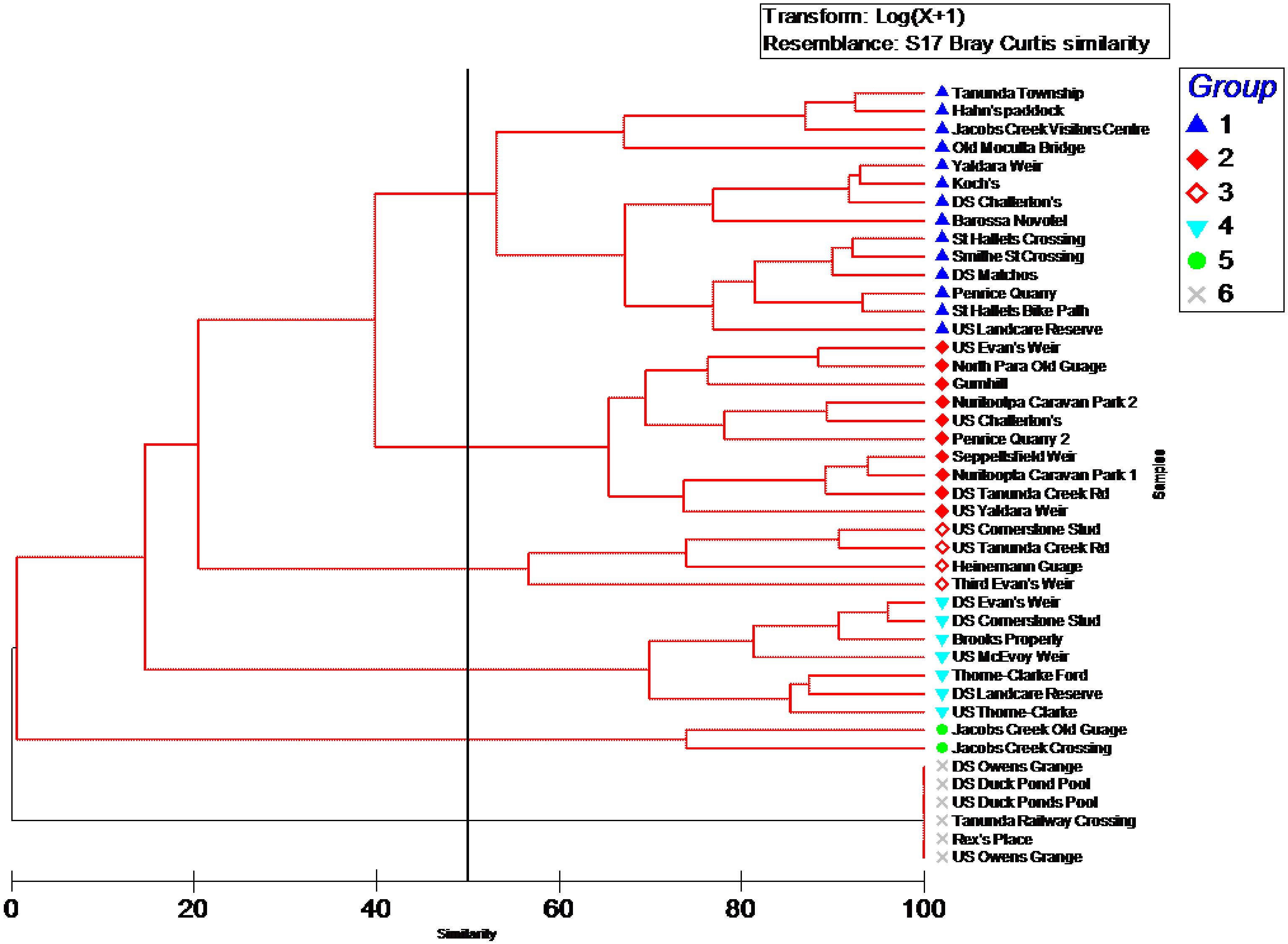

Figure 4. Dendrogram displaying cluster analysis of the normalised CPUE data for the Barossa PWRA. Group affiliation (described in text) defined by 50% similarity indicated on dendrogram by solid black line.

Distance based linear model analysis showed that minimum dissolved oxygen (p = 0.043), salinity (p = 0.002) and turbidity (p = 0.018) were three environmental variables that significantly contributed to explaining fish assemblage groups). Combined water quality parameters were calculated to an R^2 value of 0.34, suggesting that these parameters account for 34% of the variability in fish community composition (Figure 5).

Group 1 was positioned primarily along the vector of higher salinity. Group 2 and 3 were positioned along the vector of high turbidity and low dissolved oxygen. In this way, communities typified by high densities of flathead gudgeon or Gambusia may be seen to thrive in the poorer quality water of the Barossa Valley. The native mountain galaxias (Group 5) was restricted to areas with better water quality and lower turbidity, although it was also positioned along a third axis with no significant environmental correlate. Communities dominated by redfin perch (Group 4) were associated with areas of comparatively better water quality and associated negatively with salinity in the Barossa Valley.

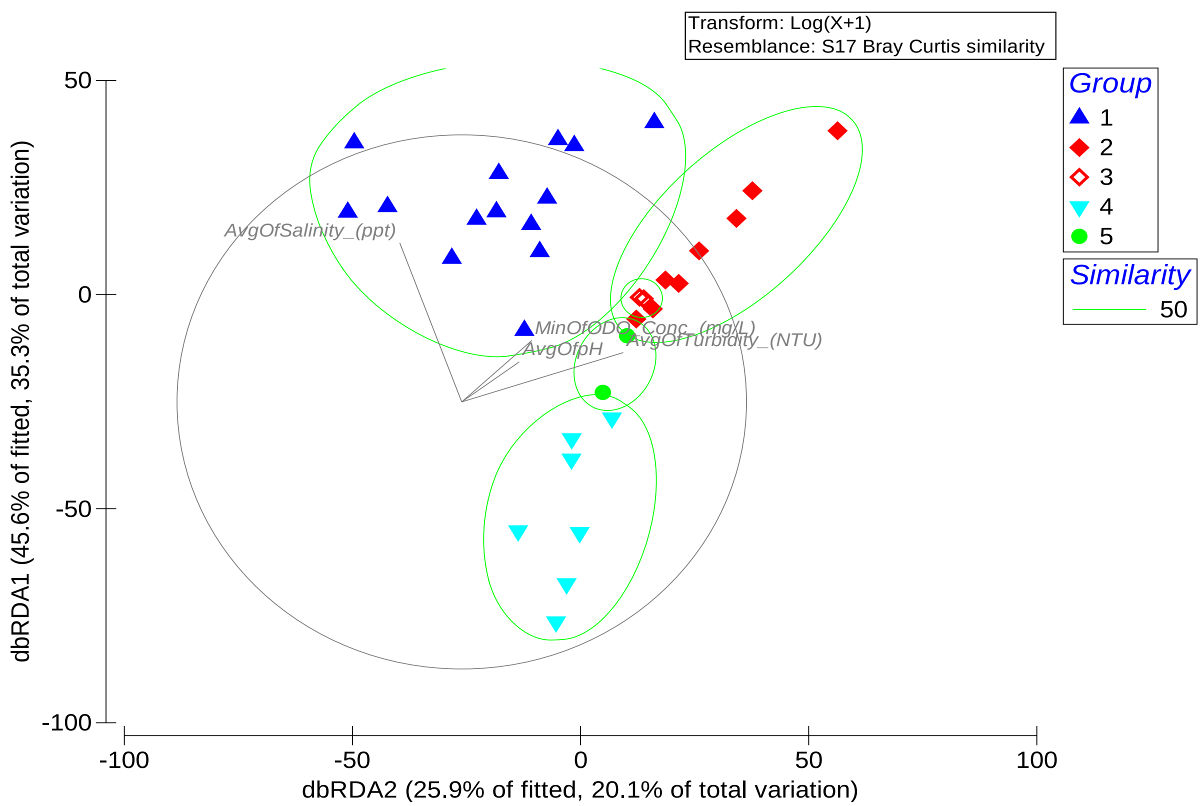

Figure 5. Plot of distance based linear model for the Barossa PWRA displaying correlation of species group clusters with environmental variables.

3.4. VWASP - Results by River

3.4.1. Tanunda Creek

Tanunda Creek was sampled at four locations during February 2013. The three upstream sites (DS Kaiserstuhl [BAR06015], US Tanunda Creek Rd [BAR0602], and DS Tanunda Creek Rd [BAR0603]) were upper pool-riffle habitats and the downstream site (Tanunda Railway Crossing [BAR0604]) was a mid pool-riffle habitat. The site of the Tanunda Creek gauging station (Tanunda Gauge [BAR06]) was dry at the time of sampling. All the sites were isolated, with no flow present during the time of sampling. The channel was a narrow, shallow channel, with some erosion present. Fish refuges were limited to a few small still pools with poor habitat qualities. The dominant riparian vegetation was *Eucalyptus* with no record of any emergent or submerged vegetation. The dominant substrate at all sites was fine sediment.

Only a single species of fish was observed on Tanunda Creek, the exotic gambusia. This species was in very high abundance at US Tanunda Creek Rd, but at lower abundances at DS Kaiserstuhl and DS Tanunda Creek Rd. The Tanunda Railway Crossing contained no fish. Maximum DO was low at US Tanunda Creek Rd and DS Kaiserstuhl (2.44 $mg.L^{-1}$). Salinity levels on Tanunda Creek were high at 3.18 ppt (Appendix C).

3.4.2. Lower North Para River reach

The lower North Para River reach was sampled at seven locations during February 2013 (US Landcare Reserve [PWNP008], DS Landcare Reserve [PWNP019], US Chattertons [BAR0301], DS Chattertons [BAR0303], Koch's [BAR0304], US Yaldara Weir [BAR0305] and Yaldara [BAR0306]). All sites were within a mid pool-riffle reach characterised by high, often steep, valley walls and rocky creek beds lined with bedrock and large boulders. The lower North Para reach two native species (flathead gudgeon and western blue spot goby) and four exotic fish species (goldfish, gambusia, redfin perch and tench). Both species of native fish were found in high abundance at most sites. The exotic gambusia was recorded in high abundance at most sites in this reach. Exotic goldfish, redfin perch and tench were distributed patchily and in varying abundance along the reach.

Emergent macrophytes were dominated by bulrush. Riparian vegetation was dominated by exotic plants such as ash and giant cane. No submerged vegetation was observed in this reach (Appendix B). Substrates were a mixture of cobble, gravel and bedrock (10+ mm). Maximum DO was relatively high across all sites within the lower North Para, with each site above 10 mg.L^{-1}. DS Landcare Reserve had the highest maximum recorded DO reading of 24 mg.L^{-1}, more than three times the average maximum DO recorded throughout the WMLR. Salinities in this reach were elevated and ranged between 2 and 5 ppt (Appendix C).

3.4.3. First Creek

First Creek is a tributary of the River Torrens and was sampled at three locations during January 2013; US Chinamans Hut [AP01015], Chinamans Hut [AP0103] and Waterfall Gully [AP01]. All sites were above First Falls and are upper pool-riffle habitats. This reach is characterised by steep, rocky terrain punctuated by waterfalls and riffles. One native species (mountain galaxias) was identified along this reach, in high abundance and with multiple age classes present in the population.

Water quality parameters including DO, temperature, salinity, pH and turbidity were within suitable levels required for the persistence of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014). Patchy emergent bulrush was observed, but no submerged macrophytes were present. Riparian vegetation was dominated by wattles (*Acacia* spp.) and blackberry (*Rubus* fruticosus) (Appendix B). Substrates were dominated by large boulders, cobble and bedrock. All sites were flowing at the time of sampling, fed by springs observed seeping into the channel further upstream.

3.4.4. Millers Creek

Millers Creek is a tributary of the River Torrens and was sampled at three locations during December 2012 (Martin Hill Rd [WMLR1402], Alexander Forest Rd [WMLR1404] and Winton Rd [WMLR1405]). All sites are within mid pool-riffle reach along a narrow, scoured channel with severe erosion apparent (Figure 6). Only a single fish species was detected In Millers Creek, the native mountain galaxias.

Water quality parameters including DO, temperature, salinity, pH and turbidity were within suitable levels required for the persistence of native fish (McNeil *et al*., 2011, Schmarr *et al*., 2014). The only submerged macrophyte observed was water ribbons. Riparian vegetation varied, but was dominated by exotic species including willow (*Salix sepulcralis*) and blackberry. Also noted were native wattle species (Appendix B). Substrates were dominated by fine sediments; no flow was present at the time of sampling.

Figure 6. Severe erosion immediately downstream of the Winton Rd site [WMLR1405].

3.4.5. Torrens River

Six sites (Mt Pleasant Golf Dam [WMLR1501], Mt Pleasant Cottage [WMLR1502], Talunga Park Bridge [WMLR15], Mt Pleasant Crash Repair [WMLR1504], Mt Pleasant Pipeline [WMLR15055] and Cromer Rd Bridge [WMLR1507]) were sampled on the Upper Torrens River between December 2012 and January 2013. No flows were recorded within the upstream sites; however at the time of sampling the Mount Pleasant pipeline (where influent waters of the River Murray enter the upper Torrens) was open and flowing strongly and both Mount Pleasant Pipeline and Cromer Road Bridge sites experienced high flows.

Two native, two exotic and one translocated fish species were caught in the Upper Torrens catchment. The most common and abundant fish was the exotic gambusia, which was caught at four sites. The two downstream sites contained the native flathead gudgeon and mountain galaxias. One exotic European carp and one translocated dwarf flathead gudgeon were caught at downstream sites.

The only emergent macrophytes observed were bulrushes. Filamentous algae was also present, predominantly in the still dark pools of the upper sites. Eucalyptus and wattle species dominated the riparian vegetation (Appendix B). Substrates were predominantly comprised of fine, silty sediments with some complex snags also present. All water quality parameters were still within suitable levels required for the persistence of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.4.6. Brownhill Creek

Brownhill Creek was sampled at two locations during January 2013; these sites were within mid pool-riffle reaches. The upper site, Brownhill Ford [AP0201] is characterised by narrow, steep banks with fine sediment dominating the substrate and oak trees (*Quercus* spp.) species lining the channel. The lower site, DS Brownhill Caravan Park [AP0202] was a wider, deeper pool enclosed by *willow* and *ash*, with copious amounts of leaf litter covering the bottom of the pool (Appendix B). Very low flows were observed at both sites at the time of sampling. The native mountain galaxias was the only species recorded at either site, with a high abundance of individuals observed at the upper site, compared to a relatively low abundance at the downstream site.

Water quality parameters including temperature, salinity, pH and turbidity were within suitable levels required for the persistence of native fish (McNeil *et al*., 2011, Schmarr *et al*., 2014). Maximum DO at the downstream site was much lower compared to that of the upstream site (Appendix C).

3.4.7. Aldgate Creek

Aldgate Creek is a tributary of the Onkaparinga River and was sampled at five locations during December 2012. The three upstream sites Aldgate Bridge [WMLR1001], Narutti Reserve [WMLR1003] and Dixons [WMLR1005] are within an upper pool-riffle reach. The two lower sites Mylor Bridge [WMLR10] and Mylor Dam [WMLR1006] are within a mid pool-riffle reach. Upstream sites were characterised by narrow channels with substrates of cobble and bedrock. The furthest downstream site Mylor Dam was a large, in-channel dam. Three fish species were observed in Aldgate Creek; two native galaxiids (climbing and mountain galaxias) were recorded in moderate-high abundances and one exotic species (redfin perch) was recorded in very high abundance and was restricted to Mylor Dam. The majority of galaxiids were recorded in the middle and upper sites of Aldgate Creek, with only 18 individuals recorded at Mylor Dam.

No submerged macrophytes and very few emergent plants were present at these sites. Riparian vegetation was dominated by exotic species including willow, oak (*Quercus* spp.) and blackberry (Appendix B). Flows were intermittent, with low flow recorded during initial sampling and no flow recorded during subsequent visits. The lowest maximum DO records (2.56-1.38 $mg.L^{-1}$) were at Narutti Reserve and Dixons. All other water quality parameters including temperature, salinity, pH and turbidity were within the levels required for the persistence of native fish (McNeil *et al*., 2011, Schmarr *et al*., 2014).

