Inland Waters & Catchment Ecology

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Condition of Freshwater Fish Communities in the Adelaide and Mount Lofty Ranges Management Region

Dale McNeil, David Schmarr and Rupert Mathwin

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Survey Report for the Adelaide and Mount Lofty Ranges Natural Resources Management Board

Government of South Australia

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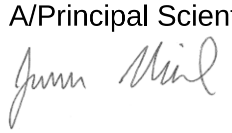
Signed: 

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

This report outlines the results of a large-scale fish survey that was conducted across the Adelaide and Mount Lofty Ranges Natural Resources Management region during autumn and winter 2011. The aim of the survey was to develop an index of ecological condition of freshwater aquatic ecosystems using fish as the principle biotic indicator group.

The survey assessed a range of variables including species assemblages (presence/absence), abundance and population size structure at sixty four sites across fourteen separate river catchments. Fish were caught at 95% of the sites sampled with a total of thirteen native and eight invasive species identified. In total 11,909 individual fish were caught (9,220 native and 2,689 exotic).

The results of the survey were analysed and a scorecard system developed to estimate a *Fish Health Index*, that allowed sites to be objectively categorized based on a number of key ecological variables. The presence of native fish species and exotic species, and the overall dominance of native over exotic species were calculated individually for each site. These three scores were integrated to provide a single score that could be used to compare the relative condition of fish communities at each site. This resulted in a ‘traffic light’ system indicating whether sites were in good, moderate or poor condition.

Survey results were discussed in relation to native fish biodiversity, exotic fish management and the protection of aquatic ecosystem health in the Adelaide and Mount Lofty Ranges Natural Resource Management Area. Suggestions were also provided for developing Natural Resource Management strategies, targets and interventions relating to the protection and improvement of freshwater ecosystems in the region.

1. INTRODUCTION

1.1. Background

Aquatic organisms such as fish are an excellent indicator for the general condition of aquatic ecosystems (Carter *et al.* 2006). As a higher trophic level consumer, healthy populations and abundances of freshwater fish 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 components focused on the monitoring of fish as an indication of riverine condition across large spatial and temporal scales (MDBC 2004, LEBMF 2011). Aquatic ecosystems in good condition are able support healthy native fish populations and should possess:

- All expected native fish species based on natural range and habitat requirements
- A high numbers of individuals (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). 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.

This type of data supports a range of management prioritisation and assessment activities and provides a very 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 general threatening processes, anthropogenic and natural impacts. This information can be extremely effective in direction of regional Natural Resource Management (NRM) investment 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 excellent temporal resolution that is very descriptive of condition trends, rates of change that are amenable to statistical testing, 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 an extremely 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 or 'The Board') 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 clearly acknowledges that there is considerable evidence of ongoing loss and declines in freshwater fishes throughout Adelaide and the Mount Lofty Ranges. This pattern 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 native fish species that were previously not known to inhabit the region, and also have identified a number of species that have become extinct or seriously endangered in the region 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 (Schmarr *et al* 2011, McNeil *et al.* 2011, Hammer In prep.).

The aim of the current project was to select a large number of sites across the Western MLR and Adelaide region incorporating all major catchments and habitat types including coastal, lowland and upland waterways. Where possible, sites were selected that had existing baseline data, as well as linking in with other Board programs such as the Verifying Water Allocation Science for Planning (VWASP) and Environmental Water Provision (EWP) programs. The survey will verify the distribution and population structure of native fish species across the region and provide a baseline of the biodiversity value and ecological condition of fish populations and aquatic habitats from which condition report cards and progress towards management targets can be measured, particularly if regular monitoring programs can be developed to provide sequential sampling over longer time frames.

The following report outlines the results of the fish survey 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 will develop an approach for presenting a simple classification process for capturing the relative ecological condition of fish communities and populations in order to provide a simple platform of ecological condition against which prioritisation of NRM investments and progress towards management targets for aquatic biodiversity and condition can be measured. Finally the report will outline management recommendations and provide ideas for the development of monitoring strategies based on the outcomes of the survey.

2. METHODS

2.1. Study site selection

The survey ran from March to July 2011 across three Water Allocation Planning Areas (Western MLR, Northern Adelaide Plains and Barossa – Figure 1) encompassing the Fleurieu Peninsula (Figure 2), Western (Figure 3) and Northern (Figure 4) Mount Lofty Ranges Regions. The survey assessed 64 sites across 16 catchments (see Figures 2-4). Additional data was included for two sites - Wirra Creek and Willunga Creek - which were concurrently sampled as part of a different project. Sites were selected across the Adelaide and Mount Lofty Ranges, with a view to maximizing representation from a broad number of river catchments and replication of sampling in different zones within each catchment. Where possible, sites were selected where previous fish data was available, or where knowledge gaps existed for particular rivers or catchments. Replication of sites within broader catchments was kept to a minimum to allow for a greater geographic spread of survey sites across the Adelaide and Mount Lofty Ranges management region. Site locations are presented, along with fish catch data, in Table 1.

2.2. Water Quality & Habitat

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) (Appendix 1). A point of maximum depth was identified within each site where water quality was recorded.

Water quality parameters, including dissolved oxygen, water temperature, pH and salinity, were analysed on site using an YSI 6920 sonde or TPS 90FL-T field meter. Measurements were taken at the water's surface and then at 50cm depth intervals concluding at the riverbed. Water quality data has been presented by catchment and displays the minimum and maximum dissolved oxygen from each site as well as mean values for temperature (^{o}C), conductivity (mS/cm-1), turbidity (NTU) and pH. Ecologists recorded land use and key threats at each site, as well as general comments on fish biota or site health, (see Appendix 2).

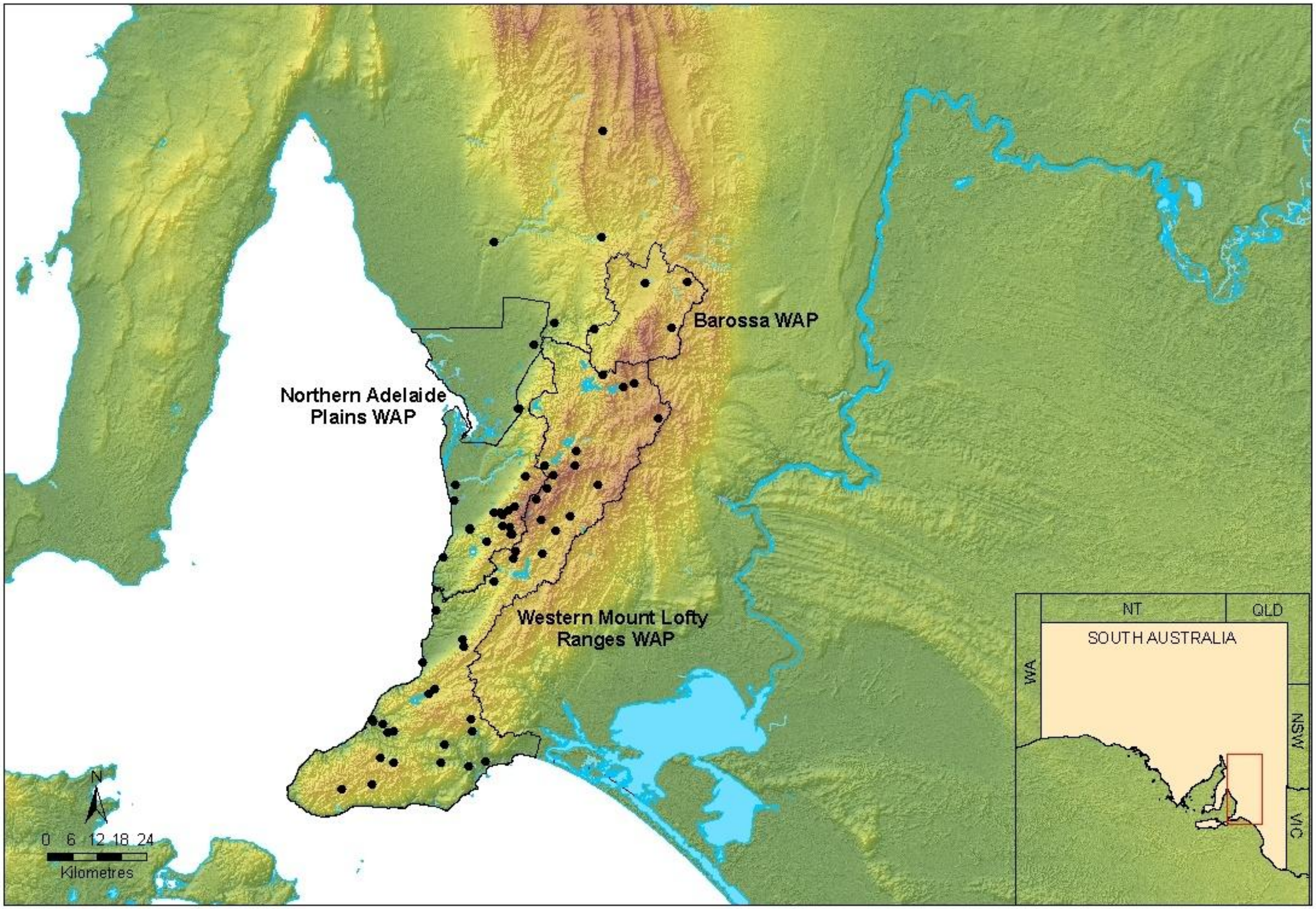

Figure 1 Survey sights in relation to Water Allocation Planning (WAP) Areas

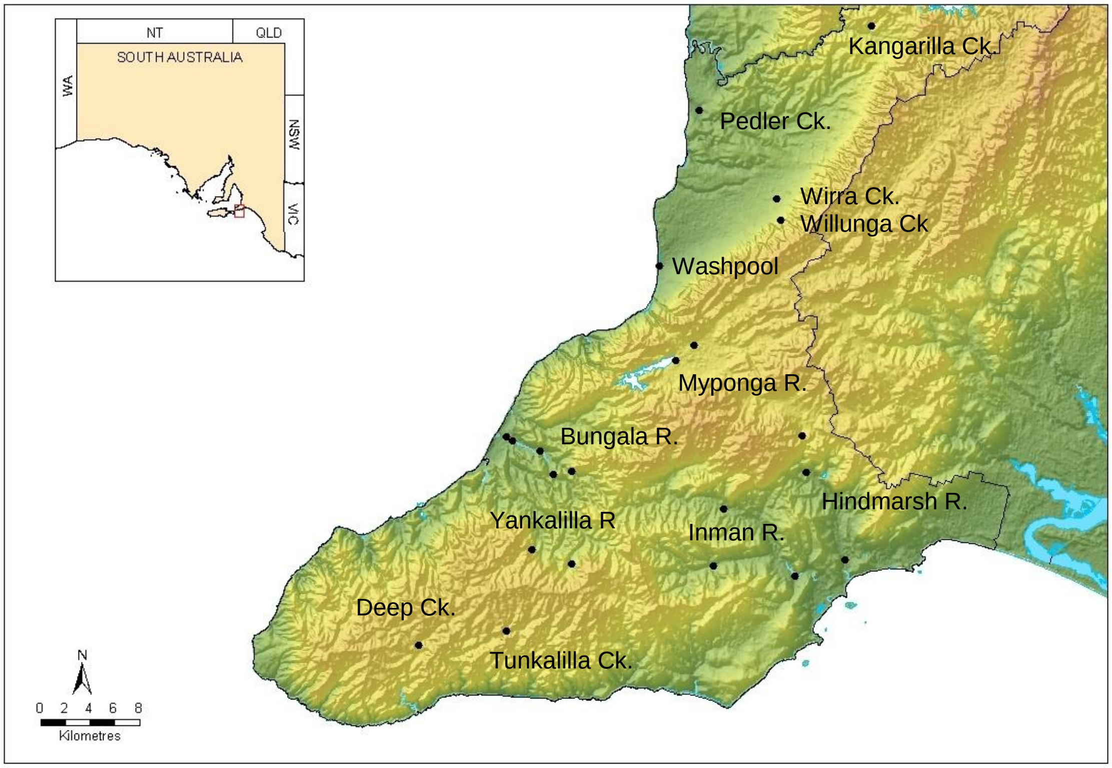

Figure 2 Survey sights the Fleurieu Peninsula region showing major river catchments surveyed.