3.4.8. Myponga River

The Myponga River was sampled at four locations during November and December 2012; DS Myponga River Gauge [WMLR1600], Rogers Rd Culvert [WMLR1604], Roger's [WMLR16045] and Myponga Township [WMLR1607]. All pools are within a mid pool-riffle reach type. Two native fish species (mountain galaxias and climbing galaxias) were recorded within moderate-high abundances within the Myponga River. Mountain galaxias were confined to small pools in the upstream sites of the river, with climbing galaxias found through the middle Myponga reach. Exotic redfin perch were recorded in the middle reaches of the river in low abundance and the lowest site (Myponga township) was dominated by juvenile redfin perch.

Common reed, bulrush and some sedges were the only macrophytes recorded in the Myponga catchment (Appendix B). Substrates were primarily comprised of fine sediments. Very low flows were observed in the upper sites with no connectivity in the lower sites. Water quality parameters including DO, temperature, salinity, pH and turbidity were within suitable levels for the persistence of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.4.9. Boat Harbour Creek

Boat Harbor Creek was sampled at three locations during June 2013. This included two sites within upper pool-riffle habitats (Boat Harbour Creek Gauge [WMLR21] and Gate 42 [WMLR2101]) and one downstream site Boat Harbour Beach [WMLR2102]) in a terminal wetland reach. Small numbers of climbing galaxias were found in the two upstream sites and a moderate number of common galaxias were observed in the terminal wetland below.

During this period emergent vegetation was dominated by reeds and sedges such as bulrush and spiny flat-sedge (*Cyperus gymnocaulos*). No submerged macrophytes were observed and riparian vegetation was dominated by ti-tree (*Melaleuca sp*.) and grasses (Appendix B). Dominant substrates ranged from fine sediment to coarse sand. At the time of sampling flows were moderate-high. The deepest pool sampled was measured at 1.2 metres deep. The furthest downstream site was within 500m of the ocean and had an average salinity of 0.17 ppt. This reading suggests a lack of oceanic ingress at this site. All water quality parameters throughout

Boat Harbour Creek, including DO, temperature, salinity, pH and turbidity were within suitable levels for the persistence of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.4.10. Callawonga Creek

Callawonga Creek was sampled at seven sites during November and December 2012. The six upstream sites (Callawonga Dam [WMLR0201], Walker's Waterfall [WMLR0203A], Walker's [WMLR0203B], Callawonga [WMLR0204], Callawonga Gauge [WMLR02], Balquhidder [WMLR0205]) were within upper pool-riffle habitats and the downstream site, Callawonga Beach [WMLR0206] was within a terminal wetland. Disregarding the uppermost site, Callawonga Dam which was a small man made dam, the majority of the upstream habitats were characterised by narrow, fast flowing channels, generally with bedrock, boulder and cobble substrate and punctuated by small waterfalls. The furthest downstream site, Callawonga Beach was characterised by broad, flat channel with shallow banks and a substrate dominated by fine sediment.

Four fish species were identified within Callawonga Creek; three native (climbing galaxias, common galaxias, congolli (*Pseudaphritis urvillii*)) and one exotic (brown trout). These fish were spatially segregated with the majority of climbing galaxias, particularly larger adult fish, observed above Walker's Waterfall. The exotic brown trout dominated the reaches below this with some climbing galaxias persisting in marginal habitats. Balquhidder and the sites downstream of this supported common galaxias. Congolli were present only at Callawonga Beach.

Water quality parameters including DO, temperature, pH and turbidity were within suitable levels required to maintain the persistence of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014), with the exception of salinity at Callawonga Beach which had an average salinity of 16.89 ppt suggesting tidal influence at this site. Submerged macrophytes observed in Callawonga Creek included fennel pondweed (*Potamogeton pectinatus*), knotweed (*Persecaria sp*.) and water milfoil. Emergent macrophytes were dominated by reeds and sedges, whilst riparian vegetation was dominated by ti-tree and sedges (Appendix B). All sites were connected via a low – moderate flow at the time of sampling.

3.4.11. Inman River

The Inman River was sampled at seven locations during November and December 2012. The furthest upstream site, Teague's [WMLR0601] is within an upper pool-riffle reach type, the remaining downstream sites are all within mid pool-riffle habitats (Appendix A). Most sites were characterised by wide, scoured channels with rocky substrates.

Seven fish species were identified within the Inman River; four native and three exotic. The furthest upstream site supported a high abundance of the locally endangered (Hammer *et al.* 2010) southern pygmy perch (*Nannoperca australis*), climbing galaxias and the exotic gambusia. Downstream of this site the river was dominated by exotic fish; European carp, gambusia and redfin perch. However, low numbers of climbing galaxias were also caught at Glacier Rock Gauging Station, and Swains Crossing had a moderate abundance of carp gudgeon.

Emergent vegetation along the Inman River was dominated by reeds and sedges. A diverse range of submerged macrophyte species were observed at Teague's, however no other submerged macrophytes were recorded in the catchment. Riparian vegetation was dominated by *Eucalyptus* species (Appendix B). Salinity was slightly elevated at the downstream site (Swains Crossing) and all other parameters were within levels suitable for the persistence of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5. WMLR Fish community monitoring – Results by river

3.5.1. Gawler River

The Gawler River was sampled at three locations during June 2013; Pony Club, Gawler Flood Pool and Old Port Wakefield Rd. All sites are along a lowland reach running through a slightly urbanised, but predominantly agricultural setting.

Five fish species were recorded within the Gawler River, three native and two exotic. Low numbers of native common galaxias were present at each site. Several congolli were present at Pony Club and Old Port Wakefield Rd. At the furthest downstream site flathead gudgeon were present in reasonable numbers. One exotic goldfish was recorded at the upstream site, Pony Club and low numbers of gambusia were recorded at both Pony Club and Old Port Wakefield Rd.

Emergent macrophytes were dominated by common reed and riparian vegetation was dominated by reeds and eucalyptus (Appendix B). Substrates were dominated by fine sediment.

No flow was present during sampling. The minimum dissolved oxygen was low (1.59 $mg.L^{-1}$) and salinity slightly elevated (3.54 ppt) at Old Port Wakefield Rd (Appendix C).

3.5.2. Little Para River

The Little Para River was sampled at three sites. The One Tree Hill Crossing site was sampled in February 2013 and the Happy Home Reserve and Whites Road Wetland sites were sampled in June 2013. The One Tree Hill Crossing site was the furthest upstream and is within a mid pool-riffle reach. One native (flathead gudgeon) and one translocated species (carp gudgeon) were recorded. This is the first record of carp gudgeon occurring in this catchment. The two downstream sites are below the Little Para Reservoir and lie within lowland reaches. The only species recorded at either of the downstream sites was gambusia.

Vegetation varied from riparian fruit trees and ash at One Tree Hill Crossing to the thoughtfully revegetated Whites Road Wetland (Appendix B). Substrate was fine and silty throughout. Strong flow was present at One Tree Hill Crossing, but not at the other two sites. Water quality parameters including DO, temperature, salinity, pH and turbidity were within suitable levels for the persistence of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.3. Sturt Creek

Sturt Creek is a tributary of the Patawalonga Catchment and was sampled at nine sites during May and June 2013 (Cherry Plantation, Sturt Valley Rd, Willow Glen, Frank Smith Park, Winns Rd, Riverglen Place, Star and Arrow Rd, Weymouth Horse Trail and Weymouth Reserve). All sites were within upper and mid pool reach habitats. One native, three exotic and one translocated fish species were recorded in Sturt Creek. The native mountain galaxias was found at Cherry Garden, Weymouth Horse Trail, Weymouth Reserve and Coromandel in a low to moderate abundance. One Murray River catfish was recorded at Frank Smith Park, in addition to five redfin perch, and two tench. This record of tench is a new record for this catchment. Four brown trout were caught at Willow Glen and another four at Winns Rd.

All measured water quality parameters were within ranges suitable for native fish persistence (McNeil *et al*. 2011, Schmarr *et al*. 2014). Emergent vegetation included water pennywort (*Hydrocotyle ranunculoides*), kikuyu (*Pennisetum clandestinum*) and giant cane. The two sites upstream contained large amounts of blackberry. Downstream sites contained common rush, eucalyptus and ash as the dominant riparian vegetation (Appendix B). Substrates ranged from fine sediments to gravel, with some small and large complex snags also recorded. All sites were connected by moderate flows during sampling, with a minor flood affecting sampling at both Weymouth Reserve and Winns Road.

3.5.4. Patawalonga River

The Patawalonga River was sampled at three sites during June 2013. All the sites were in close proximity along a near-estuarine terminal wetland reach. Four native and one exotic fish species were found in this reach. At the two upstream sites; West Beach Road Bridge and Adelaide Shores Golf Course, the native common galaxias and the exotic gambusia were recorded in relatively low abundance. The furthest downstream site, Adelaide Shores Skate Park contained common galaxias and as well as three native estuarine species; black bream (*Acanthopagrus butcheri*), Tamar goby (*Afurcagobius tamarensis*), and western blue spot goby.

Riparian macrophytes varied and included bulrush, sedges and ti-tree species (Appendix B). Substrate were predominantly fine sediment and with large and small complex snags present. These three sites were isolated from each other with no flow recorded at time of sampling, depths varied from 0.8 m to 2 m deep.

3.5.5. Christie Creek

Christie Creek was sampled at three separate locations during May 2013; all three sites are within lowland reach types. The uppermost site was a dam on Thaxted Park Golf Course; with the Christies Wetland and Galloway Rd sites further downstream along the main channel. The fish assemblage along Christie Creek consisted of one native and two exotic species. The upstream site, Thaxted Park Golf Course, contained no fish. Christie Wetland contained one individual goldfish and the furthest downstream site, Galloway Rd, contained one common galaxias and seven gambusia.

The two lower sites had low-moderate flows and macrophyte cover dominated by common reed. The upper site was isolated from the main channel, with riparian cover dominated by *Eucalyptus* (Appendix B). Substrates at all three sites were dominated by fine sediment. All water quality parameters were within the expected ranges at each site and should not present issues for fish survival (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.6. Onkaparinga River

The Onkaparinga River was sampled at eight locations during June 2013 (Appendix A). All sites were along an upper/mid pool-riffle. Five species of fish were identified within the Onkaparinga

River, three native (mountain galaxias, flathead gudgeon, dwarf flathead gudgeon) and two exotic (gambusia and redfin perch). A low abundance of native species were recorded in the upper reaches of the Onkaparinga catchment. A low-moderate abundance of redfin perch were recorded throughout many sites throughout the catchment, with the exception of Scott Creek. Just one gambusia and a small number of mountain galaxias were recorded on Scott Creek.

Emergent macrophytes, bulrush, common rush, club-rush (*Schoenoplectus* spp.) and water fern (*Azolla* spp.) were dominant. One species of submerged macrophyte, ribbon weed (*Vallisneria americana*) was recorded on Balhannah-Spoehrs road. The riparian vegetation along this catchment was dominated by various species of grass in addition to willow and club-rushes (Appendix B). All the sites were connected and flow rates varied from low to moderate during the time of sampling. Substrates varied from silt to gravel with multiple snags present across most sites.

Aquatic turbidity measurements in this catchment were varied being between 6.9 NTU at Aldgate Bridge and 95.4 NTU at Clisby Rd, with most sites displaying high values (Appendix C). All other water quality parameters were within limits considered acceptable for the survival of native fish (McNeil *et al*. 2011 Schmarr *et al*. 2014).

3.5.7. Pedler Creek

Pedler Creek was sampled at one location (DS Pedler Footbridge) during June 2013, which was within a lowland reach type and was a small, densely vegetated channel next to flood retention ponds. Two native species were identified within Pedler Creek with common galaxias found in high abundance and four mountain galaxias also recorded.

The majority of emergent macrophytes were common reed and the riparian vegetation was dominated by kikuyu (Appendix B). Substrates were predominantly fine sediments and the site was flowing at the time of sampling. Water quality parameters were within the limits considered acceptable for the survival of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.8. Wirra Creek

Wirra Creek was sampled at one site (Wirra Creek Bridge) in June 2013, which was within a mid pool-riffle reach type. The native mountain galaxias was the only species recorded at the Wirra Creek Bridge. This species was in low abundance and most individuals were in spawning condition.

Arum lily (*Zantedeschia aethiopica*) and exotic trees lined the creek and no submerged vegetation was present (Appendix B). The site was flowing moderately with a fine, silty substrate. Water quality parameters were within the limits considered acceptable for the survival of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.9. Willunga Creek

Three sites were sampled on Willunga Creek during June 2013; St Johns Rd, Methodist St and Norman Rd. These sites are within a mid pool-riffle habitat. No fish were detected in Willunga Creek on this occasion.

No submerged vegetation was observed and the dominant emergent vegetation was arum lily. Riparian vegetation included ash and willow. All sites were connected with low to moderate flows occurring during sampling. Substrates were deep silty sediment. The maximum dissolved oxygen at St. Johns Road was low (1.43 $mg.L^{-1}$, Appendix C), however all other water quality parameters were within the limits considered acceptable for the survival of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.10. Washpool Creek

Washpool Creek was sampled at a single site in June 2013. This site was within a terminal wetland reach amidst samphire swamps (Appendix B). The Washpool was isolated from the main channel, with no flow recorded at the time of sampling. A single flathead gudgeon was identified above the concrete footbridge and no other fish were observed.

Wattles and grasses were the dominant riparian vegetation with filamentous algae present submerged within the water. Salinity levels at the Washpool were lower than expected given its proximity to the ocean (Appendix C) and all water quality parameters were within the limits considered acceptable for the survival of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.11. Carrickalinga Creek

Carrickalinga Creek was sampled at two locations during June 2013. The upstream site, Rose Cottage, is within a mid pool-riffle reach and the downstream site, Riverview Drive, is within a lowland reach. Four native and one exotic fish species were found including each of the three native galaxiids species (common, climbing and mountain). Riverview Drive was dominated by common galaxias. A single exotic redfin perch was observed at Rose Cottage.

The downstream site was dominated by bulrush and eucalypts, with no submerged macrophyte species observed at either site (Appendix B). At the time both sites were set there was no flow present, however overnight rains caused moderate flows resulting in some nets being dislodged and/or closed off. Water quality parameters were within the limits considered acceptable for the survival of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.12. Yankalilla River

The Yankalilla River was sampled at a single site in June 2013; this site is within a mid pool-riffle reach type. Four native fish species were recorded in the Yankalilla River; flathead gudgeon, congolli, mountain galaxias and common galaxias.

Riparian vegetation was dominated by mature eucalyptus and grasses. No submerged or emergent vegetation was observed (Appendix B). High flows were recorded at the time of sampling. All water quality parameters were within the limits considered acceptable for the survival of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.13. Deep Creek

Deep Creek was sampled at four locations during June 2013 (Appendix A), which were within upper pool-riffle habitats. Two fish species were recorded within Deep Creek, one native (climbing galaxias) and one exotic species (brown trout). The native climbing galaxias were isolated below the Deep Creek Waterfall while brown trout occurred in low abundance along the reach.

One species of submerged macrohphyte (water ribbons) was recorded at Rangers Pump. Riparian vegetation was dominated by ti-trees (Appendix B). Substrates varied from fine sediment to gravel (5-10) and bedrock with snags present at each site. At the time of sampling the flow was moderate to high and all water quality parameters were within the limits considered acceptable for the survival of native fish (McNeil *et al*. 2011, Schmarr *et al*. 2014).

3.5.14. Hindmarsh River

The Hindmarsh River was sampled at three locations in June 2013; the furthest upstream site Hindmarsh Falls is in an upper pool-riffle habitat, the middle site at Saw Pit Road is within a mid pool-riffle habitat and the lowest site at Cootamundra Reserve was in a terminal wetland. Five native and one exotic fish species were caught in the Hindmarsh River. Several species displayed restricted distributions with the exotic brown trout only found at Hindmarsh Falls, and flathead gudgeon and black bream only found at Cootamundra Reserve.

Emergent and riparian vegetation was dominated by common reed and willow respectively. The only submerged macrophyte observed was water milfoil (Appendix B). Substrates ranged between fine sediment and bedrock and all sites were connected and flowing at the time of sampling.

3.6. WMLR Fish community monitoring multivariate analysis results

The multivariate SIMPER analysis and distance based linear models indicated that climbing galaxias, common galaxias, mountain galaxias, gambusia, redfin perch, flathead gudgeon, western blue spot goby, congolli, tench and sites where no fish were caught were all significant factors ($P<0.001$) defining similarity between sites (Figure 8). Eight significant clusters were identified within the dendrogram with over half of the sites being clumped into a single group (Figure 8). These were:

- **Group 1** is large cluster of 62 sites characterised by flathead gudgeon, gambusia and redfin perch.
- **Group 2** is a cluster of seven sites characterised by common galaxias.
- **Group 3** is a cluster of 20 sites dominated by mountain galaxias.
- **Group 4** is a cluster of 11 sites dominated by climbing galaxias
- **Group 5** is a cluster of six sites dominated by brown trout.
- **Group 6** is a cluster of two sites with multiple species in low numbers
- **Group 7** is one site where only a single goldfish was caught
- **Group 8** is a cluster comprised of 19 sites where no fish were recorded

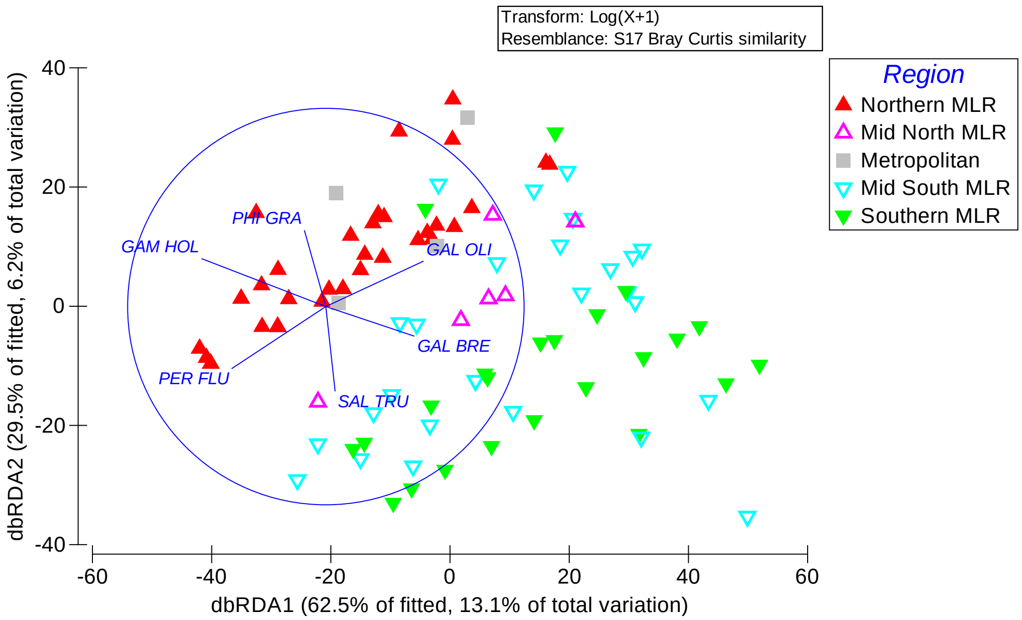

Figure 7. Plot of distance based linear model for the WMLR region surveys displaying the correlation of geographical grouping with fish species CPUE. The species that correlate significantly with region were gambusia (GAM HOL), flathead gudgeon (PHI GRA), mountain galaxias (GAL OLI), climbing galaxias (GAL BRE), brown trout (SAL TRU) and redfin perch (PER FLU).

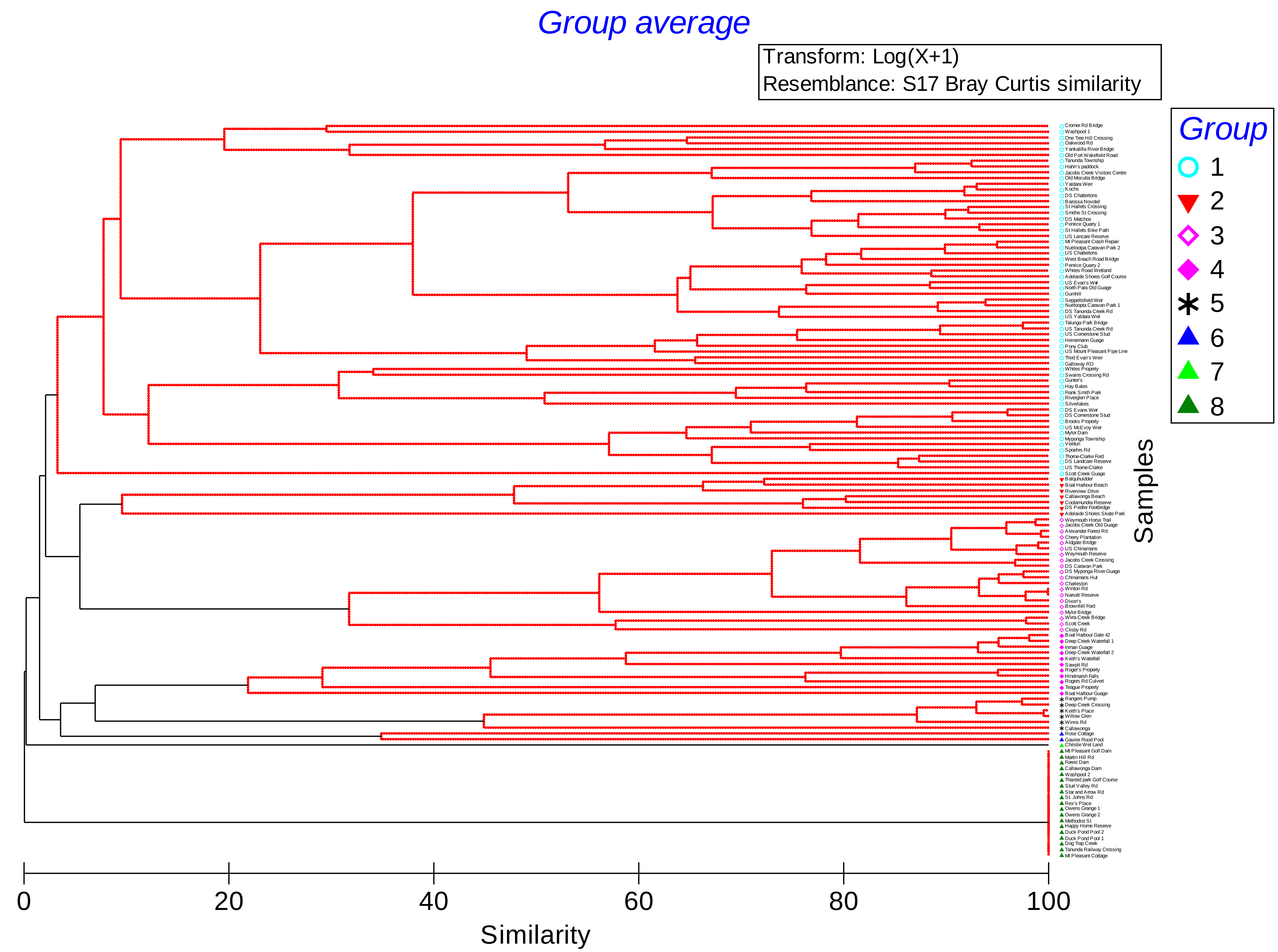

Figure 8. Dendrogram displaying cluster analysis of the normalised CPUE data for the entire WMLR region survey. Group affiliation described in text.

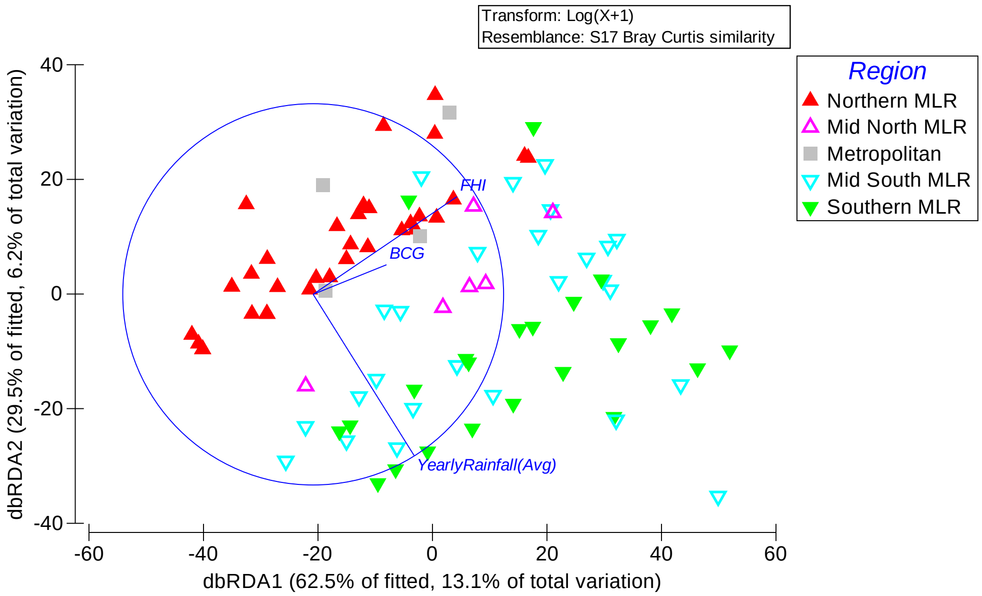

Figure 9. Plot of distance based linear model for the entire WMLR region survey displaying correlation between geographic region, annual rainfall and the biological condition gradient (BCG) and fish health index (FHI) site scores.

Distance based linear model analyses on an environmental dataset comprised of mean annual rainfall and derived condition scores (BCG and FHI) determined significance for all three variables; average rainfall ($P<0.001$), FHI scores ($P<0.001$) and BCG scores ($P<0.001$). Data were visualised on a DISTLM plot (Figure 9) and show that higher rainfalls related to both geographic region and the fish communities therein, with communities in higher rainfall areas being driven by the presence of climbing galaxias and brown trout (Figure 7). Distance based linear model analyses on the second set of environmental data (comprised of aquatic average temperature, salinity, pH, turbidity, and maximum and minimum dissolved oxygen) determined that minimum dissolved oxygen ($P<0.001$), average salinity ($P<0.001$), average pH ($P=0.001$) and average turbidity ($P<0.001$) all correlated significantly to differences in fish community. These data were plotted using a DISTLM plot (Figure 10), which displays a correlation between elevated aquatic salinity and the northern section of the WMLR. This region is also correlated with lower annual rainfall (Figure 9) and fish communities dominated by gambusia, redfin perch and flathead gudgeon (Figure 7). Conversely higher minimum dissolved oxygen values were correlated with the southern region of the WMLR (Figure 10) where annual rainfall is higher (Figure 9) and fish communities are driven by climbing galaxias and brown trout (Figure 7).

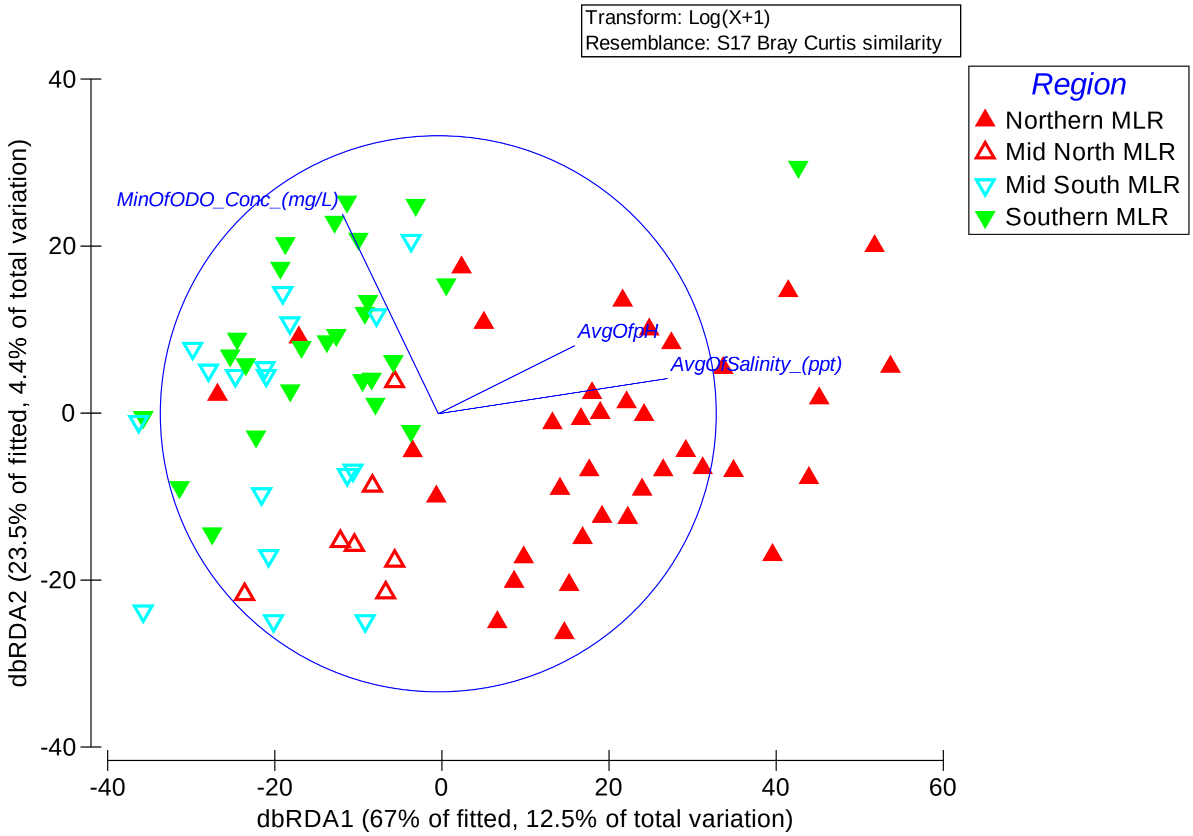

Figure 10. Plot of distance based linear model for the entire WMLR region survey displaying correlation of geographical clusters with significant environmental water quality measurements.

4. DISCUSSION

4.1. Barossa species

4.1.1. Gambusia (*Gambusia holbrooki*)

Sampling in the Barossa study yielded 20,244 exotic gambusia. This species constituted 70.2% of the 28,839 fish caught in the Barossa PWRA and the Barossa PWRA gambusia population made up 47.6% of the entire fish catch across the 120 sites examined in the greater study. This species is a highly successful invader (Lowe *et al.* 2000) with a remarkable reproductive capacity (Milton and Arthington 1983). It is able to thrive in impacted aquatic environments due to its high tolerance of elevated salinity (Chervinski 1983), low dissolved oxygen (Lewis 1970; McKinsey and Chapman 1998) and high temperatures (Meffe *et al.* 1995). The strong influence of gambusia tolerance was supported by field observations in the Barossa that saw turbidity and low DO play strong roles in fish community structure, favouring gambusia. Strong, naturally occurring seasonal flow patterns disrupt gambusia populations (Costelloe *et al.* 2010) due to their poor capacity for swimming in strong or turbulent waters (Ward *et al.* 2003). It is likely that these patterns have been impacted in many of the watercourses of the Barossa Valley due to water extraction and impoundment of natural flows (Figure 14). The modern aquatic landscape in the Barrossa PWRA is a stable environment with poor water quality and a lack of contrasting seasonal flows and the dominance of gambusia in the North Para is almost certainly an indirect effect of landscape change and water resource development in the region.

Large populations of gambusia are known to exert strong biotic effects on their environment. For other fish they act as a predator of larvae (Ivantsoff and Aarn 1999) and, despite their small size will act aggressively towards adult fish much larger than themselves, nipping fins (Macdonald *et al.* 2012) and excluding them from ideal habitats (Milton and Arthington 1983). Aggression and fin-nipping is a less common interaction with flathead gudgeon (Macdonald *et al.* 2012), the most well represented native species in the Barossa. These two species are commonly found living together with gambusia, typically inhabiting the shallow waters at the pools surface and flathead gudgeon utilising the demersal zone of the water column (Wedderburn *et al.* 2007; McNeil *et al.* 2011b). Within the North Para these species do not appear to be in direct competition.

Beyond their direct impacts on native fish, gambusia exert a range of ecosystem effects and are known to attack native frogs (Komak and Crossland 2000; Pyke and White 2000), predate and alter macro- and micro-invertebrates composition (Cardona 2006; Margaritora *et al.* 2001) and have been implicated in trophic cascades (Ho *et al.* 2011). Although high densities of gambusia may be shown to negatively impact ecosystems, it is not anticipated that they are a symptom of management practices rather than a direct cause of environmental conditions observed in this region (Figure 9). The abundance of gambusia, reduction in biological condition of ecosystems and reduction of native fish populations within this reach is a concurrent symptom of poor land practices and reduced water flow regimes.