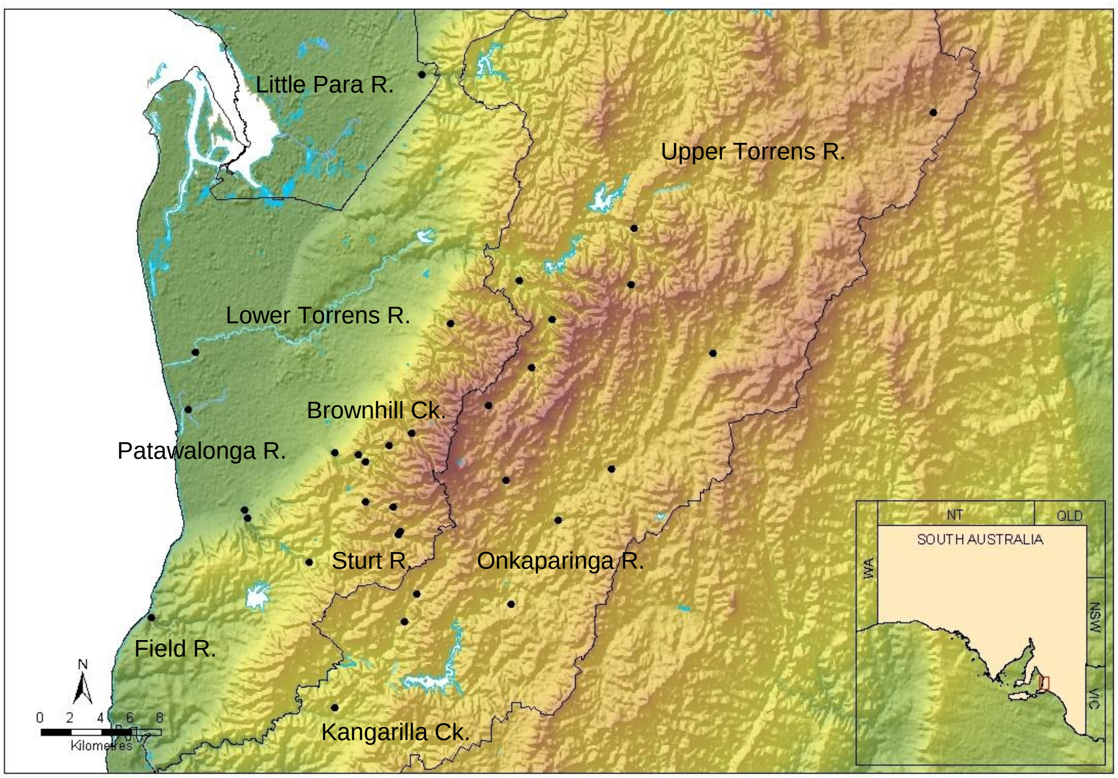

Figure 3 Survey sights the Central Adelaide and Mount Lofty Ranges showing major river catchments surveyed.

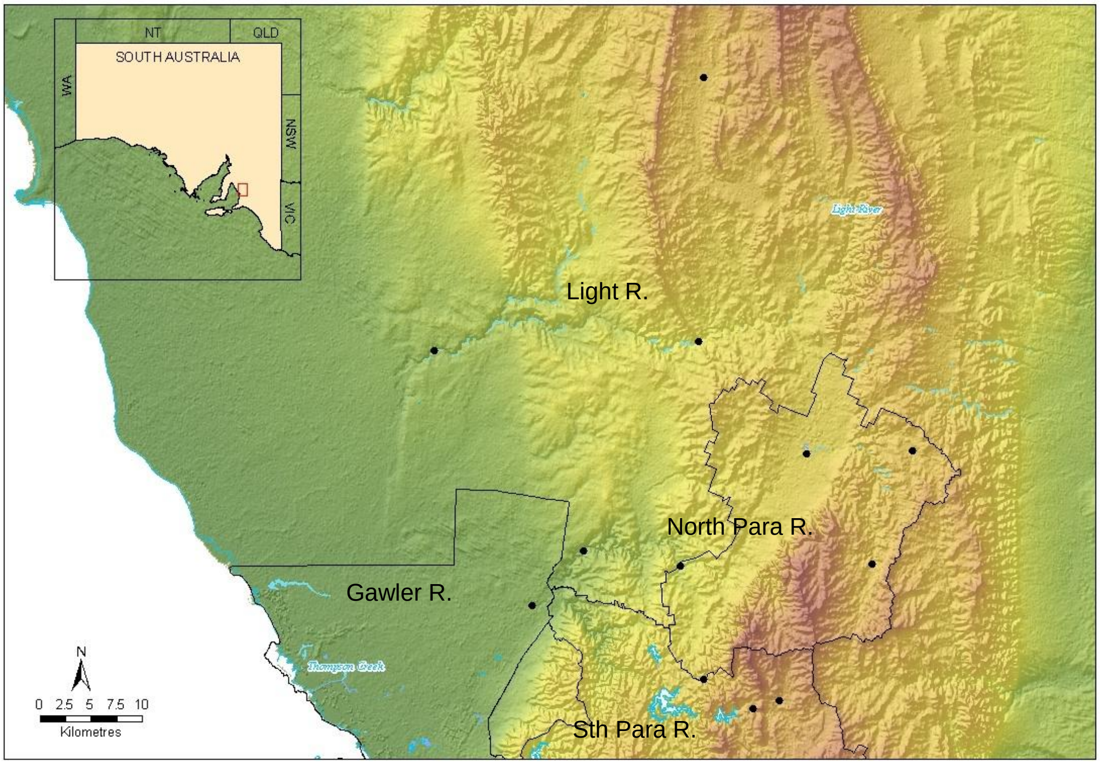

Figure 4 Survey sights the Northern Mount Lofty Ranges and Barossa region showing major river catchments surveyed.

2.3. Sampling protocol

This study utilised three different types of fyke net: 'large fykes' (5m leader, 4m funnel, 6mm mesh), 'small fykes' (3m leader, 2m funnel, 3mm mesh) and 'double-wing fykes' (2 x 5m wings, 3m funnel, 3mm mesh). An ideal set of two large, two double-wing and four small fykes was planned for each site, however, there was significant variability in the available area for setting nets at each site. While the majority of sites were sampled with the full complement of nets, some smaller sites were sampled with fewer nets and the smallest site (Washpool) received only 2 small fykes. All nets were set within 150m of the central site location (usually the site of GPS location).

At each site, nets were set within all of the available aquatic microhabitats. Nets were anchored using heavy gauge chain clipped to the cod and wing ends or were tied off against stakes. 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 (birds, turtles or water rats) could take refuge until the net was processed.

Fyke nets were set overnight (set before dusk and collected after dawn) ensuring that each site was set for a minimum of 14 hours. This time period allowed capture during crepuscular movement and allowed adequate time for nets to perform. On collection, fish were identified and a maximum of 100 fish from each species were measured (total length (TL mm)). When the 100th fish was measured part way through a fyke, measuring of this species continued until completion of the net to remove within-net size bias.

2.4. Data Analysis

2.4.1. Scorecard condition ratings

The data collected was used to create a scorecard for fish health at each site for three key criteria; *Native fish biodiversity*, *Exotic fish diversity* and *relative dominance* (based on abundance and population structure) of native fish.

The Native Fish Diversity score reflects the number of native fish species identified at each site. It was scored between -5 and 9 points. The presence of one native species of fish scored 3 points, the second and third species each add 2 points and subsequent species add a single point to a maximum of 9 points. An absence of native fish resulted in a score of -5. For the purpose of this assessment translocated native species were considered 'native'. The final value was assigned a 'traffic light' colour reflecting the diversity of native fish species observed. The colour Green indicated multiple native fish species present and was awarded to sites with two or more native species present and a Native Fish Diversity score of 5 or higher. Amber reflected simpler communities with only a single native species present (scored as 3 points), while Red was assigned to sites with no native fish present (scored as -5 points).

Opposing this was the Exotic Fish Diversity Score. This generated a negative score between 0 and -9 points which reflected the number of exotic fish species present at each site. The first exotic fish species identified scored -3 points, the second and third species each scored -2 points and subsequent species score a further -1 point to a maximum of -9 points. This value was also assigned a traffic light colour to reflect the number of exotic fish species present. Green was awarded to sites with no exotic species of fish present. Sites with one or two introduced species present (and a score of -3 or -5) were assigned Amber and sites with three or more introduced species present (score -7 to -9) were assigned Red.

A third score, Dominance, was scored to reflect the significance and stability of the native fish populations, as observed from our data. Three points were awarded if a complex population structure (e.g. the presence of a range of size classes) was observed in native fish. Three points were deducted if a complex population structure was observed in exotic fish species. Three points were awarded if there were high numbers of native fish present and three points were deducted if there were high numbers of exotic fish present. Three points were deducted if an exotic predator was present at the site. These values were summed to reach a final Dominance score for each site which ranged from 6 to -9. This score was assigned a traffic light colour to reflect the stability of native fish populations at the site. Green was awarded to sites with a score of 3 or higher and reflected stable population dynamics at the site. Amber was awarded to sites with a score of 0, meaning there were issues of concern apparent. Red was awarded to sites with a negative score indicating a serious concern for the long term viability of the native fish populations present.

These three scores were combined to create a single Fish Health Index for each site reflecting the overall condition of the native fish population present. For ease of use, a traffic light colour was also assigned to this value. Green was awarded to sites with a value of 5 or higher and reflected a healthy native fish population in an environment free from introduced predation and with very minimal competition from introduced species. Green sites are referred to as “Stable”. Amber sites scored values between 4 and -4 and may be considered sites of concern. An Amber site had issues with either predation, introduced competition or had native fish populations in precariously low numbers. Sites classified as Amber are referred to as “At-Risk”. Red sites had a score below -4 and were sites with dramatically degraded native fish populations. Red sites typically had few native fish in small numbers with significant competition from introduced species. Red sites are referred to as “Disastrous”.

2.4.2. Multivariate Analysis

Primer version 6.1.12 (with PERMANOVA add-on) (Clarke and Gorley 2006) and PCOrd version 5.12 (McCune and Mefford 2006) were used to perform multivariate analysis comparing the fish communities at the 65 sites sampled. The data were fourth root transformed and analysed using group average clustering, SIMPER and indicator species analysis (Dufrene and Legendre 1997) (based on dendrogram groups at 44% similarity). Bray-Curtis (1957) similarities were used to calculate the similarity matrix for the cluster analysis.

3. RESULTS

3.1. General Results

Fish were caught at 95% of the sites sampled with a total of 13 native and eight invasive fish species identified. In total 11,909 individual fish were caught, 9,220 native (Table 1) and 2,689 exotic (Table 2).

The most numerous native fish found was *Galaxias olidus* (3,016 individuals) and *G. maculatus* (2,337 individuals). Other numerous native fish were; *Melanotaenia fluviatilis* (1,084 individuals), *Philypnodon grandiceps* (1,005 individuals), *G. brevipinnis* (721 individuals) and *Hypseleotris* spp. (651 individuals). Of the remaining seven native species, all had fewer than 250 individuals recorded (Table 1).

The two most abundant native species (*G. olidus* and *G. maculatus*) were also the two most widespread, appearing at 21 sites each. The next most wide spread species were *G. brevipinnis* and *P. grandiceps* with 11 sites each and *Pseudaphritis urvillii* with 10 sites. *Pseudogobius olorum* appeared at five sites and the remaining seven native species all occurred at three or fewer sites (Table 1).

The most numerous exotic species caught was *G. holbrooki* with 2,085 individuals. Llarger bodied species such as *Carassius auratus* (267 individuals), *Cyprinus carpio* (132 individuals) and *Perca fluviatilis* (131 individuals) were also numerous. The study captured 64 *Salmo trutta*, while nine *Oncorhynchus mykiss* and one *Tinca tinca* were captured (Table 2).

The most widespread exotic fishes were *G. holbrooki*, which were found at 20 sites and *P. fluviatilis*, found at 16 sites. The cyprinids were observed were *C. auratus* and *C. carpio* at 12 and nine sites respectively. The salmonids were less common, with *S. trutta* occurring in seven sites (and *O. mykiss* at three (Table 2).