4.1.2. Flathead gudgeon (*Philypnodon grandiceps*)

The most abundant native fish in both the Barossa PWRA and WMLR was flathead gudgeon (Figure 11). This species is considered ecologically resistant and displays a tolerance to both low DO (Gee and Gee, 1991) and salinities in excess of 2495 $\mu S.cm^{-1}$ (Pusey *et al.* 2004). High tolerance to extremes in water chemistry contributed to this species ability to dominate fish populations in some of the Barossa's more degraded pools (Figure 5). Its cryptic colouration and sedentary life history combined with an ability to utilise shallow marginal habitats that are inaccessible to large predators may provide it with some level of protection from redfin perch. This may help explain why these two species are regularly identified in the same communities. This species is less likely to be influenced by environmental management practices and may be less useful as an indicator of aquatic health.

Figure 11. Flathead gudgeon (*Philypnodon grandiceps*).

4.1.3. Western blue spot goby (*Pseudogobius olorum*)

Along the lower North Para reach, western blue spot goby was found at every site and was common in high densities. In total 1,266 western blue spot goby were caught in the lower North Para, contrasting the eight individuals collected across the remaining WMLR. These eight individuals were caught at the near-estuarine Adelaide Shores Skate Park site on the Patawalonga Creek. This species is most commonly associated with marine and estuarine environments (Allen *et al.* 2003), but undertakes a flexible range of diadromous migrations that may include waters with lower salinity (Mathwin 2010). In rare circumstances this species is found isolated from the ocean forming landlocked populations (Hammer 2002; McNeil *et al.* 2011a). This species displays marked niche similarities to the most abundant WMLR fish species flathead gudgeon. Both are benthic specialists with behavioural adaptations to survive low dissolved oxygen (Gee and Gee 1991) and salinities far above those seen in most freshwater reaches. For western blue spot goby salinity tolerance may exceed 55 ppt (Halse 1981). That this species and flathead gudgeon are able to coexist in what appears to be the same niche within the same pools may reflect a dietary separation between the species and there is room for further work to explore this. Spawning in western blue spot goby has been linked with relocations to areas with salinity less than 30 ppt (Larson and Hoese 1996); a value far in excess of the highest salinity observed in the non-tidal section of the WMLR. There is no apparent explanation as to why western blue spot goby have established and continue to thrive in the lower North Para yet fail to do so in other catchments in the WMLR. Supporting this species requires an understanding of flow response and ongoing monitoring of this species and reach is recommended.

4.1.4. Redfin perch (*Perca fluviatilis*)

Redfin perch are an exotic species native to Eurasia (Allen *et al.* 2003) (Figure 12). They are a hardy fish tolerant to a wide range of environmental parameters. They are now common across southern Australia and display a distribution that is more reflective of past anthropogenic translocations than environmental tolerance (Rowe *et al.* 2008). Although high water temperatures (Weatherley 1977) have been implicated in limiting their survival in northern latitudes and high flow velocities in their ability to access upstream reaches in strongly flowing rivers (Hutchison and Armstrong 1993) there is insufficient data to relate either flow or water temperature to redfin perch dynamics in the current study.

Internationally this species has been shown to benefit from elevated salinities. Brackish waters of 6 ppt improve growth rates (Ložys 2004) and salinities of 2 ppt improve larval survival (Bein and Ribi 1994) although salinities of 9.6 ppt were prohibitive for larval survival. Within the Barossa Valley this is not the case as this species was negatively associated with salinity, indicating there is some other factor influencing the success of this species in this system.

In the WMLR, redfin perch populations vary in their age structure, but are typically composed of a small number of large individuals or large populations dominated by a cohort of juveniles with few large adult fish. In the Barossa PWRA, the lower North Para River populations were typically small with few large individuals. In contrast, the upper North Para, where pools were larger and deeper, populations of this species tended to be larger and dominated by a juvenile cohort.

Figure 12. Redfin perch (*Perca fluviatilis*) can dominate community composition after a successful breeding event.

4.1.5. Mountain galaxias (*Galaxias olidus*)

This species is classified as vulnerable in the WMLR (Hammer *et al.* 2010) and considered sensitive to a range of water quality parameters, though experimental data to support this is lacking (McNeil and Hammer 2007). This active, mid-water species is known to suffer heavily from exotic species predation (Lintermans 2000; McDowall 2006) and does not typically persist in the presence of predators (McNeil *et al.* 2011b).

Within the North Para, mountain galaxias were restricted to the tributary, Jacobs Creek. From the available data it appears that a source population within this reach was the Jacobs Creek Old Gauge site where this species was thriving in a series of permanent, spring fed pools, free from exotic competitors. This site probably provides emigrants to sites lower in Jacobs Creek which may persist (as seen at Jacobs Creek Crossing) or perish (as was occurring at the Jacobs Creek Visitors Centre site). Under periods of improved connectivity this upper tributary population may provide emigrants to other sites in the catchment, but persistence therein will depend on good water quality and the absence of predation, neither of which were present at the time of sampling. If river conditions were improved such that habitats in the North Para became habitable for mountain galaxias then it is anticipated that over time the range of this species would radiate from Jacobs Creek into the main channel.

With respect to fish populations, the mountain galaxias population at Jacobs Creek Old Gauge site is the primary site of conservation importance within the Barossa Valley PWRA. Beyond management of water resources it is expected that improvements to habitat condition such as riparian restoration will also aid resilience and productivity of this population. If this population is well managed then it could potentially be used as a source population to translocate endemic fish to suitably restored habitats within the catchment.

4.1.6. Tench (*Tinca tinca*)

In the WMLR, tench (Figure 13) display a limited distribution being confined to the Onkaparinga and North Para rivers (McNeil and Hammer, 2007), however, two individuals were caught in Sturt Creek during the current round of WMLR sampling (at the Frank Smith Park site). Within these three catchments the North Para appears to support the largest population with 23 of the 25 Tench collected in this catchment. Why this species is able to persist in this catchment is unclear. This species is highly tolerant of a range of water qualities, tolerating 0.4 ppm DO and salinities far above those seen in the Barossa (Weatherley 1959). Longevity may be a contributing factor to this species' persistence with long-lived and highly fecund individuals being able to survive through poor seasons and produce large numbers of recruits when conditions improve. This species has been noted to select bivalves as their preferred prey item (Giles *et al.* 1990; Petridis 1990; Brönmark 1994) which may provide an avenue for further research into factors contributing to the species distribution in the WMLR.

Figure 13. Tench (*Tinca tinca*) are large bodied fish that may produce tens of thousands of eggs during a successful spawning event.

4.1.7. Silver perch (*Bidyanus bidyanus*)

The identification of silver perch at the Barossa Novotel site almost certainly represents an escape from a stocked private dam. PIRSA require a permit and aquaculture licence to legally translocate fish from interstate and a second permit to release fish into a waterbody that includes a private dam. There have been no recent permits for stocking of silver perch in the State. The source population in this instance is likely a stocking event that was carried out without approval. This species is a first record in the catchment and probably travelled to the site via overland flow from the point of stocking. The possibility exists that the wetter months may bring successive waves of this species from this source population and that a self-sustaining population could develop in this catchment. The impact of this on the catchment is unknown, but highlights the need for education and monitoring of translocations between waterways.

4.2. Reach recommendations for the Barossa Valley Prescribed Water Resource Area

4.2.1. Duckponds Creek

Duckponds Creek contained no fish. No native fish values were identified within this reach and consideration of water requirements for this reach should be based on the requirements of other taxa.

4.2.2. Jacobs Creek

Jacobs Creek contained three fish species including the locally threatened mountain galaxias. Within this reach, the Jacobs Creek Old Gauge site was arguably the most significant survey site supporting a large, polymodal population of mountain galaxias in permanent spring fed pools. Despite the dry period in which sampling took place, this site maintained slow trickling flows supporting the observation that this is a critical refuge habitat for this species within the catchment. The maintenance of a suitable water regime supported by upstream runoff and contribution of groundwater is critical in supporting the species in this reach, and in maintaining the potential for redistribution of mountain galaxias across the PWRA should suitable aquatic habitats be reintroduced.

The nature of this site combined with the large numbers of fish present, suggest this is the potential source population of mountain galaxias emigrants for Jacobs Creek and the entire PWRA. The second most important consideration for water management would be to support instream flows in this reach to support the emigration of mountain galaxias to downstream pools. Despite the apparent success of mountain galaxias at this site, it was heavily impacted by riparian woody weeds and unrestricted stock access. Dissolved oxygen readings were low and water was dark due to substrates littered with rotting organic matter from the riparian deciduous trees. While these effects are not reflected in population dynamics at the site, it is anticipated that these factors will reduce the resilience of the population during times of environmental stress. As such, improvements in land management such as revegetation and stock exclusion will likely increase habitat quality and resilience of this highly important fish population in the context of the Barossa PWRA.

During site selection, permanent pools were identified upstream of the Jacobs Creek Old Gauge site, however access was denied. It is anticipated that these upstream sites may mirror both the fish population and management concerns of Jacobs Creek Old Gauge. In the absence of data, the recommendations presented can be extrapolated onto this upstream property.

Further downstream, at Jacobs Creek Crossing, the population of mountain galaxias appeared large and stable. This site is a secondary concern in the preservation of this species in the PWRA and water management should take account of impacts on surface and groundwater contributions maintaining these habitats.

4.2.3. Greenock Creek

The only fish species caught in Greenock Creek were the exotic gambusia. The potential exists for the large population of gambusia at Seppeltsfield Weir to be acting as a source population for the greater catchment. This is unlikely to have any notable impact on fish dynamics in the North Para catchment as gambusia are currently thriving throughout the region. While the potential exists for violent seasonal flows to disrupt the success of this species, the overall impact on the system would likely be negligible. As no native fish values were identified within this reach, consideration of water requirements for this reach should be based on the requirements of other non-fish taxa.

4.2.4. Tanunda Creek

In contrast to historical condition 70 years ago reflecting a different and more diverse environment, the current Tanunda Creek is now a degraded and predominantly dry creek with no native fish values detected. Only the exotic gambusia was present at the time of sampling. If the *status quo* is considered a desirable outcome, then water requirements for this reach should be based on the requirements of other non-fish taxa. Any attempts at environmental restoration along this reach aimed at returning native fish values will be complex and will have to simultaneously return pool permanence, provide sufficient flow to maintain water quality (sufficient for native fish survival), and provide connectivity sufficient to allow recolonisation of flathead gudgeon from the North Para population (e.g. from Tanunda Township) or mountain galaxias from Jacobs Creek.

4.2.5. Upper North Para River reach

The Upper North Para reach was characterised by a series of large, deep on-channel reservoirs held back by large dam walls that occluded the channel (Figure 14). These pools were typically in a state of algal bloom at the time of sampling and deep and stratified, supporting predominantly exotic fish assemblages. It is anticipated that these structures were erected to secure water resources several decades ago, but appear to be underutilised in the modern landscape. The weirs disrupt the natural flow regime, provide a barrier to fish movement and act as a large source population of redfin. In this instance restoration works may produce a series of smaller pools with more shallow banks of the sort that favour native flathead gudgeon and disadvantage exotic redfin perch. Each removal would improve ecosystem connectivity, water quality, but given the large number of these impoundments, ecosystem level connectivity is probably difficult without complete removal of these structures.

Figure 14. Two large dam walls on the upper North Para reach. These images display the large volume of water being held, the impassibility of the barriers and their role in eutrophication of the waterway.

The only native fish in the Upper North Para was the flathead gudgeon, a resistant and resilient fish that is able to persist under suboptimal conditions. It is difficult to consider a water management action that would improve conditions for this species in this significantly altered system. Given the limited connectivity present in this reach, the positive effects of flow provision will be localised, being truncated by damming structures. This could only be overcome through the removal of the instream dams or by the provision of volumes sufficient to achieve overdam flows. The provision of flows that provide downstream passage for flathead gudgeon may provide positive outcomes, however it is important to note that if overdam flows could be achieved that this is likely to favour pelagic gambusia and redfin perch before advantaging the demersal flathead gudgeon.

4.2.6. Mid North Para River reach

This reach was characterised by still and isolated, deep pools and ran predominantly through vineyards. The native flathead gudgeon was the only native present in the reach. This resilient species was abundant at seven of the nine sites sampled in the reach (Nuriootpa Caravan Park and DS Nuriootpa Caravan Park). These latter sites were shallow, black, anoxic and unsuitable for any fish except gambusia. Current flows appear to be providing suitable conditions for the persistence of flathead gudgeon. It is unlikely that changes in regime will be advantageous for this species, but will likely favour the four exotic species present in the reach. Although the potential exists for strong seasonal flows to disrupt surface feeding and midwater exotics, the current level of flow is unlikely to have an impact in the current environment.

4.2.7. Lower North Para River reach

Two native fish species persist in the Lower North Para Reach: flathead gudgeon and western blue spot goby. Although flathead gudgeon are common throughout the North Para (and the WMLR), the presence of large freshwater populations of western blue spot goby is unusual in the WMLR. The conditions that allow western blue spot goby to persist and thrive in this reach are unclear, but may relate to shallow edged pools with somewhat elevated salinity. As the abiotic factors that favour this species are unclear this species should be monitored carefully to ensure that efforts to improve the health of the river do not conversely disadvantage this species.

4.3. Summary of Barossa Valley PWRA recommendations

1. Protect sub-surface water along Jacobs Creek, notably at the Jacobs Creek Old Gauge site. This will ensure baseflows are maintained for critical mountain galaxias refuge pools.
2. Protect instream flows on Jacobs Creek, notably in the upper catchment. This will improve habitat quality and emigration opportunities for mountain galaxias in the upper reaches of Jacobs Creek.
3. Support works along the upper reaches of Jacobs Creek including revegetation, stock exclusion and woody weed removal.
4. Monitor the Lower North Para River reach to better understand the population dynamics of western blue spot gobies.
5. Monitor the Lower North Para River reach for serial translocations of silver perch from the unknown source population. This will allow a timely response to a translocation event.
6. Investigate options to manage the impacts of large instream impoundments and barriers to flow with a view to improving connectivity and providing flows to better promote conditions that support native fish populations.

4.4. WMLR fish dynamics

The spread of sampling effort in this report was disproportionately focused within the Barossa Valley PWRA. Of the 127 sites, 44 occurred within the Barossa and as a result the overall results are skewed towards this area. Of the 42,504 fish caught in the combined studies, 75.5% came from sampling within the Barossa PWRA. This subset was dominated (70.2%) by gambusia and causes the WMLR to appear geographically dominated by exotic fish. The ratio of native to exotic fish in the combined dataset was 1:2.2, however when the Barossa data is excluded, the ratio is 1.3:1, favouring native fish species.

While this is encouraging, it is important to note that the higher abundance of native fish does not necessarily translate to a higher biomass. The WMLR endemic fish fauna are typically small-bodied. The largest native species detected in this study was the congolli which may reach 300 mm, but the mean total length of congolli was 111 mm. The second largest native species detected was climbing galaxias that may reach 250 mm, but the mean total length of fish in this study was 74 mm. In addition to small body lengths, native fish have morphologically lower weight:length relationships than many exotic fish in the region. The majority of fishes in the WMLR display elongate and fusiform body shapes, e.g. galaxiids, congolli and flathead gudgeon (Figure 11), which result in low mass compared with their length. In contrast, exotic fish like redfin perch (maximum length 477 mm, mean total length 83 mm) (Figure 12) or tench (maximum length 549 mm, mean length 452 mm) (Figure 13) have much deeper bodies and a much higher weight:length relationship. In this way a single large exotic may have the same biomass as many hundreds of native fish. There is insufficient data to accurately calculate and compare biomass at the current time, but future allocation of funding to this task will assist in quantifying total biomass of fish populations.

Human alterations to the aquatic landscape are widespread throughout the WMLR and are major driver of fish population dynamics, especially construction of barriers limiting movement of diadromous species. This was detected in the limited distribution of common and climbing galaxias, western blue spot gobies, and congolli (Crook *et al.*, 2010), while many of the region's rarest fish that were not detected also display diadromous life histories; notably the Australian short-finned eel (*Anguila australis*), pouched lamprey (*Geotria australis*) and short headed lamprey (*Mordacia mordax*). Work is currently underway to ameliorate some of these effects in some regions in the form of constructing sequential fish ladders in the lower Torrens (McNeil *et al.*, 2010) and providing timely environmental flows to support fish movement (Schmarr *et al*., 2014).