Opportunistic observations were recorded for other aquatic fauna caught during the survey. Presence/absence data identified three species of crustacean, two species of turtle, one species of water rat and several tadpoles.

The yabby (*Cherax destructor*) was the most ubiquitous crustacean species observed, and was caught at 45 sites spread across the MLR. Glass shrimp (*Paratya australiensis*) was another widespread and common native crustacean appearing at 18 sites throughout the geographic range sampled. The exotic Marron (*Cherax cainii*) was observed at a single site in Deep Creek.

The eastern long-necked turtle (*Chelodina longicollis*) was the more common of the two turtle species. It was seen at seven sites in the; North Para, Torrens and Sturt Rivers, and in Willunga Creek. In comparison the short-necked turtle (*Emydura maquarii*) was caught at only a single site on the Sturt River (Railway Dam).

Water rats (*Hydromys chrysogaster*) were caught in nets at two sites, on the Inman and Little Para Rivers. The practice of placing two polystyrene buoys in each fyke's cod end appears to have been a success with no incidental mortality in birds, rats or turtles.

Unidentified tadpoles were caught at a total of 10 sites.

Table 1. Total catch of native fish species and native diversity for each survey site arranged by greater catchment. Species names have been abbreviated using the first three letter of genus followed by the first three letters of species. In this way; GAL MAC= *Galaxias maculatus*, GAL OLI= *Galaxias olidus*, GAL BRE= *Galaxias brevipinnis*, PHI GRA= *Philypnodon grandiceps*, ALD FOR= *Aldrichetta forsteri*, ACA BUT= *Acanthopagrus butcheri*, MEL FLU= *Melanotaenia fluviatilis*, ATH MIC= *Atherinosoma microstoma*, PSE URV= *Pseudaphritis urvillii*, HYP SPP= *Hypseleotris* spp., PSE OLO= *Pseudogobius olorum*, TAN TAN= *Tandanus tandanus* and ANG AUS= *Anguilla australis*. Tick means species present but no relative abundances recorded

Greater Catchment	Site Name	GPS	GAL MAC	GAL OLI	GAL BRE	PHI GRA	ALD FOR	ACA BUT	MEL FLU	ATH MIC	PSE URV	HYP SPP	PSE OLO	TAN TAN	ANG AUS	Native Diversity
Bungala	South Rd	54 H 256512E 6073933N	68								27					2
Bungala	Hay Flat	54 H 256971E 6073610N	103								39					2
Bungala	Stornaway	54 H 261975E 6071430N			53											1
Bungala	Yankalilla Rec Centre	54 H 259296E 6072943N	122								1					2
Bungala	Bartlett's	54 H 260494E 6071077N														0
Deep Creek	Dog Trap Creek	54 H 250289E 6056528N														0
Field	Field	54 H 271668E 6114451N	117								9					2
Gawler	Pony Club	54 H 290650E 6167442N	62			30							1			3
Gawler	Gawler Dam	54 H 295441E 6173116N	117			241										0
Gawler	Yaldara	54 H 305086E 6172145N	21			19							3			3
Gawler	Victoria Creek	54 H 307970E 6161152N			282											1
Gawler	Mt Crawford	54 H 313033E 6158509N			5	5										2
Gawler	Portuguese Bridge	54 H 315604E 6159517N														0
Gawler	Nuriootpa	54 H 316838E 6183919N														0
Gawler	Mt McKenzie	54 H 323913E 6173438N														0
Gawler	Moculta	54 H 327282E 6184778N														0
Hindmarsh	Hindmarsh Falls	54 H 280549E 6075438N		83	197											2
Hindmarsh	Sawpit Rd	54 H 281054E 6072445N	95		6						6					3
Hindmarsh	Cootamundra Reserve	54 H 284630E 6065460N	286			50	226	43	2	1	21					7
Inman	Kirk Rd	54 H 273955E 6064363N										1				1
Inman	Glacier Rock	54 H 274463E 6069031N			2											1
Inman	Guaging Station	54 H 280615E 6063902N	7									12				2
Light	Rockies	54 H 279557E 6191998N	48			86										2
Light	Marrabel	54 H 304599E 6220354N	1150													1
Light	Light Ford	54 H 305541E 6194389N	1			94										2
Little Para	Old Spot	54 H 287667E 6151695N														0
Myponga	Myponga Township	54 H 269884E 6080978N														0
Myponga	Pages Flat	54 H 271331E 6082284N			48											1
Onkaparinga	Bakers Gully	54 H 284297E 6109157N		12												1
Onkaparinga	Scott Creek Conservation	54 H 288566E 6115115N														0
Onkaparinga	Scott Creek	54 H 289274E 6117015N		26												1
Onkaparinga	Cox Creek	54 H 294812E 6124922N		99												1
Onkaparinga	Silverlakes	54 H 295609E 6116731N	3													1
Onkaparinga	Hahndorf	54 H 298451E 6122459N	3		1	2										3

Greater Catchment	Site Name	GPS	GAL MAC	GAL OLI	GAL BRE	PHI GRA	ALD FOR	ACA BUT	MEL FLU	ATH MIC	PSE URV	HYP SPP	PSE OLO	TAN TAN	ANG AUS	Native Diversity
Onkaparinga	Oakbank	54 H 301814E 6126098N		9		2										2
Onkaparinga	Charleston	54 H 308119E 6134228N		374												1
Patawalonga	Patawolonga	54 H 273370E 6128469N	24						4		2		3		1	5
Patawalonga	Warriparinga	54 H 277517E 6121972N	25										4			2
Patawalonga	Riverside Reserve	54 H 277735E 6121455N	44	3												2
Patawalonga	Coromandel	54 H 282016E 6118768N		5												1
Patawalonga	DS Caravan Park	54 H 283296E 6126115N		3												1
Patawalonga	Ellis Creek	54 H 284884E 6126071N		71												1
Patawalonga	Brownhill Ford	54 H 285345E 6125646N		306												1
Patawalonga	Railway Dam	54 H 285505E 6122967N		6												1
Patawalonga	Lake Michigan	54 H 286906E 6126827N		171												1
Patawalonga	Cherry Plantation	54 H 287394E 6122713N		154												1
Patawalonga	Sturt Tributary	54 H 287827E 6120919N		241												1
Patawalonga	Willow Glen	54 H 287977E 6121111N														0
Pedler	Commercial Rd	54 H 270612E 6101433N									2					1
Pedler	Nashwauk	54 H 270612E 6101433N	33								1		1			3
Torrens	Waterfall Gully	54 H 288338E 6127737N		40												1
Torrens	Morialta	54 H 290547E 6135186N		438												1
Torrens	Collins	54 H 293342E 6129891N		292												1
Torrens	Corkscrew Bridge	54 H 294926E 6138288N														0
Torrens	Knotts Hill	54 H 296063E 6132539N														0
Torrens	Fire Track	54 H 297238E 6135826N														0
Torrens	Cudlee Ck	54 H 302373E 6142245N				9										1
Torrens	Fox Creek	54 H 302416E 6138471N		572	1											2
Torrens	Mt Pleasant	54 H 321900E 6151076N														0
Torrens	Breakout Creek	55 H 273644E 6132456N	4			467			1078			638		12		5
Tunkalilla	Tunkalilla	54 H 257420E 6058053N			86											1
Washpool	Washpool	54 H 268118E 6088618N	4								3					2
Willunga	Willunga	54 H 277824E 6092882N														0
Wirra	Wirra	54 H 277377E 6094582N		✓												1
Yankalilla	Ingalalla Falls	54 H 259093E 6064811N			40											1
Yankalilla	Chapmans	54 H 262428E 6063836N		111												1
		Total caught:	**2337**	**3016**	**721**	**1005**	**226**	**43**	**1084**	**1**	**111**	**651**	**12**	**12**	**1**	**Mean=1.33**
		Total Sites	**21**	**20**	**11**	**11**	**1**	**1**	**3**	**1**	**10**	**3**	**5**	**1**	**1**	

Table 2. Total catch of exotic fish species and occurrence of zero fish for each survey site arranged by greater catchment. Species names have been abbreviated using the first three letters of genus followed by the first three letters of species. In this way; PER FLU= *Perca fluviatilis*, GAM HOL= *Gambusia holbrooki*, PHA CAU= *Phalloceros caudimaculatus*, CYP CAR= *Cyprinus carpio*, CAR AUR= *Carassius auratus*, ONC MYK= *Oncorhychus mykiss*, SAL TRU= *Salmo trutta* and TIN TIN= *Tinca tinca*. Tick means no fish present (in No Fish column) or that a species was present but no relative abundances recorded.

Greater Catchment	Site Name	GPS	PER FLU	GAM HOL	PHA CAU	CYP CAR	CAR AUR	ONC MYK	SAL TRU	TIN TIN	No fish	No. Exotics
Bungala	South Rd	54 H 256512E 6073933N										0
Bungala	Hay Flat	54 H 256971E 6073610N										0
Bungala	Stornaway	54 H 261975E 6071430N	1									1
Bungala	Yankalilla Rec Centre	54 H 259296E 6072943N		249								1
Bungala	Bartlett's	54 H 260494E 6071077N									✓	0
Deep Creek	Dog Trap Creek	54 H 250289E 6056528N							1			1
Field	Field	54 H 271668E 6114451N										0
Gawler	Pony Club	54 H 290650E 6167442N		251		105	40					3
Gawler	Gawler Dam	54 H 295441E 6173116N		42		3	2					3
Gawler	Yaldara	54 H 305086E 6172145N	7	3		3	6			1		5
Gawler	Victoria Creek	54 H 307970E 6161152N										0
Gawler	Mt Crawford	54 H 313033E 6158509N	1									1
Gawler	Portuguese Bridge	54 H 315604E 6159517N	7									1
Gawler	Nuriootpa	54 H 316838E 6183919N					1					1
Gawler	Mt McKenzie	54 H 323913E 6173438N	13	8								2
Gawler	Moculta	54 H 327282E 6184778N									✓	0
Hindmarsh	Hindmarsh Falls	54 H 280549E 6075438N										0
Hindmarsh	Sawpit Rd	54 H 281054E 6072445N										0
Hindmarsh	Cootamundra Reserve	54 H 284630E 6065460N										0
Inman	Kirk Rd	54 H 273955E 6064363N										0
Inman	Glacier Rock	54 H 274463E 6069031N	6									1
Inman	Guaging Station	54 H 280615E 6063902N	25	56		2						3
Light	Rockies	54 H 279557E 6191998N		32		5	6					3
Light	Marrabel	54 H 304599E 6220354N		440			103					2
Light	Light Ford	54 H 305541E 6194389N				9	2					2
Little Para	Old Spot	54 H 287667E 6151695N									✓	0
Myponga	Myponga Township	54 H 269884E 6080978N	7	6								2
Myponga	Pages Flat	54 H 271331E 6082284N	3									1
Onkaparinga	Bakers Gully	54 H 284297E 6109157N										0
Onkaparinga	Scott Creek Conservation	54 H 288566E 6115115N									✓	0
Onkaparinga	Scott Creek	54 H 289274E 6117015N										0
Onkaparinga	Cox Creek	54 H 294812E 6124922N										0
Onkaparinga	Silverlakes	54 H 295609E 6116731N	5									1
Onkaparinga	Hahndorf	54 H 298451E 6122459N		4								1
Onkaparinga	Oakbank	54 H 301814E 6126098N	2	1								2

Greater Catchment	Site Name	GPS	PER FLU	GAM HOL	PHA CAU	CYP CAR	CAR AUR	ONC MYK	SAL TRU	TIN TIN	No fish	No. Exotics
Onkaparinga	Charleston	54 H 308119E 6134228N		1								1
Patawalonga	Patawolonga	54 H 273370E 6128469N		3		2	14					3
Patawalonga	Warriparinga	54 H 277517E 6121972N	15	291		2						3
Patawalonga	Riverside Reserve	54 H 277735E 6121455N	6									1
Patawalonga	Coromandel	54 H 282016E 6118768N	14					3	2			3
Patawalonga	DS Caravan Park	54 H 283296E 6126115N										0
Patawalonga	Ellis Creek	54 H 284884E 6126071N										0
Patawalonga	Brownhill Ford	54 H 285345E 6125646N										0
Patawalonga	Railway Dam	54 H 285505E 6122967N										0
Patawalonga	Lake Michigan	54 H 286906E 6126827N										0
Patawalonga	Cherry Plantation	54 H 287394E 6122713N										0
Patawalonga	Sturt Tributary	54 H 287827E 6120919N										0
Patawalonga	Willow Glen	54 H 287977E 6121111N							9			1
Pedler	Commercial Rd	54 H 270612E 6101433N		381		1	87					3
Pedler	Nashwauk	54 H 270612E 6101433N		80			1					2
Torrens	Waterfall Gully	54 H 288338E 6127737N	1									1
Torrens	Morialta	54 H 290547E 6135186N										0
Torrens	Collins	54 H 293342E 6129891N										0
Torrens	Corkscrew Bridge	54 H 294926E 6138288N						2	18			2
Torrens	Knotts Hill	54 H 296063E 6132539N						4	4			2
Torrens	Fire Track	54 H 297238E 6135826N							23			1
Torrens	Cudlee Ck	54 H 302373E 6142245N	18	5			1					3
Torrens	Fox Creek	54 H 302416E 6138471N										0
Torrens	Mt Pleasant	54 H 321900E 6151076N		225								1
Torrens	Breakout Creek	55 H 273644E 6132456N		7			4					2
Tunkalilla	Tunkalilla	54 H 257420E 6058053N										0
Washpool	Washpool	54 H 268118E 6088618N										0
Willunga	Willunga	54 H 277824E 6092882N		✓	✓	✓						0
Wirra	Wirra	54 H 277377E 6094582N										0
Yankalilla	Ingalalla Falls	54 H 259093E 6064811N							7			1
Yankalilla	Chapmans	54 H 262428E 6063836N										0
		Total Caught:	**131**	**2085**	**0**	**132**	**267**	**9**	**64**	**1**		
		Total Sites:	**16**	**19**	**0**	**9**	**12**	**3**	**7**	**1**		

3.2. Results by River

3.2.1. Bungala

The Bungala River was sampled at five different locations during March 2011. During this period, four of the five sites had no submerged vegetation and had become isolated due to poor flow. Emergent vegetation in the Bungala was a mixture of *Typha domingensis* and *Phragmites australis*. Land clearance had left little riparian vegetation at most of the sites; however Stornaway was situated amongst a stand of remnant tea tree (*Leptospermum lanigerum*) in the more generously wooded hills.

Due to the open mouth of the Bungala and the proximity of two of the sites to the ocean (Hay Flat and South Road) salinities were moderately high at these two sites, being 5.9 and 6.16 $mS.cm^{-1}$ respectively. The salinity inland at Bartletts was notably high at 8.00 $mS.cm^{-1}$ which, combined with water temperatures of 17.58^{o} C may have contributed to the lack of fish at this site. In contrast, Stornaway was positioned in a small spring fed tributary of the Bungala and had a markedly lower salinity (2.67 $mS.cm^{-1}$) than other sites in this catchment (Table 3).

In total, three native and two exotic species of fish were identified within the Bungala catchment. The lower three sites (Yankalilla Rec Centre, Hay Flat and South Rd) appeared to support diadromous movement as they all supported populations of *G. maculatus* and *P. urvillii* (Table 1). The still, permanent waters of Yankalilla Rec Centre also supported a large population of *G. holbrooki* whose numbers were not reflected in sampling results (Table 2). Although this was the only site where *G. holbrooki* was identified, it is anticipated that this site is acting as a source population for *G. holbrooki* within the system. Further upstream at Bartletts none of these species were identified which suggests permanent barriers to fish movement may be present between Yankalilla Rec Centre and Bartletts. In the higher tributary, Stornaway retained a small (53 individuals) population of *G. brevipinnis* (Table 1). Of some concern was the identification of a *P. fluviatilis* within this population (Table 2), as well as the low dissolved oxygen levels observed (2.94 - 1.32 $mg.L^{-1}$) (Table 3).

The Fish Health Index for the Bungala showed two Stable sites (Hay Flat and South Rd), two At-Risk sites (Stornaway and Yankalilla Rec Centre) and one Disastrous site (Bartletts). Both Hay Flat and South Rd scored well due to an absence of introduced fish and generally complex population structures of the native fish present. The high numbers of *G. holbrooki* contributed to Yankalilla Rec Centre being scored as At-Risk. Stornaway scored as At-Risk due to the presence of an introduced predator within a small population, and Bartletts scored as Disastrous due to a complete lack of fish (Table 4).

3.2.2. Deep Creek

Dog Trap Creek was within the Deep Creek Conservation Park and was the only site examined within this catchment. The site supported submerged *Vallisneria australis* and was positioned within healthy native scrub dominated by Eucalypts. Water quality was stable with low salinity (2.36mS/cm) and healthy levels of dissolved oxygen (6.28 $mg.L^{-1}$ at its lowest) (Table 3).

This site contained no native fish, only a single *S. Trutta* (Table 2). Also present was a number of the translocated crustacean *C. cainii*, which was only found at this site throughout the study.

The Fish Health Index for this site is Disastrous. This reflects the absence of any native fish and the presence of a translocated predator (Table 4).

3.2.3. Field River

Field was the only site examined within this catchment. This site had no submerged vegetation. The dominant emergent plant was *T. domingensis* and *Salix* spp. dominated the riparian zone. Due to technical issues with the water quality meter, results for this site are limited; however conductivity was accurately collected and was low at 2.3 $mS.cm^{-1}$ (Table 3).

Two native fish species (*G. maculatus* and *P. urvillii*) were identified at Field River (Table 1) and no exotic species were found. This site appears to support seasonal diadromous movement.

The Fish Health Index for this site was listed as Stable reflecting an absence of exotic fish and a large, stable population of *G. maculatus* (Table 4).

3.2.4. Gawler River

A total of nine sites were examined within the greater Gawler River catchment. Four of these sites fell within the North Para sub-catchment, three within the South Para and two further downstream in the Gawler River. No submerged vegetation was recorded at any site within this catchment. The dominant emergent vegetation throughout was a mixture of *T. domingensis* and *P. australis*, though one site (Moculta) lacked emergent vegetation. Eucalypts dominated the riparian zone at the majority of sites however environmental weeds *Betula pendula* (Victoria Creek) and *Fraxinus angustifolia* (Pony Club) dominated two of the sites.

Dissolved oxygen levels were variable throughout the catchment. Two of the more degraded sites with no flow (Moculta and Nuriootpa) had very low dissolved oxygen profiles, while most other sites were acceptable for fish habitation with at least 6 $mg.L^{-1}$ surface oxygen. Conductivity levels were predominantly less than 2 $mS.cm^{-1}$, however, the more degraded sites of Portuguese Bridge and Moculta had conductivities of 4.39 and 3.85 $mS.cm^{-1}$. Turbidity readings at Moculta were the highest observed in this study at 336.17 NTU (Table 3).

A total of four native and five exotic species were identified within the Gawler catchment. The most commonly observed native fish species was *P. grandiceps* which was present at four sites (Table 1). Three sites contained *G. maculatus*, while *P. olorum* and *G. brevipinnis* each occurred at two sites (Table 1). The most commonly observed exotic fishes were *P. fluviatilis*, *G. holbrooki* and *C. auratus*, each seen at four of the nine sites (Table 2). Two sites contained *C. carpio* and one site, Yaldara, contained a single *Tinca tinca*, the only example of this species in this study (Table 2). One site, Moculta, had no fish.

Fish Health Indices for the Gawler River reflect a degraded system with high levels of anthropogenic interference. The North Para River was predominantly without native fish, or when present, native fish were grossly outnumbered by exotic species. This resulted in four of five North Para sites classified as Disastrous. The remaining North Para site (Gawler Dam) was classified as At-Risk (Table 4).

Victoria Creek in the upper reaches of the South Para River was the most highly scored site in the Gawler River catchment, and the only site classified as “Stable” This was due to a large and complex population of *G. brevipinnis* with no exotic fish present. The remaining sites in the South Para scored low as they contained few or no native fish and exotic predators were present (Table 4). Three native species were found at Pony Club, the lowest site on the Gawler River, but this site had greater numbers of exotic fish and was therefore classified as At-Risk (Table 4).

3.2.5. Hindmarsh River

Three sites were sampled from within the Hindmarsh Catchment. Vegetation was variable between the sites sampled. Hindmarsh Falls supported thick, submerged *Persicaria decipiens* and ran through heavily wooded native scrub, dominated by eucalypts. Sawpit Rd lacked aquatic vegetation entirely and was dominated by *Salix* sp. Cootamundra Reserve was an urban park that lacked submerged vegetation probably due to the apparently tidal nature of the site. Remnant eucalypts lined this urban section of creek.

Water quality throughout the Hindmarsh catchment was generally good with low conductivities and reasonable levels of dissolved oxygen at both Cootamundra Reserve and Hindmarsh Falls. Sawpit Rd displayed poorer water quality with a slightly higher conductivity (5.9 $mS.cm^{-1}$) and lower surface dissolved oxygen concentrations (3.31 $mg.L^{-1}$) (Table 3).

Sampling within the Hindmarsh River failed to locate any exotic fish species (Table 2). A total of nine native species were identified making this the most diverse river sampled. Cootamundra reserve was the most species rich site in this study with seven native species identified. Three of the species identified at Cootamundra Reserve (*Aldrichetta forsteri*, *Acanthopagrus butcheri* and *Atherinosoma microstoma*) are usually considered to be estuarine fish, suggesting a tidal influence on this section of river and good connectivity to the ocean (Table 1). The Hindmarsh River supported healthy populations of all three galaxiid species (Table 1).

The Fish Health Index score for sites on the Hindmarsh River were high and reflected the high abundance and diversity of native fish as well as the absence of exotic fish. All three sites were scored as Stable and had the three highest scores calculated during this study (Table 4).

3.2.6. Inman River

Three sites were sampled on the Inman River. All three sites were in grazing areas with eucalypts dominating the riparian zone and generally poor riparian understorey. Glacier Rock supported some *V. australis* which was the only submerged species noted in this catchment. Emergent vegetation was a mixture of *T. domingensis* and *P. australis*.

Conductivity was generally low in the Inman. Turbidities were notably high at Kirk Rd and Gauging Station (60.37 and 111 NTU respectively) and dissolved oxygen was notably low at Kirk Road (max 3.32 $mg.L^{-1}$) (Table 3).

A total of three native species and three exotic species were identified in the Inman River. Kirk Rd contained only a single *Hypseleotris* spp. while Glacier Rock contained two *G. brevipinnis* (Table 1) and six predatory *P. fluviatilis* (Table 2). At Gauging Station native species, *G. maculatus* and *Hypseleotris* spp, (Table 1) were grossly outnumbered by three exotic species (*G. holbrooki*, *P. fluviatilis* and *C.carpio*) (Table 2).

Fish Health Indexes reflect the high numbers of exotic and predatory species in the system and the precipitously low numbers of native fish observed therefore Glacier Rock and Gauging Station were both scored as Disastrous. Kirk Rd was scored as At-Risk primarily due to the absence of exotic fish; however in this instance it is important to highlight that only a single fish was found placing this site at risk (Table 4).

3.2.7. Light River

Three sites were sampled on Light River. Flow was moderate at Light Ford and the Rockies, however no submerged vegetation was observed at any of the three sites. At Light Ford emergent vegetation was dominated by *Juncus usitatus*, the other two sites were predominantly dominated by *P. australis*. Dominant riparian vegetation was *Allocasurina* sp. (Light Ford) and eucalypt (Rockies) with Marabel being more degraded and dominated by *Rosa* sp.

Conductivity was notably high at all sites in the Light River ranging from 4.96-7.14 $mS.cm^{-1}$ (Table 3).

In total two native species (*G. maculatus* and *P. grandiceps*) and three exotic fish species were identified within Light River. Marabel had the highest abundance of *G. maculates* (n=1150) and l also contained a high number of *G. holbrooki* (*n*=440) and *C. auratus* (*n*=103). Both *C. auratus* and *G. maculatus* were found at all three sites, while *P. grandiceps*, *C. carpio* and *G. holbrooki* each appeared at only two of the sites.