4.5. WMLR discussion of multivariate grouping

A total of 127 sites were analysed by multivariate analysis and clustered into eight significant groups characterised by one or more fish species.

4.5.1. Group 1

Of the 127 sites analysed, 64 fell into Group 1. The fish communities in Group 1 were characterised by native flathead gudgeon, exotic redfin perch and gambusia. These were the three most abundant species in the study and three of the four most widely distributed species. Group 1 sites were associated with elevated average salinity and elevated average pH. These sites were most commonly associated with the Northern Mount Lofty Ranges and lower average annual rainfall. The sites in Group 1 scored lowest on both the FHI and BCG condition assessments and may be considered the most degraded in the study. These sites typically occurred in highly altered landscapes characterised by water abstraction and an associated decline in water quality.

It is suggested that fish populations dominated by flathead gudgeon, gambusia and/or redfin perch may be considered a useful indicator for ecological degradation.

4.5.2. Group 2

The presence of common galaxias was characteristic of the seven sites in Group 2. This species is partially diadromous (Mathwin 2010) and although it is a sub-optimal state (Pollard 1974), landlocked populations of common galaxias may be present in the WMLR (McNeil *et al.* 2011b). The capacity for seasonal diadromy within a population bolsters population resistance through improved genetic diversity (Neville *et al.* 2006) and resilience through seasonal immigration events. In 2012-13 Group 2 sites were confined exclusively to near coastal reaches. This trend is probably an artefact of the modern landscape which has made barriers to migration commonplace in the WMLR (Figure 15). A combination of flow abstraction and barrier construction in the region has restricted successful diadromous migrations to the lowest river reaches below significant barriers. This is placing populations of diadromous species, like the common galaxias, under increasing stress. Efforts to support this species should be focussed on timely seasonal flow provision and the removal or alteration of barriers to reinstate passage. There are works currently underway to address these concerns at key WMLR sites (McNeil *et al.* 2010; Schmarr *et al.* 2014).

Figure 15. Collage of typical barriers encountered in the WMLR.

4.5.3. Group 3

A dominance by mountain galaxias characterised fish communities in Group 3. This species was the fourth most abundant and third most widespread species during this period. This group was associated with higher scores on both the BCG and FHI, suggesting that this species may be used as an indicator of high aquatic values in the WMLR region. Efforts to support this group should focus on supporting existing aquatic values like vegetation to support bank stability and existing flows to maintain pool quality over drier periods.

4.5.4. Group 4

Climbing galaxias were characteristic of the 11 sites in Group 4. This species is rare in the WMLR (Hammer *et al.* 2010) with populations strongest in the less altered southern catchments with the highest rainfall, notably Boat Harbour and Deep Creek. Like the common galaxias, this species is partially diadromous (Mathwin *et al.*, 2014) and the strongest populations were observed in the less altered southern catchments where anthropogenic barriers were absent. Efforts to support this group should focus on maintaining the unaltered nature of the catchments where they were found.

4.5.5. Group 5

Group 5 was comprised of six sites dominated by brown trout. These sites contained clear, cool flowing water with good water quality parameters. These niches are similar to those used by the regionally vulnerable climbing galaxias. At three of these sites, climbing galaxias and brown trout were caught in close proximity with brown trout dominating the larger pools and climbing galaxias found only in the marginal habitats. It is anticipated that, due to niche similarities between these two species, the presence of brown trout will have a significant impact on the continued survival of climbing galaxias at a site. While trout may be legally stocked into six rivers in South Australia (the Broughton, Wakefield, Light, Finnis and Hindmarsh Rivers and Currency Creek) the removal of trout from other rivers may improve the long term survival of climbing galaxias in the region. It is important to note that trout are an iconic recreational species and that alterations to their management will be contentious.

4.5.6. Group 6

Group 6 contained two sites with low numbers of fish and galaxias present. These sites occurred on rivers with strong galaxiid populations and may be considered stepping stone habitats. While the sites themselves may appear to be of low overall significance, the presence of a single migratory fish at these sites infers a high importance as a seasonal stepping stones. These sites may also be considered high priorities for rehabilitation which could potentially allow a proportion of transient migrants to remain *in situ* and establish a new population along the reach.

4.5.7. Group 7

This group was a single site on Christie Creek and contained a single goldfish. This site should be a low priority for management. Attempts to improve fish ecology at the site should be focused further downstream to restore diadromous passage to upper Christie Creek.

4.5.8. Group 8

In total 19 sites were sampled that contained no fish. These sites varied in location and morphology, but were typically; small, ephemeral, anoxic or distant from the main channel. Sites in Group 8 held few ecological values and should be the lowest priorities for management.

4.6. Fish community discussion and recommendations for catchments the WMLR

4.6.1. Gawler River catchment.

The North Para River and its tributaries have been considered in detail within the Barossa Valley PWRA discussion. The Gawler River main channel was sampled at three sites and contained four fish species. The presence of gambusia and flathead gudgeon (both Group 1 species) suggests a degraded environment. The presence of two native diadromous species (congolli and common galaxias) along this reach reflects antecedent spring connectance to the ocean, as well as an absence of impassable barriers downstream.

Of the two diadromous species, congolli have a lesser ability to swim through strong water velocities or to overcome barriers (McNeil *et al.* 2010). This species was detected as far upstream as the Pony Club site, but was not detected further upstream at the Gawler flood retention dam or Yaldara weir in 2011 (McNeil *et al.* 2011b) nor in 2006 or 2007 Waterwatch sampling at Yaldara weir. There is insufficient data at the current time to decisively determine if congolli can penetrate upstream of Pony Club in the current altered landscape. This species is known upstream at Woodlands Weir on the South Para River, however it is believed that this population may be the result of a translocation event. Regardless, this species' ability to migrate inland to the Pony Club gives it access to 30 km of stream habitat and (along with strong populations at the Old Port Wakefield Rd site) suggests that the status of this species remains stable in this catchment.

The common galaxias are the more vigorous swimmer of these two diadromous species (McNeil *et al.* 2010). In 2011, this species was detected as far upstream as Yaldara Weir on the North Para River, but was not detected at Yaldara during 2013 sampling, nor in 2006 or 2007 Waterwatch sampling. This species is also known at the Woodlands Weir site on the South Para, but it is believed that this population also coincides with a translocation event (Schmarr *et al*. 2014)

The opportunity for diadromous fish to penetrate so far upstream in this catchment is encouraging and suggests that, during downstream migration events, this river is providing a significant contribution to the seasonal population of oceanic juveniles. This catchment is probably acting as a source population for smaller catchments along the coast and as a stepping stone habitat for gene flow between the strong populations of diadromous fish in the Light River to the north and the less stable diadromous populations to the south. Future management of this reach should focus on maintaining diadromous passage in this reach and alterations to this lower catchment should be considered carefully for their potential to restrict passage, either through abstraction or impoundment of flow or barrier creation.

4.6.2. Little Para River

In 2006, Waterwatch sampled four sites in this catchment and identified four native and two exotic fish species (Waterwatch unpublished data). Sampling at a single site in 2011 failed to identify any fish, and only detected water rats (McNeil *et al.* 2011b). Three sites were examined in the current study. The furthest upstream site (One Tree Hill Crossing) was flowing strongly at the time of sampling probably related to manipulation of water at the Little Para Reservoir. This site contained the hardy flathead gudgeon and a single carp gudgeon. The carp gudgeon is a new record for the catchment and is probably a recent inter-basin transfer via the Mannum-Adelaide Pipeline. Downstream Happy Home Reserve contained no fish and the thoughtfully constructed White's Rd Reservoir contained only gambusia. This catchment remains poorly studied and it is recommended that future sampling examine key refuge sites within this Catchment. This will indicate whether the species loss since 2006 Waterwatch sampling is an artefact of site selection processes or indicates genuine environmental degradation.

4.6.3. River Torrens catchment

4.6.4. Millers Creek

Millers Creek is a tributary of the upper Torrens River. It flows primarily through farming (grazing) areas and despite the altered environment (Figure 6), two of the three sites supported strong populations of mountain galaxias (80 and 222 fish respectively) and no exotic fish. This species was most commonly associated with sites that scored higher on biological assessments (both BCG and FHI) suggesting this reach is an anomaly. Which remaining habitat values support the continued survival of this regionally vulnerable species is unclear. The selection of the Alexander Forest Rd and Winton Rd sites for ongoing VWASP monitoring is fortuitous as it will allow flow response to be monitored for this vulnerable species. The VWASP site on Millers Creek was not implemented at the time of writing and is at risk of being dropped from the program. Further sampling under the Fish Community monitoring may provide further insight into the habitat values supporting a healthy population of mountain galaxias in this catchment.

4.6.5. First Creek

The three sites sampled along this reach all lie within the Cleland Conservation Park. Dense vegetation encompasses all of the tributaries of this reach and serves as a protective barrier improving water quality and protecting resident fish populations from the effects of urbanisation common in the downstream catchment. This reach supports large stable populations of regionally vulnerable mountain galaxias in a stable environment. At the lowest end of the study reach lies the Waterfall Gully Falls. This natural structure plays a protective role, eliminating upstream passage for the exotic and translocated fish species downstream in this catchment.

4.6.6. Upper River Torrens

The inter-basin transfer at the time of sampling caused a dichotomy in the sites along this reach. At the four sites above the point of input (Mt Pleasant Golf Dam, Mt Pleasant Cottage, Talunga Park Bridge and Mt Pleasant Crash Repair) pools were small, shallow, green and either devoid of fish or (at Talunga Park Bridge and Mt Pleasant Crash Repair) supported a strong population of gambusia, with both outcomes reflecting a highly degraded environment. At the time of sampling, inter-basin transfers were occurring and the Mt Pleasant pipeline was open and flowing strongly. Here and downstream at Cromer Rd Bridge, flow was strong and pools were deep, clear and turbulent. The Mt Peasant Pipeline site appears to be a more permanent habitat than the pools upstream and supported small numbers of mountain galaxias, as well as gambusia and flathead gudgeon. Downstream at Cromer Rd Bridge the flow remained strong and a more diverse fish assemblage was detected including goldfish and dwarf flathead gudgeon. The upper Torrens (above the pipeline) is a highly degraded environment and was devoid of native fish values at the time of sampling, though small numbers of tadpoles were evident at some sites and the Golf Course Dam supported a large population of turtles. Talunga Park Bridge, Mt Pleasant Pipeline and Cromer Rd Bridge are suitable for consideration as future VWASP monitoring sites. Management to improve native fish values in the Mt Pleasant reach would be complex and would have to simultaneously rebuild permanent pool habitats (such as has occurred on Glendevon Rd) and restore connectivity. If sufficient pool restoration was deemed to have occurred then translocation of native fish from elsewhere in the catchment could be an option to return native fish values to the reach.

Figure 16. The Upper River Torrens varied greatly with sites above the transfer point being small, still and isolated (Mount Pleasant Crash Repair, left) while below the pipeline sites were deep and flowing strongly (US Mount Pleasant Pipeline, right).

4.6.7. Pedler Creek

Pedler Creek is a heavily altered catchment. In the upper reaches, several on-channel dams have been constructed and in the lowest reach (at the intersection of Commercial Rd and Dalkeith Rd) three constructed sedimentation pools provide a refuge for large populations of gambusia and goldfish (Schmarr *et al.* 2011). The reach between is thickly vegetated (with dense stands of bulrush) masking the identification of on channel refuges difficult.

Past sampling (McNeil *et al.* 2011b) focussed on the Commercial Rd, Dalkeith Rd intersection, sampling upstream and downstream of Commercial Rd on the main channel and also in the three sedimentation ponds along Dalkeith Rd. Sampling in 2011 identified two of the artificial dams above Commercial Rd as densely populated refuges for goldfish and gambusia respectively. The pools sampled below Commercial Rd were dominated by exotic gambusia (and a single goldfish), but also contained three species of diadromous natives; common galaxias, congolli and western blue spot gobies. The current study focused on an ephemeral creek immediately upstream of the artificial dams which was flowing at the time of sampling. A large single cohort of common galaxias was identified which most likely entered the river during the previous spring. These 253 individuals were using winter flows to penetrate further inland in an attempt to find permanent refuge. Alternatively, they may have dispersed from the pools below Commercial Rd seeking upstream refuge.

The presence of three species of diadromous fish highlights this habitat as one of importance for diadromous fish in the region. This environmental functionality is at risk from the two previously sampled dams above Commercial Rd that have the potential to overwhelm the downstream biota with exotic emigrants during periods of connectivity. This could be managed through annual summer drainage of the pools and careful filtering of the exotic fish to remove them from the system. Due to high extraction of water in the upper reaches of Pedler Creek, it is unlikely that large improvements in aquatic habitat availability will occur to support significant fish populations. Management efforts at a catchment scale should focus on maintaining seasonal flows sufficient to enable spring and autumn diadromous movements.

4.6.8. Christies Creek

Christies Creek was sampled at three sites under the current study. This catchment is known to contain three species of diadromous native fish; common galaxias, congolli and western blue spot goby (McNeil and Hammer 2007), however under the current study common galaxias was the only native species identified. This catchment is highly urbanised with few permanent pools separated by ephemeral reaches punctuated by barriers (e.g. Galloway Rd, Morrow Rd, Dyson Rd and the Railway crossing). At the time of sampling this reach was dominated by exotic fish with no native fish identified upstream the lowest barrier at Galloway Rd.

Given the proximity of Christie Creek to the Onkaparinga River it is anticipated that large, permanent pools, such as the Christie Creek Wetland site, would contain large populations of diadromous native fish. As this site contained only a single goldfish it appears that one or all of the barriers mentioned above are obstructing diadromous passage in this system.

Management of this system would be best approached through the implementation of fish ladders or rock ramps at key sites (prioritising from downstream to upstream) with the aim of restoring passage and allowing seasonal diadromous immigrants to penetrate upstream. Given the large number of barriers between the ocean and existing aquatic refuges in the system (including the Christie Creek Wetland) significant work would most likely be required to restore ecological values in this reach.

4.6.9. Onkaparinga River catchment

4.6.10. Aldgate Creek

A total of five sites were examined along Aldgate Creek. Along the upper reaches of this tributary, small populations of mountain galaxias were distributed in shallow pools and riffles along the reach as far as Mylor. These pools seem ephemeral, but must contain sufficient dry weather refuges to allow this species to survive periods of drought. As the tributary approached Mylor (at Dixons and Mylor Bridge sites) a few climbing galaxiids were noted among the mountain galaxiids. It is unclear if this population of climbing galaxias are a resident population or a small number of immigrants from the Onkaparinga main channel that have ascended the Mylor Dam and Mylor Bridge barriers during periods of suitable flow. The Mylor Dam site was a privately owned dam that contained a large (2,468) population of juvenile redfin perch as well as a few mountain galaxias restricted to the shallow margins of the dam. This site is probably acting as a source population of redfin perch into the downstream Onkaparinga main channel. Management actions along this reach should be focussed on maintaining pool depth and quality during times of drought in the reach between Mylor and Aldgate. A second positive action to improve the reach could be to work with the landholder to drain the Mylor Dam site in the hope of removing redfin perch from Aldgate Creek.

4.6.11. Scott Creek

Past studies have identified Scott Creek as maintaining a small, but stable population of mountain galaxias along the reach (McNeil *et al*. 2011b). This remains the case with the 'Scott Creek' site containing 11 (compared to 26 in July 2011) mountain galaxias. This reach is unusual due to the patchy distribution of fish populations along the reach. At the Scott Creek Gauge site only a single gambusia was caught while at the Scott Creek Conservation Park site in 2011 no fish were caught. There were no morphological or abiotic reasons apparent for this absence, which suggests that issues with connectivity combined with a seasonal decline in water quality may be implicated. This catchment may warrant further enquiries about water quality, flow and connectivity with the Onkaparinga main channel to ascertain the cause of the fish absence.

4.6.12. Onkaparinga Main channel

The Onkaparinga main channel was sampled at six sites between Charleston and Mylor. This reach presented a picture of increasing degradation the further downstream that sampling took place. At Charleston a large strong population of mountain galaxias was observed in the absence of exotic fish, this population remained largely unchanged since 2011 sampling. Seven kilometres downstream at Clisby Rd a small population of mountain galaxias were coexisting with a small population of redfin perch. This population of mountain galaxias were probably forced into marginal habitats by the presence of large exotic predators. Onkaparinga sites sampled further downstream displayed fish populations characteristic of Group 1 (Figure 8) indicating overall environmental degradation and a loss of native fish value. These populations were dominated by a combination of redfin perch, gambusia and flathead gudgeon. Notable was a single dwarf flathead gudgeon.