Fish Health Indexes reflect the high incidence and large populations of exotic species within the catchment and resulted in all three sites being scored as At-Risk (Table 4).

3.2.8. Little Para River

Only a single site, Old Spot, was sampled on the Little Para River. It contained turbid water (75.25 NTU) and minimal vegetation beyond the remnant eucalypts that lined the creek (Table 3).

No fish were caught at this site. Water rats damaged two of the nets and a member of the public interfered with a third net. One water rat was the caught in a fyke net.

A lack of any fish at this site gave Old Spot a Fish Health Index of Disastrous (Table 4).

3.2.9. Maslin Creek

Wirra creek contained only *G. olidus* (Table 1), however, as only presence/absence data was available for fish numbers, this makes Wirra unsuitable for inclusion in scorecard calculations.

3.2.10. Myponga River

Two sites were sampled on the Myponga River, both upstream of Myponga Reservoir. The sections of stream observed ran through grazing country with little riparian vegetation. While some revegetation attempts were observed along the river, exotic trees (*Salix* spp. and *Fraxinus angustifolia*) dominated the sites that were sampled. Conductivity was found to be low and turbidities were high at both sites along the Myponga River, and this may be attributed to sampling these sites in July 2011 following heavy rainfall (Table 3).

One native species (*G. brevipinnis*) and two exotic species (*G. holbrooki* and *P. fluviatilis*) were identified in the Myponga River (Tables 1 and 2). Pages Flat supported both *G. brevipinnis* and *P. fluviatilis* while Myponga Township contained only the two exotic species *G. holbrooki* and *P. fluviatilis*.

The Fish Health Index classed Pages Flat as At-Risk primarily due to the presence of an introduced predator. Myponga Township was classed as Disastrous due to a lack of any native fish at the site (Table 4).

3.2.11. Onkaparinga River

Eight sites were sampled along the Onkaparinga main channel and two of its tributaries (Kangarilla Creek and Scott Creek). Sites were predominantly in, or near, grazing land. Submerged vegetation (*V. australis*, *P. decipiens* and *Myriophyllum* sp.) was observed at four of the eight Onkaparinga sites. Emergent vegetation in the Onkaparinga was dominated by *T. domingensis* and riparian zones were predominantly Eucalypts, though Oakbank was dominated by *Salix* sp.

Onkaparinga sites were sampled during May and July 2011. Flow rates were moderate at several sites with turbulent riffles and falls near water testing sites. This caused dissolved oxygen readings to be high at four of the sites (Bakers Gully, Cox Creek, Scott Creek and Scott Creek Conservation), with no apparent variation in vertical profile. Conductivities were generally low which may have been due to high rainfalls during the months of sampling (Table 3).

A total of four native and two exotic species were caught within the Onkaparinga Catchment. The most common fish found was *G. olidus*, which was caught at five of the eight sites sampled (Table 1). The Onkaparinga also contained *G. maculates, G. brevipinnis* and *P. grandiceps* (Table 1). Exotic fish (*P. fluviatilis* and *G. holbrooki*) were only caught at half of the sites sampled and in total fewer than eight individuals were caught for each species (Table 2). Fish numbers were often low within this catchment and no fish were found at one site (Scott Creek Conservation).

In many cases, the Onkaparinga's Fish Health Indexes were affected by low overall numbers of fish and poor population structure. Charleston at the top of the catchment and the tributary Cox Creek both were scored as Stable due to large complex populations of *G. olidus*. Silverlakes was scored as Disastrous due to the dominance of a complex population of breeding condition *P. fluviatilis*. Scott Creek Conservation also was scored as Disastrous, due to its lack of fish. The remaining sites were scored as At-Risk (Table 4).

3.2.12. Patawalonga River

The Greater Patawalonga catchment encompasses a number of highly urbanised creeks and tributaries. A total of twelve sites were sampled from Brownhill, Sturt, Minno and Ellis creeks as well as the Patawalonga River. Submerged vegetation was rare, occurring at only three of the sites. Emergent vegetation varied between sites and was not found at five of the sites. Riparian zones tended to be dominated by environmental weeds. Two sites retained old growth *Eucalyptus camaldulensis* as the dominant riparian plants.

Dissolved oxygen levels within the Patawalonga were generally good with most sites displaying very little drop in vertical profile. Conductivities were low across all sites as were turbidities, With the exception of Cherry Plantation which had a turbidity of 72.40 NTU (Table 3).

In total six native and six exotic fish species were found in the catchment. The most common fish was *G. olidus*, appearing at nine sites and *G. maculatus* which appeared at three sites (Table 1). Five species of native fish were found at the Patawalonga site, which was the second highest native diversity observed (Table 1). A short-finned eel (*Anguilla australis)* was found at this site and this was the first record of the species in this catchment and the only eel caught in this study. The presence of this species can be attributed to marine migration or to translocation via Murray River water transfers into the WMLR catchment. Exotic fish were caught at five of the 12 Patawalonga sites sampled and, when caught, tended to be in complex communities (Table 2).

Fish Health Indices were variable but in general the higher sites within the catchment scored better than those further downstream. Willow Glen was an exception to this with resident *S. trutta* the only fish present. At-Risk sites tended to be small stream habitats which supported small, simple populations, resulting in low Dominance scores. Two sites (Coromandel and Warraparinga) were classified as Disastrous due to their dominance by exotic fish (Table 4).

3.2.13. Pedler Creek

Two sites were sampled on Pedler Creek, the open section of creek on Nashwauk Crescent and the artificial pond system immediately upstream and to the East of Commercial Rd. There was no submerged vegetation at either site, but notable filamentous algae at Commercial Rd. Emergent vegetation was a mix of *T. domingensis* and *P. australis*. The Commercial Rd riparian zone was dominated by recently planted Eucalypts, while Nashwauk was nested in a stand of exotic *Betula pendula*.

Due to technical issues, water quality data is limited to temperature, conductivity and pH for this site (Table 3).

Commercial Road contained the native *P. urvillii* (n=2) (Table 1), and large complex populations of *G. holbrooki* and *C. auratus*, as well as a single *C. carpio* (Table 2). It is likely that this site is acting as a source population for exotic species within the system. Downstream, Nashwauk contained three native diadromous species *G. maculatus*, *P. urvillii* and *P. olorum* (Table 1), suggesting unimpinged, seasonal access to the ocean from this site. Also present were *G. holbrooki* (*n*=80) and *C. auratus* (*n*=1) (Table 2).

Fish Health Indexes in the Pedler reflects the high numbers of exotic species present in the system therefore Commercial Rd was classified as a Disastrous site and Nashwauk was considered At-Risk (Table 4).

3.2.14. Torrens River

A total of ten sites were sampled in the Torren River Catchment. The most commonly observed submerged plant within the catchment was *P. decipiens* (usually an emergent plant), and this was seen at three of the ten sites sampled. Emergent vegetation was a mix of *T. orientalis* and *P. australis*, though Morialta sites were dominated by *J. usitatus*. Riparian zones in the highly urbanized areas of the Torrens River were often dominated by exotic weed species such as *Fraxinus*, *Salix* and *Olea*.

Flow rates in the Torrens were typically higher than seen in other catchments, which resulted in more turbulent flow and vertical mixing. Dissolved oxygen levels where vertically uniform except for Fox Creek, which was an off-channel pool and the only still water site examined. Conductivities were low across all sites (Table 3).

A total of seven native and five exotic fish species were caught within the Torrens catchment. The most common native fish was *G. olidus*, caught at four of the ten sites (Table 1). Breakout creek was the most species-rich site and this was the second highest native diversity observed throughout the study (*n*=5 native species); more native fish than the other Torrens sites combined (Table 1). Exotic predators were common in the Torrens with *P. fluviatilis* and *O. mykiss* each appearing at two sites and *S. trutta* appearing at three (Table 2). Four sites (Mt Pleasant, Corkscrew, Fire Track and Knotts Hill) contained no native fish. A large number of *G. olidus* were captured at Morialta, however there were no fish captured above or below this site (Table 1).

Each of the four sites that lacked native fish scored a Fish Health Index of Disastrous. Cudlee Creek also scored Disastrous due to the high number and diversity of exotic fish species. Four sites were classified as Stable, these sites were either free from exotic fish (Fox Creek, Collins and Morialta) or had a large number and high diversity of native fish (Breakout Creek). Only Waterfall Gully was classified as At-Risk and this was due to the presence of a single *P. fluviatilis* amongst a small population of *G. olidus* (Table 4).

3.2.15. Tunkalilla Creek

Tunkalilla Creek was a single site with low flow. Submerged (*V. australis*), emergent (*Diplachne fusca*) and riparian vegetation (*Eucalyptus* spp.) was all dominated by native species. Water quality was good with no stratification of dissolved oxygen and low turbidity (0.25 NTU) (Table 3).

This site contained only *G. brevipinnis* in a large complex community (Table 1). This site was classified as Stable (Table 4).

3.2.16. Washpool Creek

Washpool was a single site sampled within 20m of the beach. This site was chosen for inclusion after galaxiids were observed during a visual survey. Washpool Creek is a small still section of hypersaline creek (Table 3) set amongst a samphire swamp. The creek was lined with algal mats both floating and submerged.

Two diadromous native species were identified during sampling, *G. maculatus* and *P. urvillii* (Table 1). All nets set were tampered with overnight and were left dry on the bank, as such the number of fish reported is not a true reflection of the population. The Fish Health Index for Washpool places it in the Stable category primarily due to an absence of exotic fish and the presence of key native species (Table 4).

3.2.17. Willunga Creek

Willunga contained three exotic fish species and no native species. Exotic species included a population of *Phalloceros caudimaculatus* which has been the ongoing focus of an eradication project. Only presence/absence data was available for fish, thus making this site unsuitable for inclusion in scorecard calculations. Water quality and vegetation data were not recorded for this site.

3.2.18. Yankalilla River

Two sites were sampled in this catchment, Ingalalla Falls (a public use area in an upper tributary), and Chapmans along the main channel. Ingalalla Falls had *T. domingensis* emerging and was dominated by eucalypts, among a wide variety of native and introduced riparian trees. Chapmans supported *V. australis*, had *P. decipiens* emergent, and a riparian zone dominated by eucalypts.

Turbulent mixing was apparent with little vertical variation in dissolved oxygen profiles. Turbidities were notably high at both sites in the Yankalilla catchment (Table 3).

Ingalalla Falls contained the native *G. brevipinnis* (Table 1), but also the introduced predator *S. trutta* (Table 2). Chapmans supported a large complex population of *G. olidus* with no exotic fish present (Table 1).

Fish Health Indexes in the Yankalilla were influenced by the presence of predators, with Chapman's classified as a Stable site and Ingalalla Falls At-Risk (Table 4).

Table 3. Water quality parameters for each site arranged by greater catchment. * indicates reliable water quality parameters not recorded.