Management actions along this reach are complex and unlikely to return native fish values to the entire reach, but should focus on key sites along the reach. Charleston remains a key site for mountain galaxias in the upper Onkaparinga and any efforts aimed at improving the riparian vegetation at the site from deciduous weeds to native evergreens is expected to reduce the possibility of hypoxia. The Silverlakes site is also worth highlighting. Silverlakes has contained common galaxias in the past and significant effort has been put into removing exotic weeds along this site. While this has been effective, failure to replace the emergent and riparian zones is causing increasing bank erosion and channelisation. Immediate revegetation of this site is suggested to stop this process and stabilise the ecology of this site.

4.6.13. Wirra and Willunga Creeks

Willunga Creek has been an intensively studied reach since around 2009 when the exotic speckled livebearer (*Phalloceros caudimaculatus*) was identified. This was the first record of this species in the State and prompted a collaboration between Biosecurity SA and SARDI to eradicate this species. Since 2010, no speckled livebearer have been identified in the catchment and this species is no longer considered to exist in South Australia. In addition, neither goldfish nor gambusia, both previously caught in the catchment have been observed in Willunga Creek following the eradication.

Wirra Creek is also well studied and contains a large stable population of mountain galaxias. A single attempt to reintroduce mountain galaxias from Wirra Creek into Willunga Creek has been unsuccessful with few or no fish noted on subsequent sampling. There is room for further work to be done reintroducing this species to the catchment however translocations should only be undertaken following a review of threats and some works to ameliorate these issues. Wirra Creek continues to be the most appropriate site for source fish.

4.6.14. Myponga River

The Myponga River was sampled at four sites. The furthest downstream site, Myponga Township, site does not sit along the main channel of the river, but is rather an outflow of the reservoir and provides some insight into fish residing in the reservoir. This site contained large numbers of redfin perch and climbing galaxias. Redfin perch appear to have recently boomed in the reservoir and dominated the catch at Myponga Township. This species is also known upstream (at the Rogers Rd Culvert and also along Pages Flat Rd), however the capacity for the reservoir to seed upstream populations is unclear. There are no known barriers immediately upstream of the reservoir and it is anticipated that the reservoir is acting as a source population for redfin perch above the reservoir wall.

Climbing galaxias have been identified only above the reservoir wall (McNeil *et al.* 2009). The reservoir wall is significant and is an impassable barrier for diadromous migrations restricting common galaxias below the reservoir and climbing galaxias above the reservoir. This suggests that climbing galaxias populations above the reservoir wall are landlocked and their proximity to the reservoir suggests that the reservoir is currently supporting a large population of climbing galaxias and may be acting as a source population for the reach above the reservoir.

The furthest upstream site, DS Myponga Gauge, contained a large population of mountain galaxias. This species is rarely found further upstream than climbing galaxias due to the climbing galaxias ability to penetrate upstream during migration. There are two likely explanations for this, either that climbing galaxias, having been landlocked since the reservoir’s 1962 completion, have a lesser drive to migrate than their partially migratory ancestral state, or that a barrier exists somewhere along the upper Myponga River which is keeping the populations discrete.

As this river contains all three species of galaxiids, displays unusual species dynamics and has a flow gauge, there are strong grounds for its continued study. Monitoring should revisit the reach below the reservoir and examine in more detail the reach between the mountain galaxias populations at DS Myponga Gauge and the climbing galaxias populations at Rogers Rd Culvert.

4.6.15. Carrickalinga Creek

Three species of galaxiids were caught in the same pool at both sites on Carrickalinga Creek. This is highly unusual and has only occurred on five of the 226 SARDI WMLR sampling occasions since 2006. This may have been an artefact of the strong flow that occurred immediately after the nets were set. For two of these five occasions to have occurred simultaneously in the same creek warrants further investigation and it is suggested that Carrickalinga Creek be prioritised for more intensive sampling in the future.

4.6.16. Yankalilla River

The Yankalilla River was sampled at only a single site, Yankalilla River Bridge. A strong, unexpected flow event occurred shortly after nets were set and four of the six nets were washed away and destroyed. There is a strong likelihood that the results presented do not accurately detail all of the species present at the site, however some comments can be made. The presence of congolli in this reach highlights that this may be important for diadromy in this catchment. It is possible that other diadromous species exist in the catchment, but were undetected during the current sampling. The fish biota of this river is poorly studied and warrants prioritisation in future years of sampling.

4.6.17. Deep Creek and Boat Harbour Creek

Both Boat Harbour Creek and Deep Creek catchments lie almost entirely inside the Deep Creek Conservation Park and are the most pristine rivers in the study. These catchments lack the flow abstraction and artificial barriers that are common throughout the WMLR. These rivers were characterised by climbing galaxias, common galaxias and brown trout. Common galaxias were identified in the lowest reach of Boat Harbour Creek, within 500m of the ocean. This species is diadromous, but lacks the climbing ability of the climbing galaxias and as a result is typically restricted to reaches with lower elevation (Mathwin *et al.* 2014). The common galaxias was not identified in Deep Creek, however this is probably an artefact of site selection. Site morphology made access to the near estuarine reach of this river impossible with the sample site, Deep Creek waterfall, 2 km inland and 115 m above sea level. It is anticipated that common galaxias exist in the lowest reaches of Deep Creek; however this cannot be confirmed at the current time.

Climbing galaxias were found at four of the six sites sampled and appear able to traverse the significant waterfalls in the region under suitable flow conditions. As flow abstraction is minimal, this species can be considered stable from landscape effects. More concerning is the strength of self-sustaining trout populations in these rivers. This species is known to be a voracious predator of native fish and specifically implicated in the decline of galaxiids (McDowall 2006). These rivers also host strong populations of exotic marron which may likewise impact the survival of galaxiids and native yabby populations. A possible management solution would be to create a special provision for recreational fishing activities in the park. These activities would have to be regulated and conditions imposed to protect galaxiid and yabby populations, but it could be a cost effective measure to improve popularity of the park and simultaneously improve ecological values within the park.

4.6.18. Callawonga Creek

The vast majority of Callawonga Creek flows through pastoral properties, terminating at the southern ocean. Flows within the creek remain relatively unaltered, with a few on-channel dams present in the uppermost portion of the catchment. Changes in species composition between the upper, middle and lower reaches of this creek display a high degree of spatial divergence and habitat partitioning, possibly associated with geography (such as natural barriers) and hydrology (such as flow and/or water quality). This partitioning may also be influenced by the presence of brown trout (McDowall 2006) within the middle reaches of the creek. Conversely, geographical and hydrological influences may in-fact be restricting movements of brown trout, thus providing refuge habitats for native species above and below the reach. Potential threats to native fish in Callawonga Creek include established brown trout populations, illegal stocking of exotic trout and alterations to natural flow regimes resulting from dams and water extraction in the upper catchment. The proximity of grazing areas is also a concern due to the potential for eutrophication. Walker's Waterfall, Callawonga and Balquhidder are the most appropriate sites for future fish sampling in terms of both spatial coverage and species composition. Although the Callawonga Gauge site provides comparable flow data, it is less suitable for fyke netting due to a lack of deeper pool habitats.

4.6.19. Inman River

The Inman River flows through pastoral areas within the Inman Valley and suburban areas of Victor Harbor, terminating at Encounter Bay. Previous records of endangered southern pygmy perch within the upper reaches of the Inman, reported in Hammer *et al.* (2010), were confirmed during this study. Populations of climbing galaxias also remained stable when compared with previous studies (McNeil *et al.* 2011b). This suggests that upstream habitats have remained in relatively good condition and are more suitable for maintaining populations of sensitive taxa. The lower reaches of the river were typically more degraded, containing fewer fish and fish communities dominated by redfin perch. European carp were observed at Gunter's, but were not caught in the nets. Anecdotal evidence from land owners suggests the presence of carp to be more widespread than the findings of this study indicate. Severe scouring and erosion was evident throughout the entire catchment, particularly the lower half of the river, evidently caused by land clearance and disturbance from cattle. One landowner (Teague property, Boundy River) had made efforts to improve aquatic habitats upstream through the creation of small wetland areas, which appear to benefit southern pygmy perch populations. Indeed, this property should be studied as a blueprint for further restoration works in the Inman River catchment. Threats include severe erosion, a lack of aquatic habitat for sensitive native taxa within downstream reaches, in addition to the presence of exotic fish species and alterations to flow caused by dams and water extraction. The most appropriate sites for future monitoring include the Teague property due to the presence of southern pygmy perch, the Inman Gauge for comparable flow data in addition to previous sampling records and Swains crossing to achieve adequate spatial coverage.

4.6.20. Hindmarsh River

The Hindmarsh River flows through farm land and suburban areas of Victor Harbor, terminating at Encounter Bay. The majority of the river is dominated by native fish species, with exotic brown trout recorded in pools above Hindmarsh Falls. The majority of common and climbing galaxias populations have remained steady when compared with McNeil *et al.* (2011b), however mountain galaxias were not recorded this round. The presence of brown trout, whether through illegal stocking or migration, poses a real threat to native fish populations and may explain the absence of mountain galaxias during this study. Similar to previous studies, brown trout were not recorded within the same pool as other species, suggesting a partitioning of habitats. Common galaxias recorded at Saw Pit Road suggest that connectivity is relatively good between the Cootamundra estuary and Saw Pit Road. The only major impediment of fish movement throughout the system is Hindmarsh Falls itself, which appears to separate common and mountain galaxias populations. Other threats at this site include evidence of intensive yabbying and nutrient pollution from runoff. All three sites surveyed on this river present as suitable locations for future sampling.

4.7. Summary of WMLR recommendations

Species specific or fish community based recommendations:

1. Consider fish populations dominated by flathead gudgeon, gambusia and/or redfin perch as a useful indicator for ecological degradation.
2. In catchments where diadromous species are present, but display a limited distribution, timely seasonal flow provision and the removal or alteration of barriers to reinstate passage should be considered.
3. Reinstate or maintain aquatic habitat values to support mountain galaxias sites.
4. Maintain climbing galaxias habitat where they occur and provide passage for diadromy.
5. Maintain current limits on trout stocking and remove illegally stocked trout from streams where they co-occur with native species (notably Boat Harbour Creek and Deep Creek).
6. Prioritise sites for rehabilitation where galaxiid numbers are low, but other threats are absent or low.

4.8. Site or river specific recommendations:

1. Maintain and enhance diadromous fish passage in the Gawler River.
2. Undertake weed removal, revegetation and fencing at the Jacob's Creek Old Gauge site to improve resilience of the mountain galaxias within the Gawler River.
3. Continue to monitor western blue spot goby populations in the lower North Para and consider dietary studies for this species and flathead gudgeon in this reach.
4. Periodically monitor the lower North Para River (particularly the Barossa Novotel site) for reintroductions of silver perch from the unknown source population.
5. Repeat sampling in greater spatial detail in Little Para River to confirm fish community.
6. Maintain Miller's Creek as a VWASP monitoring site or substitute it into future Fish Community Health monitoring surveys.
7. Restore connectivity and aquatic habitat values to upper Torrens sites in the Mt Pleasant reach.
8. Maintain diadromous fish passage in the Pedler Creek.
9. Capitalise on existing Christie Creek Wetland by providing passage for diadromous species.
10. Explore management options to reduce the emigration of redfin perch from the Myponga Reservoir.
11. Undertake sampling in the data deficient reach below the Myponga Reservoir.
12. Examine the Myponga River reach between DS Myponga Gauge and Rogers Rd Culvert to determine if barriers to movement and migration are present.

13. AMLRNRMB examine water quality, connectivity and flow with the Onkaparinga main channel to ascertain the cause of the fish absence in Scott Creek.
14. Consider approaching the landholders to drain the Mylor Dam site to remove the large source population of redfin perch from Aldgate Creek and the Onkaparinga.
15. Strategic investment in aquatic habitat restoration at key sites (notably Charleston and Silverlakes) in the Onkaparinga, in concert with catchment-wide programs already in place.
16. Review suitability of Willunga Creek aquatic habitat for repeat reintroduction of mountain galaxias.
17. Maintain Myponga River in routine VWASP monitoring. Fish Community Health monitoring should examine sites below reservoir.
18. Prioritise Carrickalinga Creek and Yankalilla River for intensive sampling in future rounds of WMLR fish monitoring.
19. Explore management solutions for removal or abatement of marron and trout populations in Southern Fleurieu sites, this may include the opening of the Deep Creek Conservation Park to recreational fishers.
20. Strategic investment in aquatic and riparian habitat restoration at key sites in the Inman River.

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6. APPENDIX A

A summary of site names, location, date sampled and the source project. These projects were the Barossa Valley Prescribed Water Resource Area Fish Community Study (BVFCS), the Verification of Water Allocation Science Project (VWASP) and the Western Mount Lofty Ranges Fish Community Monitoring Project (MLRFCM).

Catchment	Reach	Site	GPS	Sample Date	Project
Gawler River	Duck Ponds Creek	Rex's Place	54 H 324742.28 6186174.12	18-Feb-13	BVFCS
		US Duck Ponds Pool	54 H 322969.61 6186088.43	18-Feb-13	BVFCS
		DS Duck Ponds Poll	54 H 322969.61 6186088.43	18-Feb-13	BVFCS
	Greenock Creek	Seppeltsfield Weir	54 H 309000.96 6183865.37	14-Feb-13	BVFCS
		Owen's Grange	54 H 309444.3 6180519.46	14-Feb-13	BVFCS
		Owen's Culvert	54 H 309444.3 6180519.46	14-Feb-13	BVFCS
	Tanunda Creek	DS Kaiser Stuhl	54 H 318680.22 6172956.23	05-Feb-13	BVFCS
		US Tanunda Creek Rd	54 H 318698.01 6174762.13	06-Feb-13	BVFCS
		DS Tanunda Creek Rd	54 H 318377.65 6175334.94	06-Feb-13	BVFCS
		Tanunda Railway Crossing	54 H 313405.84 6176527.62	06-Feb-13	BVFCS
	Jacobs Creek	Jacobs Creek Old Gauge	54 H 312982.52 6172765.99	11-Feb-13	BVFCS
		Jacobs Creek Crossing	54 H 311077.12 6173268.66	07-Feb-13	BVFCS
		Jacobs Creek Visitors Centre	54 H 310541 6173476	07-Feb-13	BVFCS
	Little Para River	One Tree Hill Crossing	54 H 294463.77 6150853.71	05-Feb-13	WMLRFCM
		Happy Home Reserve	54 H 284167.59 6151174.71	25-Jun-13	WMLRFCM
		Whites Road Wetland	54 H 279514.45 6148445.06	25-Jun-13	WMLRFCM
	North Para River	North Para Old Gauge	54 H 323841.88 6172738.05	19-Feb-13	BVFCS
		Brooks Property	54 H 324058.6 6174301.53	21-Feb-13	BVFCS
		US Cornerstone Stud	54 H 322875.21 6174370.62	21-Feb-13	BVFCS
		Cornerstone Stud	54 H 324015.35 6174812.86	20-Feb-13	BVFCS
		US Evan's Weir	54 H 323677 6177029	20-Feb-13	BVFCS
		DS Evans Weir	54 H 323664.01 6177070.04	20-Feb-13	BVFCS
		Third Evan's Weir	54 H 323543.241 6178225.865	27-Mar-13	BVFCS
		US McEvoy Weir	54 H 323154.05 6179162.51	19-Feb-13	BVFCS
		US Thorne-Clarke	54 H 323445.53 6179771.85	19-Feb-13	BVFCS
		Thorne-Clarke Ford	54 H 323602.64 6180599.69	18-Feb-13	BVFCS
		Gumhill	54 H 323609.631 6182762.954	27-Mar-13	BVFCS
		Old Moculta Bridge	54 H 323077.08 6184249.05	18-Feb-13	BVFCS
		Penrice Quarry 2	54 H 321912.12 6184861.07	21-Feb-13	BVFCS
		Penrice Quarry	54 H 321912.12 6184861.07	21-Feb-13	BVFCS
		Nuritootpa Caravan Park	54 H 316955.6 6184087.98	14-Feb-13	BVFCS
		DS Nuritoopta Caravan Park	54 H 316955.6 6184087.98	14-Feb-13	BVFCS
		Smythe St Crossing	54 H 312702.05 6178875.92	13-Feb-13	BVFCS
		Hahn's paddock	54 H 314324.49 6181705.72	13-Feb-13	BVFCS