Greater Catchment	Site ID	Max O_2 (mg.L^{-1})	Min O_2 (mg.L^{-1})	Temperature (^{o}C)	Conductivity (mS.cm^{-1})	Turbidity (NTU)	pH
Bungala	Bartletts	8.39	3.51	17.58	8.00	23.15	8.03
Bungala	Hay Flat	5.60	4.98	17.94	6.16	14.18	7.77
Bungala	South Rd	3.31	2.87	17.26	5.90	13.80	8.07
Bungala	Stornoway	2.94	1.32	16.37	2.67	27.87	8.05
Bungala	Yankalilla Rec Centre	6.53	4.68	18.86	6.31	10.97	8.18
Deep Creek	Dog Trap Creek	6.73	6.28	15.31	2.36	155.10	8.27
Field	Field	*	*	*	2.30	*	8.95
Gawler	Gawler Dam	7.81	7.59	19.90	1.97	124.43	8.37
Gawler	Pony Club	4.58	3.91	21.32	1.53	43.88	8.28
Hindmarsh	Hindmarsh Falls	8.83	8.57	17.14	1.06	19.85	8.26
Hindmarsh	Sawpit Rd	3.31	2.87	17.26	5.90	13.80	8.07
Hindmarsh	Cootamundra Reserve	6.66	4.94	16.60	2.85	7.15	8.20
Inman	Kirk Rd	3.32	0.72	15.67	2.00	60.37	7.75
Inman	Glacier Rock	7.06	5.91	16.53	2.16	8.06	7.98
Inman	Guaging Station	8.67	7.73	19.09	3.17	111.00	8.11
Light	Light Ford	8.13	2.56	20.48	7.14	6.20	8.40
Light	Marrabel	7.17	1.96	19.28	4.96	14.94	8.30
Light	Rockies	6.63	2.33	21.27	5.93	22.24	8.40
Little Para	Old Spot	8.52	8.49	19.80	0.65	75.25	8.73
Myponga	Myponga Township	4.49	4.17	13.65	0.82	104.73	8.12
Myponga	Pages Flat	8.27	7.95	9.34	0.74	43.80	8.70
Gawler	Moculta	3.73	2.29	20.12	3.85	336.17	8.36
Gawler	Mt McKenzie	7.66	6.17	17.80	2.20	27.30	7.93
Gawler	Nuriootpa	0.76	0.47	17.06	1.26	22.83	7.89
Gawler	Yaldara	8.23	8.05	19.22	2.00	7.40	8.58
Onkaparinga	Bakers Gully	10.87	10.67	10.22	0.83	43.70	8.35
Onkaparinga	Charleston	7.51	1.35	11.50	1.50	*	7.22
Onkaparinga	Cox Creek	11.04	10.66	9.67	0.22	13.70	9.63
Onkaparinga	Hahndorf	7.18	5.19	12.88	0.82	*	7.04
Onkaparinga	Oakbank	*	2.90	11.32	0.89	*	6.58
Onkaparinga	Scott Creek	11.14	11.06	9.92	0.36	13.20	8.66
Onkaparinga	Scott Creek Conservation	10.92	10.78	10.04	0.35	17.45	8.67
Onkaparinga	Silverlakes	*	*	12.90	0.47	*	7.31

Greater Catchment	Site ID	Max O_2 ($mg.L^{-1}$)	Min O_2 ($mg.L^{-1}$)	Temperature (°C)	Conductivity ($mS.cm^{-1}$)	Turbidity (NTU)	pH
Patawolonga	Brownhill Ford	8.64	8.21	16.30	0.73	11.07	8.62
Patawolonga	Cherry Plantation	4.47	2.94	13.36	0.80	72.40	7.97
Patawolonga	Coromandel	8.79	7.25	16.64	1.18	15.83	8.47
Patawolonga	DS Caravan Park	5.44	3.87	15.22	1.17	22.80	8.08
Patawolonga	Ellis Creek	8.13	8.13	21.56	0.84	16.30	8.68
Patawolonga	Lake Michigan	8.19	2.28	19.32	0.69	13.83	8.29
Patawolonga	Patawolonga	6.46	6.20	11.20	0.64	27.38	8.48
Patawolonga	Railway Dam	6.31	3.83	20.65	1.65	9.11	8.33
Patawolonga	Riverside Reserve	7.86	5.04	17.40	1.95	4.33	8.15
Patawolonga	Sturt Tributary	9.43	9.45	13.58	1.32	7.40	8.42
Patawolonga	Warraparinga	7.56	6.17	17.64	1.84	31.91	8.37
Patawolonga	Willow Glen	9.05	8.85	13.84	0.85	10.27	8.52
Pedler	Commercial Rd	*	*	14.82	0.23	*	8.46
Pedler	Nashwauk	*	*	14.82	0.23	*	8.46
Gawler	Mt Crawford	6.61	5.46	18.27	1.31	41.40	8.15
Gawler	Portuguese Bridge	6.40	1.60	18.48	4.39	33.90	7.20
Gawler	Victoria Creek	8.25	8.18	19.43	1.11	12.63	8.36
Torrens	Breakout Creek	*	*	*	0.74	*	7.55
Torrens	Collins	11.72	11.47	8.83	0.17	8.80	9.43
Torrens	Corkscrew Bridge	12.02	12.02	10.98	0.52	*	7.84
Torrens	Cudlee Creek	9.06	8.87	17.08	1.38	34.68	8.36
Torrens	Fire Track	*	*	10.70	0.46	*	8.26
Torrens	Fox Creek	3.26	1.50	16.14	0.58	20.60	8.14
Torrens	Knotts Hill	11.24	11.24	8.99	0.21	1.90	8.87
Torrens	Morialta	*	*	9.50	0.41	*	8.53
Torrens	Mt Pleasant	5.86	5.54	15.65	0.90	21.83	8.61
Torrens	Waterfall Gully	12.37	11.42	12.05	0.29	*	7.80
Tunkalilla	Tunkalilla	7.95	7.55	14.56	0.25	22.75	8.57
Washpool	Washpool	*	*	14.40	71.84	*	5.72
Yankalilla	Chapmans	8.56	8.26	15.02	0.39	60.45	9.30
Yankalilla	Ingalalla Falls	10.12	9.88	16.18	0.72	131.10	8.88

Table 4. Fish health scorecard for all sites arranged by greater catchment. Green cells indicate a good score (Stable fish population), amber indicates a moderate score (At-risk population) and red indicates a bad score (Disastrous fish population).

Greater Catchment	Site ID	Native Biodiversity (9 to -5)	Introduced Diversity (0 to -9)	Dominance (6 to -9)	Fish Health Index
Bungala	Bartletts	-5	0	0	-5
Bungala	Hay Flat	5	0	3	8
Bungala	South Rd	5	0	6	11
Bungala	Stornoway	3	-3	0	0
Bungala	Yankalilla Rec Centre	5	-3	0	2
Deep Creek	Dog Trap Creek	-5	-3	-3	-11
Field	Field	5	0	6	11
Gawler	Gawler Dam	5	-7	3	1
Gawler	Moculta	-5	0	0	-5
Gawler	Mt Crawford	5	-3	-3	-1
Gawler	Mt McKenzie	-5	-5	-3	-13
Gawler	Nuriootpa	-5	-3	0	-8
Gawler	Pony Club	7	-7	-3	-3
Gawler	Portuguese Bridge	-5	-3	-3	-11
Gawler	Victoria Creek	3	0	6	9
Gawler	Yaldara	7	-9	-3	-5
Hindmarsh	Cootamundra Reserve	9	0	6	15
Hindmarsh	Hindmarsh Falls	5	0	6	11
Hindmarsh	Sawpit Rd	7	0	6	13
Inman	Glacier Rock	3	-3	-6	-6
Inman	Guaging Station	5	-7	-9	-11
Inman	Kirk Rd	3	0	0	3
Light	Light Ford	5	-5	3	3
Light	Marrabel	3	-5	0	-2
Light	Rockies	5	-7	3	1
Little Para	Old Spot	-5	0	0	-5
Myponga	Myponga Township	-5	-5	-3	-13
Myponga	Pages Flat	3	-3	0	0
Onkaparinga	Bakers Gully	3	0	0	3
Onkaparinga	Charleston	3	-3	6	6
Onkaparinga	Cox Creek	3	0	6	9

Greater Catchment	Site ID	Native Biodiversity (9 to -5)	Introduced Diversity (0 to -9)	Dominance (6 to -9)	Fish Health Index
Onkaparinga	Hahndorf	7	-3	0	4
Onkaparinga	Oakbank	5	-5	-3	-3
Onkaparinga	Scott Creek	3	0	0	3
Onkaparinga	Scott Ck Conservation	-5	0	0	-5
Onkaparinga	Silverlakes	3	-3	-6	-6
Patawolonga	Brownhill Ford	3	0	6	9
Patawolonga	Cherry Plantation	3	0	3	6
Patawolonga	Coromandel	3	-7	-9	-13
Patawolonga	DS Caravan Park	3	0	0	3
Patawolonga	Ellis Creek	3	0	0	3
Patawolonga	Lake Michigan	3	0	3	6
Patawolonga	Patawolonga	9	-7	0	2
Patawolonga	Railway Dam	3	0	0	3
Patawolonga	Riverside Reserve	5	-3	0	2
Patawolonga	Sturt Tributary	3	0	6	9
Patawolonga	Warraparinga	5	-7	-6	-8
Patawolonga	Willow Glen	-5	-3	-3	-11
Pedler	Commercial Rd	3	-7	-6	-10
Pedler	Nashwauk	7	-5	-3	-1
Torrens	Breakout Creek	9	-5	3	7
Torrens	Collins	3	0	6	9
Torrens	Corkscrew Bridge	-5	-5	-9	-19
Torrens	Cudlee Creek	3	-7	-9	-13
Torrens	Fire Track	-5	-3	-6	-14
Torrens	Fox Creek	5	0	6	11
Torrens	Knotts Hill	-5	-5	-6	-16
Torrens	Morialta	3	0	6	9
Torrens	Mt Pleasant	-5	-3	-6	-14
Torrens	Waterfall Gully	3	-3	-3	-3
Tunkalilla	Tunkalilla	3	0	6	9
Washpool	Washpool	5	0	3	8
Yankalilla	Chapmans	3	0	3	6
Yankalilla	Ingalalla Falls	3	-3	-3	-3

3.3. Fish Health Index by Water Planning Area

GPS locations were used to geographically illustrate the distribution of Fish Health Index classifications (Figure 5). The strongest trend observed was within the Barossa Valley water planning area. All four sites within this area were classified as Disastrous. North of the Barossa Valley and downstream of the Barossa sites classifications were uniformly At-Risk.

Central Adelaide was a mix of health indices. Two of the three coastal sites scored highly while a third was At-Risk. A clump of Stable sites appear to the east of this planning area, most other sites in Central Adelaide scored more poorly. The western Mount Lofty Ranges was likewise mixed. Coastal areas and the Hindmarsh River all scored Stable. The remainder of this area lacks obvious trends.

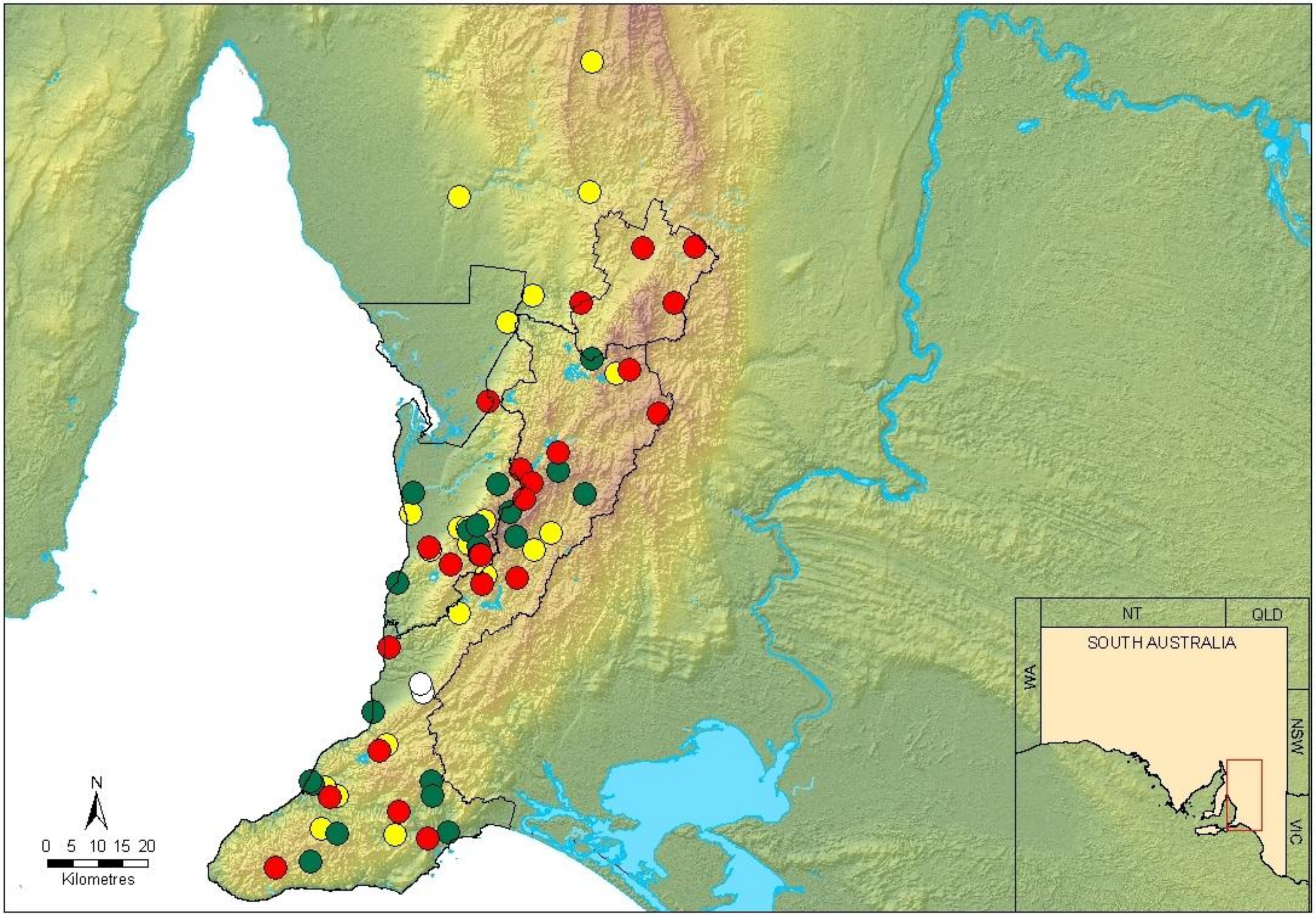

Figure 5. Geographic representation of scorecard values indicates that Northern sites tended to be more degraded and coastal sites tended to be in better condition.

3.4. Multivariate Analysis

Multivariate analyses was conducted on fish data aimed to explore which sites were more – or less similar based on abundance and community patterns. The output from the multivariate analysis (Figure 6) sorted sites according to statistical similarities in their fish populations. At a level of approximately 76% dissimilarity (selected from the dendogram as a level where clear groups of sites were evident), the data fell into eight clusters each containing several sites with the exception of a single site that was highly dissimilar to all others. Simper and indicator species analyses provided an indication of the species that contribute strongly to the formation of these groups and therefore, can be used as descriptive indicators for each cluster of sites. The results of these analyses concluded that:

- Group one comprised six sites (Figure 6) and had *G. brevipinnis* as a significant indicator species (p = 0.0001).
- Group two comprised ten sites (Figure 6). It had *P. fluviatilis* as a significant indicator species (p = 0.0002).
- Group three comprised 16 sites (Figure 6). It had *G. olidus* as a significant indicator species (p = 0.0001).
- Group four comprised seven sites (Figure 6). The group was a depauperate one, with no significant indicators as most sites in this group had no fish or a very small number of one species.
- Group five comprised six sites (Figure 6). It had both *O. mykiss* (p = 0.0011) and *S. trutta* (p = 0.0002) as a significant indicators.
- Group six comprised 13 sites (Figure 6). It had *P. olorum* (p = 0.004), *G. holbrooki* (p = 0.0001), *C. carpio* (p = 0.0001) and *C. auratus* (p = 0.0002) as a significant indicators.
- Group seven comprised six sites (Figure 6). It had *G. maculatus* (p = 0.0001) and *P. urvilli* (p = 0.0001) as a significant indicators.
- Group eight was a single site (Breakout Creek) and could not be included in indicator species analyses.

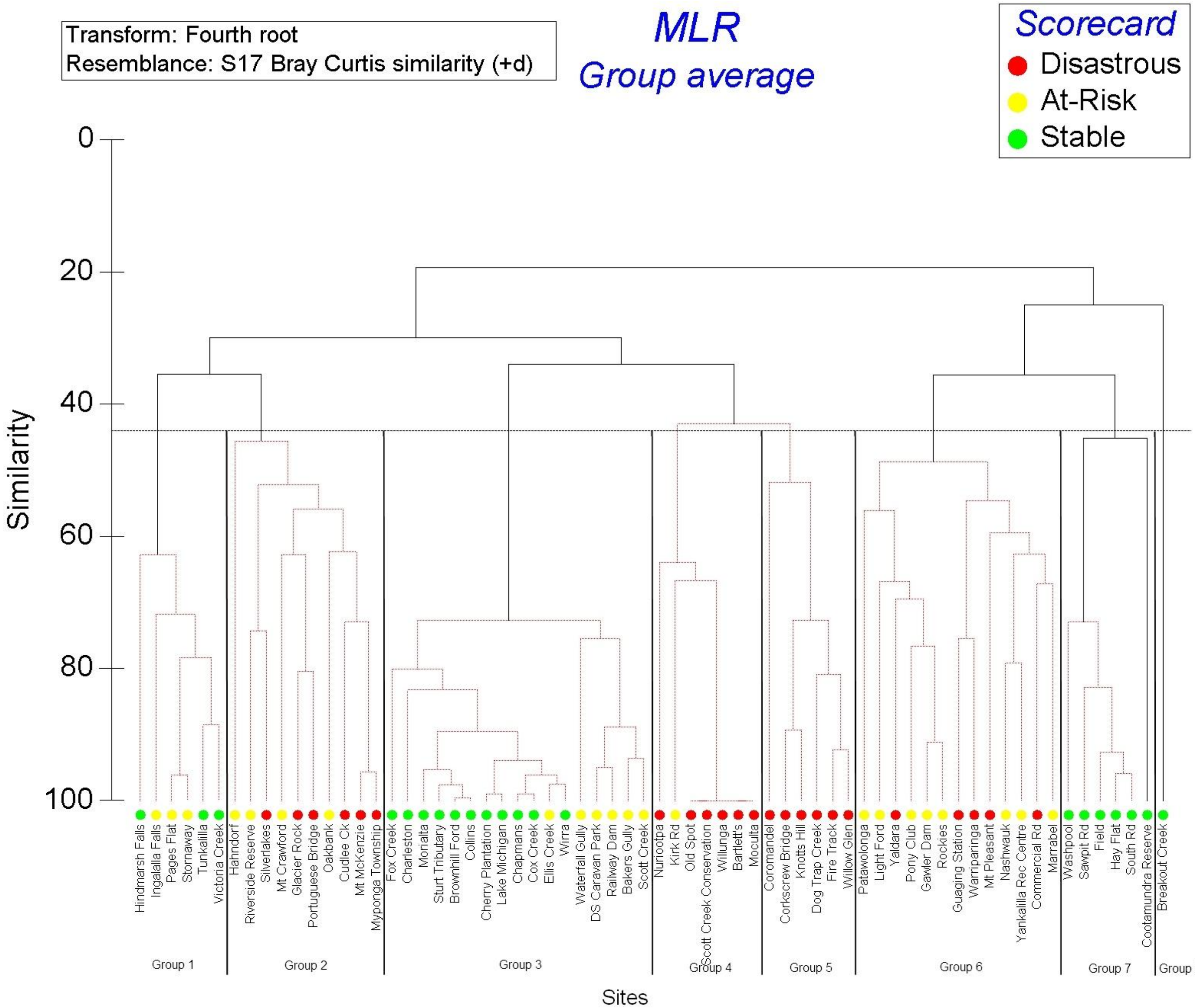

Figure 6. Multivariate analysis of fish communities denotes significant differences with black lines and non-significance with red lines. 9 statistically similar groups are considered, each with a specific suite of environmental requirements.

3.5. Geographic Multivariate Groupings

Groups one and three, which were dominated by *G. brevipinnis* and *G. olidus* respectively, were found almost exclusively in upland sites (Figure 7). The groups dominated by *P. fluviatilis* (group 2), and *S. trutta* and *O. mykiss* (group five) were also within the same range of upland sites. The depauperate group four appears to be distributed evenly throughout the survey area in both lowland and upland sites. The group dominated by three exotic species (group six) was also represented throughout the survey area, but was overrepresented in the north in the Barossa and Light Districts. Group seven was a diadromous fish (*G. maculatus* and *P. urvillii*) dominated group and occupied coastal and lowland sites. Whilst group eight couldn't be analysed for indicator species, it was dominated by highly abundant *P. grandiceps*, *M. fluviatilis* and *Hypseleotris* spp.

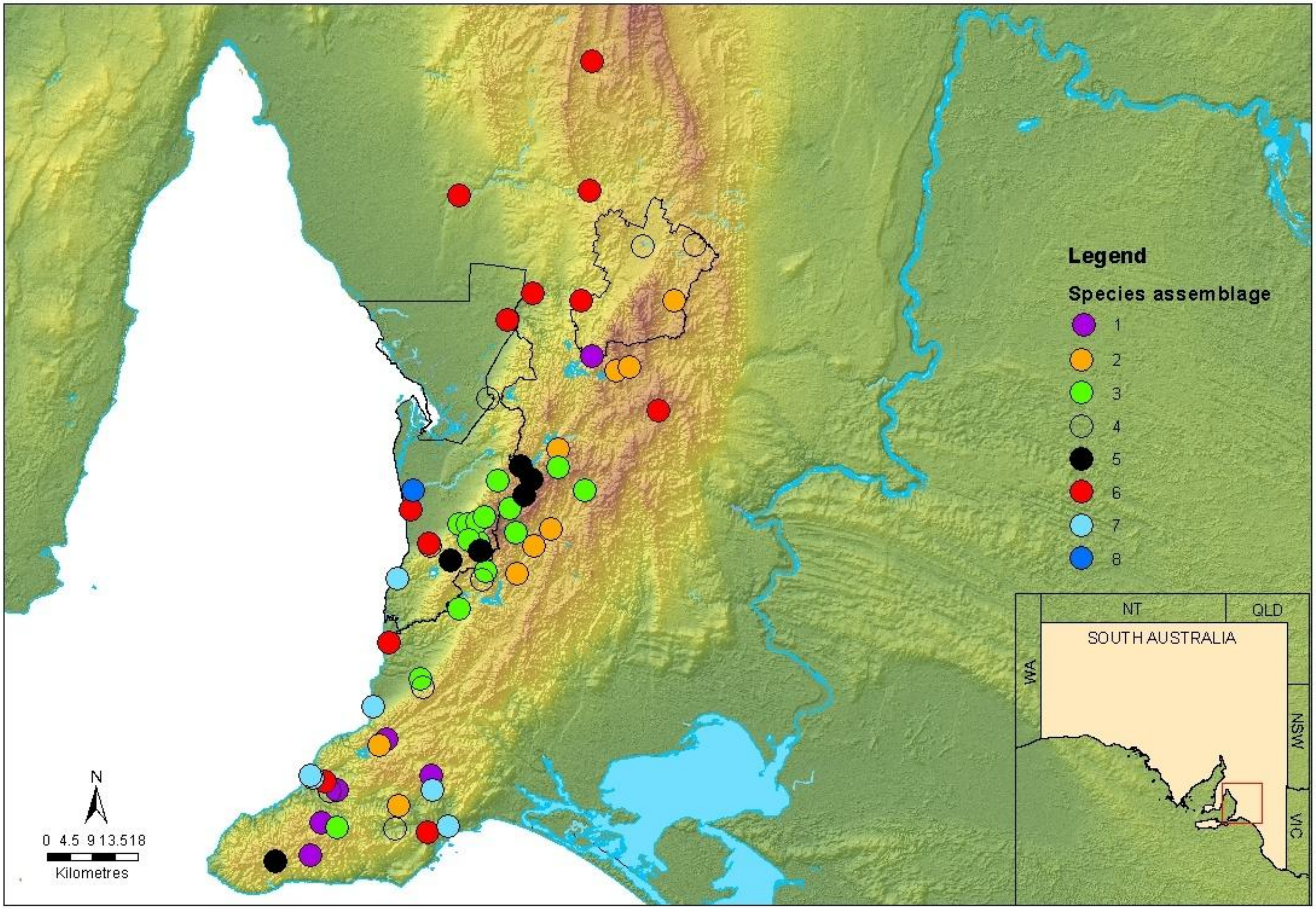

Figure 7. The five significant groups of fish display some patterning when displayed geographically. Groups 3, 4 and 9 run along the more elevated habitats, while Group 7 and 8 sites were coastally located.

4. DISCUSSION

4.1. Discussion by site

4.1.1. Bungala River

Extensive comparable records exist for 2006 in the Bungala River (Hammer 2006). Over the last five years there appears to have been some significant changes, and some cause for concern.