Catchment	Reach	Site	GPS	Sample Date	Project
		DS Matchos	54 H 313801.94 6180917.99	13-Feb-13	BVFCS
		Tanunda Township	54 H 311940.7 6177837.09	12-Feb-13	BVFCS
		Tanunda Heinemann Gauge	54 H 311706 6177112	12-Feb-13	BVFCS
		Barossa Novotel	54 H 311940.7 6177837.09	11-Feb-13	BVFCS
		St Hallets Bike Path	54 H 310804.52 6174300.6	11-Feb-13	BVFCS
		St Hallets Crossing	54 H 311326.14 6174943.36	12-Feb-13	BVFCS
		US Landcare Reserve	54 H 309093.11 6171107.15	07-Feb-13	BVFCS
		DS Landcare Reserve	54 H 308654.27 6172059.28	07-Feb-13	BVFCS
		Kochs	54 H 306430.83 6172615.72	04-Feb-13	BVFCS
		US Chattertons	54 H 307466.63 6172586.49	05-Feb-13	BVFCS
		DS Chattertons	54 H 307319.82 6172830.02	04-Feb-13	BVFCS
		US Yaldara weir	54 H 305977.47 6172420.84	04-Feb-13	BVFCS
		Yaldara Weir	54 H 305050.26 6172112.76	04-Feb-13	BVFCS
	Gawler River	Pony Club	54 H 290650 6167442	24-Jun-13	WMLRFCM
		Gawler Flood Pool	54 H 287628.15 6167167.77	24-Jun-13	WMLRFCM
		Old Port Wakefield Road	54 H 275236.99 6164524.61	24-Jun-13	WMLRFCM
Torrens River	Upper Torrens	Mount Pleasant Golf Dam	54 H 323156 6152697	22-Jan-13	VWASP
		Mount Pleasant Cottage	54 H 322250 6151599	21-Jan-13	VWASP
		Talunga Park Bridge	54 H 321660 6150487	21-Jan-13	VWASP
		Mount Pleasant Crash Repair	54 H 320320.00 6149926.59	21-Dec-12	VWASP
		US Mount Pleasant Pipeline	54 H 344656.27 139149.30	22-Jan-13	VWASP
		Cromer Rd Bridge	54 H 313882.37 6145446.07	22-Jan-13	VWASP
	Millers Creek	Winton Rd	54 H 307280 6146332	13-Dec-12	VWASP
		Alexander Forest Road	54 H 307422 6147864	14-Dec-12	VWASP
		Martin Hill Rd	54 H 309019 6149085	13-Dec-12	VWASP
	First Creek	Chinaman's Hut	54 H 345823.84 138411.82	23-Jan-13	VWASP
		Waterfall Gully	54 H 345814.38 1384053.64	23-Jan-13	VWASP
		US Chinaman's Hut	54 H 288890.00 6127501.0	21-Jan-13	VWASP
Onkaparinga River	Aldgate Creek	Aldgate Bridge	54 H 293239 6123008	04-Dec-12	VWASP
		Nurrutti Reserve	54 H 294131 6121078	12-Dec-12	VWASP
		Dixons	54 H 295518 6120653	12-Dec-12	VWASP
		Mylor Bridge	54 H 295761 6120278	04-Dec-12	VWASP
		Mylor Dam	54 H 295826 6119267	12-Dec-12	VWASP
	Scott Creek	Scott Creek	54 H 289274 6117015	03-Jun-13	WMLRFCM
		Scott Creek Gauge	54 H 288009.97 6113417.63	03-Jun-13	WMLRFCM
	Onkaparinga River	Charleston	54 H 308119 6134228	05-Jun-13	WMLRFCM
		Clisby Rd	54 H 304611.19 6128239.80	05-Jun-13	WMLRFCM
		Oakwood Rd	54 H 302927.21 6126892.85	05-Jun-13	WMLRFCM
		Spoehrs Rd	54 H 300274.15 6125277.67	05-Jun-13	WMLRFCM
		Verdun	54 H 298796.23 6123925.96	05-Jun-13	WMLRFCM

Catchment	Reach	Site	GPS	Sample Date	Project
		Silverlakes	54 H 295609 6116731	05-Jun-13	WMLRFCM
Patawalonga River	Brownhill Creek	Brownhill Ford	54 H 345920.72 1383853.63	24-Jan-13	VWASP
		DS Caravan Park	54 H 283296 6126115	24-Jan-13	VWASP
	Sturt Creek	Cherry Plantation	54 H 287394 6122713	13-Jun-13	WMLRFCM
		Star & Arrow Rd	54 H 286849.67 6117905.87	13-Jun-13	WMLRFCM
		Weymouth Horse Trail	54 H 285727.15 6117971.39	28-May-13	WMLRFCM
		Weymouth Reserve	54 H 282891.28 6118517.23	28-May-13	WMLRFCM
		Riverglen Place	54 H 282016 6118768	30-May-13	WMLRFCM
		Winns Rd	54 H 283214.75 6120313.38	30-May-13	WMLRFCM
		Frank Smith Park	54 H 283654.67 6120735.85	23-May-13	WMLRFCM
		Willow Glen	54 H 287977 6121111	30-May-13	WMLRFCM
		Sturt Valley Rd	54 H 289106.85 6121755.85	13-Jun-13	WMLRFCM
	Patawalonga	West Beach Road Bridge	54 H 272953.64 6130215.36	25-Jun-13	WMLRFCM
		Adelaide Shores Golf Course	54 H 272861.03 6129566.04	25-Jun-13	WMLRFCM
		Adelaide Shores Skate Park	54 H 272917.48 6128527.92	25-Jun-13	WMLRFCM
Christie's Creek	Christie's Creek	Thaxted Park Golf Course	54 H 277264.17 6110872.94	30-May-13	WMLRFCM
		Galloway Rd	54 H 270456.48 6110087.90	29-May-13	WMLRFCM
		Christie Wetland	54 H 273287.10 6110638.87	29-May-13	WMLRFCM
Pedler Creek	Pedler Creek	DS Pedler Footbridge	54 H 270694.06 6100877.36	12-Jun-13	WMLRFCM
Washpool Creek	Washpool Creek	Washpool	54 H 268118 6088618	12-Jun-13	WMLRFCM
Wirra Creek	Wirra Creek	Wirra Creek Bridge	54 H 277535.47 6094424.48	07-Jun-13	WMLRFCM
Willunga Creek	Willunga Creek	St. Johns Rd	54 H 277842.10 6092860.58	05-Jun-13	WMLRFCM
		Methodist St	54 H 277323.57 6093442.76	05-Jun-13	WMLRFCM
		Norman Road (Giles Rd)	54 H 276978.08 6093933.85	07-Jun-13	WMLRFCM
Myponga River	Myponga River	DS Myponga River Gauge	54 H 274911 6085605	03-Dec-12	VWASP
		Rogers Rd Culvert	54 H 273191 6084172	22-Nov-12	VWASP
		Roger's Property	54 H 273088 6083605	21-Nov-12	VWASP
		Myponga Township	54 H 269884 6080978	21-Nov-12	VWASP
Carrickalinga Creek	Carrickalinga Creek	Rose Cottage	54 H 259671.11 6074596.75	09-Jun-13	WMLRFCM
		Riverview Drive	54 H 257132.55 6075782.46	11-Jun-13	WMLRFCM
Yankalilla River	Yankalilla River	Yankalilla River Bridge	54 H 254886.55 6071364.81	11-Jun-13	WMLRFCM
		DS Yankalilla Crossing	54 H 254906.54 6071443.77	17-Jun-13	WMLRFCM
Hindmarsh River	Hindmarsh River	Hindmarsh Falls	54 H 280549 6075438	25-Jun-13	WMLRFCM
		Sawpit Rd	54 H 281054 6072445	25-Jun-13	WMLRFCM
		Cootamundra Reserve	54 H 284630 6065460	26-Jun-13	WMLRFCM
Inman River	Inman River	Teague Property	54 H 271165 6072083	15-Nov-12	VWASP
		Forest Dam	54 H 271766 6068367	04-Dec-12	VWASP
		Inman Gauge	54 H 274479 6069038	20-Nov-12	VWASP
		Hay Bales	54 H 271165 6072083	15-Nov-12	VWASP
		White's Property	54 H 277846 6067803	14-Nov-12	VWASP

Catchment	Reach	Site	GPS	Sample Date	Project
		Gunter's	54 H 276077 6068639	14-Nov-12	VWASP
		Swains Rd Crossing	54 H 282000 6064240	20-Nov-12	VWASP
Deep Creek	Deep Creek	Dog Trap Creek	54 H 250289 6056528	18-Jun-13	WMLRFCM
		Deep Creek Crossing	54 H 249646.69 6054166.07	20-Jun-13	WMLRFCM
		Rangers Pump	54 H 250432.20 6056211.04	18-Jun-13	WMLRFCM
		Deep Creek Waterfall	54 H 249284.76 6052091.36	18-Jun-13	WMLRFCM
		Deep Creek WF Below	54 H 249284.76 6052091.36	19-Jun-13	WMLRFCM
Boat Harbour	Boat Harbour	Boat Harbour Gauge	54 H 254144.22 6056106.81	20-Jun-13	WMLRFCM
		Boat Harbour Gate 42	54 H 252864.74 6055570.53	19-Jun-13	WMLRFCM
		Boat Harbour Beach	54 H 253984.48 6052940.30	20-Jun-13	WMLRFCM
Callawonga	Callawonga	Callawonga Dam	54 H 263353 6060378	16-Nov-12	VWASP
		Walker's Waterfall	54 H 261238.63 6056293.32	13-Nov-12	VWASP
		Walker's Place	54 H 261238.63 6056293.32	13-Nov-12	VWASP
		Callawonga	54 H 261823 6055504	13-Nov-12	VWASP
		Callawonga Gauge	54 H 262147 6055176	19-Nov-12	VWASP
		Balquhidder	54 H 262891 6054203	03-Dec-12	VWASP
		Callawonga Beach	54 H 263314 6053185	03-Dec-12	VWASP

7. APPENDIX B

Dominant vegetation at each site. Black printed text denotes native, Red text denotes exotic. Note that vegetation data was not routinely collected by this group for the BVFCS and VWASP projects. More detailed vegetation components were being carried out concurrently.

Greater Catchment	Site Name	Dominant Aquatic	Dominant Emergent	Dominant Riparian (Exotic = Red)
Gawler	One Tree Hill Crossing		*Phragmites australis*	*Fraxinus angustifolia*
Patawalonga	Weymouth Reserve		*Pennisetum clandestinum*	*Pennisetum clandestinum*
Patawalonga	Weymouth Horse Trail		*Hydrocotyle ranunculoides*	*Juncus usitatus*
Christie's Creek	Christie Wetland		*Phragmites australis*	*Phragmites australis*
Pedler Creek	DS Pedler Footbridge		*Phragmites australis*	*Pennisetum clandestinum*
The Washpool	Washpool			
The Washpool	Washpool US barrier		*Acacia* sp.	
Patawalonga	Cherry Plantation			*Rubus fruticosus*
Onkaparinga	Spoehrs Rd	*Vallisneria americana*	*Juncus usitatus*	*Pennisetum clandestinum*
Christie's Creek	Galloway Rd		*Phragmites australis*	*Phragmites australis*
Onkaparinga	Oakwood Rd		*Juncus usitatus*	
Onkaparinga	Silverlakes		*Schoenoplectus* sp.	*Schoenoplectus* sp.
Onkaparinga	Verdun		*Juncus usitatus*	*Eucalyptus* sp.
Onkaparinga	Scott Creek			*Pennisetum clandestinum*
Onkaparinga	Scott Creek Gauge		*Typha domingensis*	*Ruppia* sp.
Wirra Creek	Wirra Creek Bridge			
Willunga Creek	St. Johns Rd			*Fraxinus* sp.
Willunga Creek	Methodist St			*Salix sepulcralis*
Willunga Creek	Norman Road (Giles Rd)			
Onkaparinga	Charleston		*Typha domingensis*	
Onkaparinga	Clisby Rd		*Azolla* sp.	*Salix sepulcralis*
Carrickalinga	Riverview Drive			
Carrickalinga	Rose Cottage		*Typha domingensis*	*Eucalyptus* sp.
Patawalonga	Star & Arrow Rd			*Eucalyptus* sp.
Patawalonga	Sturt Valley Rd			*Rubus fruticosus*
Yankalilla	Yankalilla River Bridge			
Patawalonga	Winns Rd			*Pennisetum clandestinum*
Patawalonga	Willow Glen			*Pennisetum clandestinum*
Christie's Creek	Thaxted Park Golf Course			*Eucalyptus* sp.
Patawalonga	Riverglen Place		*Bamboo species*	*Fraxinus* sp.
Deep Creek	Dog Trap Creek			
Deep Creek	Rangers Pump	*Triglochin* sp.		*Melaleuca* sp.
Gawler	Pony Club		*Phragmites australis*	
Gawler	Gawler Flood Pool		*Phragmites australis*	
Gawler	Old Port Wakefield Road		*Phragmites australis*	*Phragmites australis*
Deep Creek	Deep Creek Crossing		*Melaleuca* sp.	
Gawler	Whites Road Wetland			
Deep Creek	Deep Creek WF Below			
Deep Creek	Deep Creek Waterfall			
Boat Harbour	Boat Harbour Gate 42		*Cyperus* sp.	
Boat Harbour	Boat Harbour Beach			*Melaleuca* sp.
Boat Harbour	Boat Harbour Guage		*Typha domingensis*	
Gawler	Happy Home Reserve			
Yankalilla	DS Yankalilla Crossing			
Hindmarsh	Cootamundra Reserve		*Phragmites australis*	*Phragmites australis*
Hindmarsh	Hindmarsh Falls		*Phragmites australis*	*Acacia* sp.
Hindmarsh	Sawpit Rd		*Salix sepulcralis*	*Rubus fruticosus*
Patawalonga	West Beach Road Bridge		*Typha domingensis*	*Cyperus* sp.
Patawalonga	Adelaide Shores Golf Course			*Melaleuca* sp.

Greater Catchment	Site Name	Dominant Aquatic	Dominant Emergent	Dominant Riparian (Exotic = Red)
Patawalonga	Adelaide Shores Skate Park			
Patawalonga	Frank Smith Park			
Onkaparinga	Mylor Bridge			
Myponga	Roger's Property		*Phragmites australis*	
Torrens	Martin Hill Rd		*Triglochin* sp.	*Acacia* sp.
Torrens	Alexander Forest Road		*Typha domingensis*	*Salix sepulcralis*
Myponga	Myponga Township			
Onkaparinga	Dixons			
Inman	Forest Dam			
Callawonga	Callawonga Guage			
Onkaparinga	Mylor Dam			
Onkaparinga	Aldgate Bridge			
Callawonga	Callawonga Dam	*Myriophyllum* sp.		*Triglochin* sp.
Inman	Teague Property	*Myriophyllum* sp.	*Juncus usitatus*	
Inman	Hay Bales			
Callawonga	Callawonga	*Persicaria* sp.	*Triglochin* sp.	*Melaleuca* sp.
Callawonga	Walker's Place			
Callawonga	Balquhidder	*Potamogeton pectinatus*	*Phragmites australis*	
Callawonga	Callawonga Beach		*Triglochin* sp.	
Torrens	Winton Rd			*Rubus fruticosus*
Myponga	DS Myponga River Gauge		*Typha domingensis*	
Inman	Inman Gauge		*Typha domingensis*	*Eucalyptus* sp.
Inman	Gunter's			
Onkaparinga	Nurrutti Reserve			
Inman	Swains Rd Crossing		*Typha domingensis*	*Eucalyptus* sp.
Callawonga	Walker's Waterfall			
Inman	White's Property			
Myponga	Rogers Rd Culvert			
Torrens	Waterfall Gully		*Typha domingensis*	*Acacia* sp.
Torrens	Talunga Park Bridge			*Eucalyptus camaldulensis*
Torrens	US Mount Pleasant Pipeline		*Typha domingensis*	
Torrens	Cromer Rd Bridge)		*Typha domingensis*	*Eucalyptus* sp.
Torrens	Mount Pleasant Cottage			*Acacia* sp.
Torrens	US Chinaman's Hut			
Torrens	Chinaman's Hut			
Patawalonga	Brownhill Ford			*Querous* sp.
Patawalonga	DS Caravan Park			*Salix sepulcralis*
Torrens	Mount Pleasant Golf Dam			*Eucalyptus* sp.
Torrens	Mount Pleasant Crash Repair			
Gawler	DS Chattertons		*Typha domingensis*	*Fraxinus angustifolia*
Gawler	Kochs		*Typha domingensis*	
Gawler	US Yaldara weir		*Tecticornia* sp.	*Eucalyptus* sp.
Gawler	US Chattertons		*Typha domingensis*	*Bamboo species*
Gawler	Jacobs Creek Visitors Centre		*Phragmites australis*	*Eucalyptus camaldulensis*
Gawler	Owen's Culvert			
Gawler	Hahn's paddock	*Potamogeton crispus*	*Phragmites australis*	*Eucalyptus* sp.
Gawler	DS Matchos		*Phragmites australis*	*Eucalyptus* sp.
Gawler	Nuritootpa Caravan Park			*Eucalyptus camaldulensis*
Gawler	DS Nuritoopta Caravan Park			*Eucalyptus camaldulensis*
Gawler	Barossa Novotel		*Typha domingensis*	*Fraxinus angustifolia*
Gawler	US Landcare Reserve		*Typha domingensis*	*Fraxinus angustifolia*
Gawler	DS Landcare Reserve		*Phragmites australis*	*Fraxinus angustifolia*
Gawler	Tanunda Township		*Typha domingensis*	*Eucalyptus camaldulensis*
Gawler	Seppeltsfield Weir		*Phragmites australis*	*Eucalyptus camaldulensis*
Gawler	DS Tanunda Creek Rd			*Eucalyptus* sp.
Gawler	US Tanunda Creek Rd			
Gawler	Jacobs Creek Crossing	*Chara* sp.	*Typha domingensis*	*Eucalyptus* sp.
Gawler	Yaldara Weir		*Typha domingensis*	*Eucalyptus* sp.

Greater Catchment	Site Name	Dominant Aquatic	Dominant Emergent	Dominant Riparian (Exotic = **Red**)
Gawler	Smythe St Crossing		*Typha domingensis*	*Fraxinus angustifolia*
Gawler	Jacobs Creek Old Gauge		*Juncus usitatus*	*Fraxinus angustifolia*
Gawler	Tanunda Heinemann Guage	*Rosa canina*	*Phragmites australis*	
Gawler	St Hallets Crossing		*Typha domingensis*	*Eucalyptus* sp.
Gawler	St Hallets Bike Path		*Phragmites australis*	*Fraxinus angustifolia*
Gawler	DS Kaiser Stuhl			
Gawler	Tanunda Railway Crossing			
Gawler	Owen's Grange			
Gawler	Brooks Property	*Triglochin* sp.		*Eucalyptus camaldulensis*
Gawler	Cornerstone Stud	*Myriophyllum* sp.	*Typha domingensis*	*Eucalyptus* sp.
Gawler	US Cornerstone Stud	*Triglochin* sp.	*Typha domingensis*	*Eucalyptus* sp.
Gawler	DS Evans Weir			*Eucalyptus* sp.
Gawler	US Duck Ponds Pool		*Typha domingensis*	*Eucalyptus* sp.
Gawler	DS Duck Ponds Poll		*Typha domingensis*	*Eucalyptus* sp.
Gawler	North Para Old Gauge			
Gawler	US McEvoy Weir		*Typha domingensis*	*Eucalyptus* sp.
Gawler	Old Moculta Bridge			*Betula* sp.
Gawler	Penrice Quarry		*Typha domingensis*	*Eucalyptus* sp.
Gawler	Rex's Place		*Phragmites australis*	*Eucalyptus* sp.
Gawler	Penrice Quarry 2		*Typha domingensis*	*Eucalyptus* sp.
Gawler	Thorne-Clarke Ford		*Phragmites australis*	*Eucalyptus* sp.
Gawler	US Thorne-Clarke		*Phragmites australis*	*Salix sepulcralis*
Gawler	US Evan's Weir			*Eucalyptus camaldulensis*
Gawler	Gumhill		*Phragmites australis*	
Gawler	Third Evan's Weir		*Typha domingensis*	

8. APPENDIX C

Catchment	Site_Name	Average Temperature (°C)	Average Salinity (ppt)	Average pH	Average Turbidity (NTU)	Minimum Disolved Oxygen (mg.L^{-1})	Maximum Disolved Oxygen (mg.L^{-1})
Gawler River	Rex's Place	17.64	6.14	8.18	54.57	0.36	1.96
Gawler River	US and DS Duck Ponds Pool	18.76	3.52	8.23	38.04	0.53	2.72
Gawler River	Jacobs Creek Old Gauge	19.50	0.62	8.77	5.43	0.41	1.32
Gawler River	Jacobs Creek Crossing	20.46	1.00	8.71	10.85	4.29	6.09
Gawler River	Jacobs Creek Visitors Centre	20.00	3.22	8.70	30.70	0.83	7.71
Gawler River	Seppeltsfield Weir	24.85	9.90	9.36	44.62	9.32	9.88
Gawler River	Owen's Culvert	22.20	8.65	8.85	17.67	1.41	12.53
Gawler River	Owen's Grange	20.33	3.94	8.84	63.43	1.66	5.57
Gawler River	DS Kaiser Stuhl	21.22	3.19	8.80	133.80	2.45	2.45
Gawler River	US Tanunda Creek Rd	15.58	3.19	8.17	26.33	0.39	2.10
Gawler River	DS Tanunda Creek Rd	20.70	2.45	9.00	63.90	4.50	5.05
Gawler River	Tanunda Railway Crossing						
Gawler River	Brooks Property	23.86	2.31	8.88	13.07	2.04	6.99
Gawler River	North Para Old Gauge	20.46	1.35	8.54	18.80	6.14	6.68
Gawler River	US Cornerstone Stud	21.36	2.72	8.78	180.10	4.30	7.19
Gawler River	Cornerstone Stud	20.69	2.07	8.89	4.82	2.48	5.97
Gawler River	US Evan's Weir	23.95	1.20	10.15	72.67	2.10	24.21
Gawler River	DS Evans Weir	20.11	1.27	9.13	58.67	3.00	8.48
Gawler River	Third Evan's Weir						
Gawler River	US McEvoy Weir	23.11	1.22	8.71	28.02	0.42	7.54
Gawler River	US Thorne-Clarke	18.46	1.05	8.60	12.61	0.28	3.40
Gawler River	Thorne-Clarke Ford	24.70	1.23	8.88	7.72	3.30	7.83
Gawler River	Gumhill						
Gawler River	Old Moculta Bridge	18.57	2.28	9.02	27.17	3.95	4.69
Gawler River	Penrice Quarry	18.82	1.87	8.59	7.45	0.29	1.39
Gawler River	Nuritootpa Caravan Park	21.61	1.48	8.69	90.70	0.60	0.60
Gawler River	DS Nuritoopta Caravan Park	21.67	1.48	9.14	49.90	2.29	2.29
Gawler River	Hahn's paddock	22.13	4.87	8.47	3.93	0.66	4.48
Gawler River	DS Matchos	22.57	5.15	8.34	9.55	2.73	10.63
Gawler River	Smythe St Crossing	19.67	3.22	8.51	16.23	0.43	4.83
Gawler River	Tanunda Township	23.31	3.45	8.90	3.97	4.60	6.45
Gawler River	Tanunda Heinemann Guage	24.04	5.05	9.02	121.30	5.35	5.96
Gawler River	St Hallets Crossing	21.57	3.57	8.83	8.57	1.62	3.87
Gawler River	St Hallets Bike Path	23.75	4.52	8.96	15.60	10.33	11.61
Gawler River	Barossa Novotel	20.14	4.82	9.57	62.25	6.51	16.84
Gawler River	US Landcare Reserve	21.49	2.86	9.25	35.16	1.49	24.56

Catchment	Site_Name	Average Temperature (°C)	Average Salinity (ppt)	Average pH	Average Turbidity (NTU)	Minimum Disolved Oxygen ($mg.L^{-1}$)	Maximum Disolved Oxygen ($mg.L^{-1}$)
Gawler River	DS Landcare Reserve	22.39	2.63	9.75	38.67	1.70	24.01
Gawler River	US Chattertons	19.40	2.48	8.74	30.93	11.93	13.98
Gawler River	DS Chattertons	24.18	4.03	9.18	51.47	10.55	10.85
Gawler River	Kochs	19.87	4.91	9.72	94.27	1.76	12.37
Gawler River	US Yaldara weir	19.25	2.78	9.37	260.00	11.37	12.84
Gawler River	Yaldara Weir	22.96	3.77	9.72	26.45	3.81	15.72
Gawler River	Pony Club	10.60	0.12	9.04	44.80	6.15	6.36
Gawler River	Gawler Flood Pool	13.12	0.11	8.63	50.32	8.09	11.00
Gawler River	Old Port Wakefield Road	11.60	3.54	8.00	10.32	1.60	5.87
Little Para River	One Tree Hill Crossing	23.14	0.19	9.20	55.48	7.83	7.93
Little Para River	Happy Home Reserve						
Little Para River	Whites Road Wetland	12.60	0.11	9.51	9.95	6.48	6.93
Torrens	Martin Hill Rd	19.72	1.27	8.40	121.15	3.38	4.82
Torrens	Alexander Forest Road	19.86	0.44	8.57	45.45	4.06	5.01
Torrens	Winton Rd	21.59	0.89	8.28	6.87	3.48	4.47
Torrens	US Chinaman's Hut	21.01	0.18	8.92	1.20	8.06	8.06
Torrens	Chinaman's Hut	17.25	0.19	9.10	1.40	7.43	8.29
Torrens	Waterfall Gully						
Torrens	Mount Pleasant Golf Dam	23.16	0.80	8.57	11.22	1.58	3.56
Torrens	Mount Pleasant Cottage	16.37	2.95	8.58	29.60	5.53	7.56
Torrens	Talunga Park Bridge	16.97	0.75	8.50	112.23	2.84	7.51
Torrens	Mount Pleasant Crash Repair						
Torrens	US Mount Pleasant Pipeline	19.32	0.19	8.84	30.83	2.23	7.62
Torrens	Cromer Rd Bridge)	23.69	0.17	8.39	71.95	7.02	7.10
Patawalonga	Cherry Plantation	11.10	0.55	8.68	0.30	7.92	7.92
Patawalonga	Sturt Valley Rd	12.44	0.43	8.63	18.30	9.25	9.25
Patawalonga	Frank Smith Park						
Patawalonga	Winns Rd						
Patawalonga	Willow Glen						
Patawalonga	Riverglen Place						
Patawalonga	Star & Arrow Rd	11.60	0.45	8.59	12.30	6.24	6.24
Patawalonga	Weymouth Horse Trail						
Patawalonga	Weymouth Reserve						
Patawalonga	Brownhill Ford	17.97	0.34	8.90	9.60	6.97	7.35
Patawalonga	DS Caravan Park	18.86	0.23	8.56	9.60	1.13	2.68
Patawalonga	West Beach Road Bridge						
Patawalonga	Adelaide Shores Golf Course						
Patawalonga	Adelaide Shores Skate Park						
Pedler Creek	DS Pedler Footbridge	12.88	2.21	8.49	15.55	7.62	7.99
Christie's Creek	Thaxted Park Golf Course						
Christie's Creek	Christie Wetland						

Catchment	Site_Name	Average Temperature (^oC)	Average Salinity (ppt)	Average pH	Average Turbidity (NTU)	Minimum Disolved Oxygen (mg.L^{-1})	Maximum Disolved Oxygen (mg.L^{-1})
Christie's Creek	Galloway Rd						
Onkaparinga	Aldgate Bridge	14.90	0.27	8.07	6.90	8.62	8.62
Onkaparinga	Nurrutti Reserve	17.76	0.30	8.24	49.30	2.56	2.56
Onkaparinga	Dixons	16.63	0.36	7.37	28.30	0.63	1.38
Onkaparinga	Mylor Bridge	13.83	0.24	8.30	17.90	2.02	4.82
Onkaparinga	Mylor Dam	23.35	0.27	8.28	22.03	3.91	10.38
Onkaparinga	Scott Creek	12.70	0.56	8.70	34.50	9.20	9.20
Onkaparinga	Scott Creek Gauge	12.45	0.63	9.06	18.90	7.92	7.92
Onkaparinga	Charleston	11.45	0.35	8.28	50.90	6.21	6.21
Onkaparinga	Clisby Rd	11.74	0.32	8.32	95.40	5.30	5.30
Onkaparinga	Oakwood Rd	11.75	0.31	8.60	42.80	5.17	5.17
Onkaparinga	Spoehrs Rd	12.38	0.30	8.49	48.90	6.12	6.12
Onkaparinga	Verdun	12.13	0.28	8.64	41.40	5.57	5.57
Onkaparinga	Silverlakes	12.40	0.26	9.12	45.00	8.89	8.89
Wirra Creek	Wirra Creek Bridge	13.55	1.10	8.75	20.60	9.01	9.01
Willunga Creek	St. Johns Rd	14.06	1.58	8.04	12.70	1.44	1.44
Willunga Creek	Methodist St	13.83	1.24	8.46	15.30	9.02	9.02
Willunga Creek	Norman Road (Giles Rd)						
The Washpool	Washpool US barrier	12.56	0.42	8.76	3.70	5.81	6.19
The Washpool	Washpool	13.03	2.78	8.42	18.70	9.54	9.54
Myponga	Rogers Rd Culvert	13.51	0.62	8.29	5.30	8.03	8.03
Myponga	Roger's Property	11.76	0.39	8.50	10.54	7.07	8.08
Myponga	DS Myponga River Gauge	16.54	0.24	8.12	24.90	5.79	5.79
Myponga	Myponga Township	17.92	0.56	7.82	16.48	2.88	5.55
Carrickalinga	Rose Cottage	12.87	0.99	9.24	23.97	8.91	8.93
Carrickalinga	Riverview Drive	13.00	0.67	9.01	140.57	9.43	9.46
Yankalilla	Yankalilla River Bridge	12.60	0.19	9.08	309.60	9.95	9.95
Yankalilla	DS Yankalilla Crossing						
Deep Creek	Dog Trap Creek	9.45	1.08	8.62	96.00	9.83	9.85
Deep Creek	Rangers Pump	10.19	0.61	9.14	24.93	9.46	9.51
Deep Creek	Deep Creek Crossing	9.70	0.65	9.00	22.65	9.48	9.59
Deep Creek	Deep Creek Waterfall	9.14	0.55	9.20	16.50	10.40	10.40
Deep Creek	Deep Creek WF Below						
Boat Harbour	Boat Harbour Guage	9.61	0.13	9.15	15.40	9.92	9.92
Boat Harbour	Boat Harbour Gate 42						
Boat Harbour	Boat Harbour Beach	9.21	0.18	9.17	4.70	10.53	10.53
Callawonga	Callawonga Dam	14.24	0.13	7.87	48.18	0.37	5.38
Callawonga	Walker's Waterfall	13.21	0.23	8.73	18.40	9.87	9.89
Callawonga	Walker's Place	12.32	0.22	9.24	9.50	9.69	9.71
Callawonga	Callawonga	16.57	0.32	8.58	26.33	9.09	9.13
Callawonga	Callawonga Guage						

Catchment	Site_Name	Average Temperature (°C)	Average Salinity (ppt)	Average pH	Average Turbidity (NTU)	Minimum Disolved Oxygen ($mg.L^{-1}$)	Maximum Disolved Oxygen ($mg.L^{-1}$)
Callawonga	Balquhidder	17.27	0.74	8.88	9.75	9.14	9.33
Callawonga	Callawonga Beach	20.76	16.89	8.37	43.07	5.89	9.27
Inman	Teague Property	15.54	0.49	7.91	35.33	8.41	9.35
Inman	Forest Dam	17.79	0.20	8.02	52.73	3.34	8.50
Inman	Inman Gauge	16.51	1.25	8.11	7.43	6.63	6.90
Inman	Hay Bales	17.05	1.28	8.53	4.00	7.80	8.02
Inman	Gunter's	17.91	1.52	8.37	4.26	8.10	8.87
Inman	White's Property	16.61	1.80	8.36	30.33	6.13	6.54
Inman	Swains Rd Crossing	19.05	2.81	7.84	12.88	2.54	6.86
Hindmarsh	Hindmarsh Falls						
Hindmarsh	Sawpit Rd						
Hindmarsh	Cootamundra Reserve						