Both *G. maculatus* and *P. urvillii* are still present in the lower Bungala, however, numbers of *G. maculatus* appear lower in comparison to 2006 sampling. This alone is not cause for alarm *per se* as, within a South Australian context, seasonal and annual variation in fish numbers should be considered part of a natural response to an unpredictable climate. Sites where reductions in population size are apparent should be among the priority sites for future monitoring to determine if observations are based on stochastic variation or represent genuine species decline. Timely, ongoing monitoring will be the key to identifying trends in this instance.

The site at Yankalilla Recreation Centre was an artificially constructed dam just north of the tennis courts in Yankalilla Township. Efforts have been made to incorporate fish passage in the dam wall design. This may have been successful as the current study identified *P. urvillii* in the dam that were not caught in 2006. Unfortunately the construction of the dam appears to have created a lentic habitat that has favoured the proliferation of exotic fish. While the 2006 study did not identify any *G. holbrooki* in the Bungala, this study found the dam teeming. The numbers of *G. holbrooki* recorded in this study should not be considered representative of the true population size which could be seen shoaling thickly across the entire surface of the pool. Although this site remains the only record of *G. holbrooki* in the catchment the potential for it to act as a source population for nearby sites should not be overlooked. Efforts to manage this exotic population should focus on periodically disrupting the stable environment created by the dam. Intermittent draining of the pool (while filtering effluent water for *G. holbrooki*) is a reasonable first step. Here native fish could be removed and either relocated or replaced. The large yabby population in the dam has the capacity to burrow during periods of drying and should not be affected by the temporary loss of water. The dam itself appears to require maintenance as cracking and under-dam flow was apparent during sampling. Work on the dam wall could be incorporated into any draining planned.

With the exception of the Stornoway site, No fish have been identified above Yankalilla Township in either study.

Sampling at Stornoway in 2006 using dip nets and bait traps captured 39 *G. brevipinnis* living in a small permanent spring section of an upper tributary. The more extensive sampling used in this study captured 53 *G. brevipinnis* but also a single exotic *P. fluviatilis*. It is unclear if failure to locate any *P. fluviatilis* in 2006 was due to limitations in gear type or if they are a recent immigrant to the site. Landholders near the site believe that stocked dams exist higher in the catchment and may be the source of any introductions that have occurred. Regardless of the mode of introduction, the presence of an exotic predator in a small, isolated population of rare fish (SAFF Action Plan) deserves priority examination, especially as Stornoway remains the only record of *G. brevipinnis* in the Bungala catchment.

4.1.2. Deep Creek

In 2006, two sites were examined in Deep Creek which located *G. brevipinnis*, *S. trutta* and the exotic crustacean *C. cainii* (Hammer, 2006). The current study examined only a single site, but failed to discover any *G. brevipinnis*. While this may be due to limitations in sampling, it is of some concern as 2006 sampling only identified *G. brevipinnis* in the same sites as *S. trutta*. Waterwatch sampling from 2009 examined two sites in Deep Creek and, like the current study, failed to locate *G. brevipinnis* but did catch one *S. trutta*. The apparent absence of *G. brevipinnis* in the last two rounds of Deep Creek sampling is worrying and the possibility of predator-driven local extinction cannot be eliminated at the current time. Future efforts in this catchment should prioritise the identification and characterisation of *G. brevipinnis* populations in Deep Creek and respond accordingly.

4.1.3. Field River

Waterwatch sampling was carried out in 2009 and 2010 at the Field River site using two small fyke nets. The same species in approximately the same proportions were found on all three sampling records. Despite the urbanised nature of the lower river, fish populations in the lower Field River appear stable. Further downstream, Waterwatch identified small numbers of *P. grandiceps* which have not established populations at the site sampled (Jeremy Gramp, MLR NRM Education, unpublished data).

4.1.4. Gawler River Catchment

Prior to this study Mt McKenzie, Nuriootpa and Yaldara were sampled as part of a trial fish monitoring program, carried out by Waterwatch in 2006 and 2007.

At Mt McKenzie the current study identified small numbers of *G. holbrooki* and *P. fluviatilis*. The site was similarly degraded in 2007 when sampling found only *G. holbrooki*. The methodology used in the Waterwatch study was limited to two small fykes per site and fyke entrances were covered with fencing mesh. The use of exclusion mesh reduces the likelihood that their study would have identified any *P. fluviatilis* present at the site and so it is unclear if *P. fluviatilis* have recently extended their range into this site or are long term residents.

Nuriootpa was also sampled as part of the 2007 Waterwatch program. Despite the more limited methodology used, the 2007 study identified small numbers of *P. grandiceps*, as well as exotic *G. holbrooki* and *C. auratus*. This site appears to have degraded since 2007; the current study identified only a single beleaguered *C. auratus*.

Yaldara was a site of interest; it had the equal highest fish diversity, supporting eight species of fish in visually ideal habitat. Unfortunately five of the eight species found at Yaldara were exotic. This was the most exotic species seen at any site in this study. The only exotic fishes seen during 2006 Waterwatch sampling were 20 *G. holbrooki*. Exclusion screens on the Waterwatch fykes reduced the likelihood of their catching the four large bodied exotic fish currently present at Yaldara. As such we are unable to confidently infer temporal changes in the exotic composition of this site.

The current study identified *G. maculatus* at Yaldara that were not seen in the earlier study. It is unclear if the reduced number of nets in 2006 explains the failure to locate *G. maculatus*, or if they are recent colonisers to the site. *G. maculatus* are strong swimmers capable of movement across long distances and recolonisation is quite feasible. An alternative explanation could relate to a seasonal downstream migration to spawn (Allen *et al*., 2003) during Waterwatch sampling, although this seems unlikely.

Regardless of compositional changes a reduction in the overall numbers of *P. grandiceps* and *P. olorum* between sample dates is apparent. Waterwatch caught over 200 *P. grandiceps* in their two small fykes while the current study found only 19 in a full set of nets. Waterwatch also caught 10 *P. olorum* while the current study located only three. There is not enough data to infer causation; however, competitive exclusion by novel exotic species could explain the trends observed. This site is an interesting one and there is merit for its ongoing monitoring.

4.1.5. Hindmarsh River

A total of 11 sites were sampled along the Hindmarsh River in 2006 (Hammer, 2006). The current study examined three Hindmarsh sites, all of which have records from the previous study.

Hindmarsh Falls retains populations of both *G. brevipinnis* and *G. olidus* in numbers far greater than were seen by electrofishing in 2006. The exotic *S. trutta* previously caught here were no longer present. The population response seen in galaxiids may be explained by a release from predation pressure due to the absence of *S. trutta* from the system. However it cannot be discounted that catch differences relate, not to intrinsic changes in species composition, but to inherent strengths in sampling approach. It is well documented that differing gear types have different strengths (Bevacqua *et al,.* 2009) and that electrofishing and fyke nets vary significantly in their respective catches (Ruetz *et al*., 2007).

At Sawpit Rd native species presence and composition remains almost identical to earlier catch data. An encouraging trend is another failure to locate *S. trutta* within the system. Previously 11 were found at this site, the current study located none.

The final Hindmarsh site of this study, Cootamundra Reserve, possessed a similar community to past records. Notable variations were higher proportions of *G. maculatus* and *P. urvilli*, a failure to catch *P. olorum* and the discovery of *M. fluviatilis*. This appears to be the first time that *M. fluviatilis* have been seen in the Hindmarsh. It is unclear if the *M. fluviatilis* caught at this site are the result of a recent translocation or are an isolated population from an earlier range extension from the Murray River. While a recent translocation is far more likely, a sample of these fish should be included in future genetic work on this species to determine if this population constitutes a unique conservation unit. The outcome may alter management priorities at this site.

There were temporal variations in the species of estuarine fish present at Cootamundra Reserve. Given the estuarine nature of the community and the site, this is likely due to localised (possibly seasonal) movement within the estuary or between the estuary and the ocean. It is anticipated that, with more specialized sampling, the missing species could be located within the local system. Overall, the Hindmarsh River possessed a very high level of ecological integrity and represents a strong target for protection. In particular, the linkages between the estuary and mid freshwater reaches, allowing diadromous fish movements far inland, is of state significance, with very few river-estuary linkages remaining in the state in which these species can flourish..

4.1.6. Inman River

A notable issue in the Inman was a failure to identify any *Nannoperca australis* in Back Valley Creek. Past records observed strong populations at multiple sites along this section of stream (Hammer, 2006; Bice *et al.* 2010) however the current study did not detect any *N. australis* at the Kirk Road site and found only one *Hypseleotris* spp. While this absence is most likely an artifact of limited sampling, future sampling in this area should be prioritised and designed to include multiple sites along Back Valley Creek. Sampling undertaken by SARDI and AQUASAVE in the weeks following this survey identified remnant populations of *N. australis* within the creek, and the absence of *N. australis* in this study is most likely due to the particular placement of nets during the survey. The species should still be considered rare and given a high conservation priority.

The Gauging Station site was dominated by exotic species (*P. fluviatilis, G. holbrooki* and *C. carpio*) with low diversity and abundance in native species (*G. maculatus* and *Hypseleotris* spp.) while upstream at Glacier Rock, the catch was dominated by *P. fluviatilis*, with only a few *G. brevipinnis.* Given the failure to capture any *N. australis* and the dominance of exotic species in other parts of the Inman River, the general fish health of the catchment is considered low. Future management in the catchment should incorporate improvement of riparian vegetation, maintenance of adequate fish passage and removal of exotic species.

In contrast to the nearby Hindmarsh River, the ecological values of the Inman remain at higher risk and valuable conservation assets require targeted restoration investment to rebuild and protect freshwater populations. The protection of those assets, however, warrants significant investment in restoration and the two catchments (Inman and Hindmarsh) could be paired as management examples for protection versus restoration focused programs. Fish Health Index Scores have been particularly effective in highlighting these differences.

4.1.7. Light River

Past data exist for several sites on the Light River (Hammer, 2001). Two sites in the current study are proximate to 2001 sites: Light Ford and the Rockies. The Rockies fish communities appear stable for both native and exotic fishes observed in this study. The Gorge site was sampled in 2001 about eight kilometres downstream of the current study's Light Ford site. In

2001, at the Gorge, no native fish were identified whereas the current study identified a strong population of *P. grandiceps* and a single *G. maculatus*. Light Ford appears to be the more favourable habitat within this stretch of creek for native fishes.

In 2001 the Gorge site contained the exotic *C. carpio* and *G. holbrooki* while Light Ford contained *C. carpio* and *C. auratus* (Hammer, 2001). The absence of *G. holbrooki* at Light Ford in the current survey is probably a reflection of stronger winter flows during 2011 sampling rather than any trends within the system. High flows are considered to be disadvantageous for this species (Costelloe *et al.* 2010). Cyprinids appear well established within the system with *C. auratus* well represented in both studies and located at all 2011 sites within the Light. Over the decade the most dominant fish within this system remains *G. holbrooki*.

Marabel was a noteworthy site containing almost half of the *G. maculatus* seen in this study. It also contained large populations of the exotic *C. auratus* and *G. holbrooki*. Despite variations in catch between sites, the trend appears to be one of a stable and exotic dominated community. Management within this catchment should refrain from implementing alterations to flow or structure that would further favour exotic species. Priority management should be strongly considered for Marabel which supported remarkably high fish numbers.

4.1.8. Little Para River

This study examined only a single site in the Little Para Catchment. Water rats chewed through two nets and one rat was caught in a third. Tampering from the public was apparent in our final net for the site. No fish were caught in this catchment. While these results suggest a depauperate fish community, this should not be considered reflective of the natural values of the system. Waterwatch sampling carried out in 2006 examined four sites in the Little Para and identified six native and two exotic fish species within the catchment, although they did not capture any fish at the site that was sampled in the present study. Future surveys should include sites near the estuary and at the top of this catchment.

4.1.9. Myponga River

Two sites were sampled along the Myponga catchment, both in degraded environments. While the Pages Flat site has retained a small population of *G. brevipinnis* since 2005 (Hammer, 2005), *G. olidus* were not located again. An unsurprising new record for *G. holbrooki* was recorded at Myponga Township and *P. fluviatilis* numbers remain steady within the system. The Myponga River upstream of the reservoir appears to be a highly degraded environment but is worthy of more detailed surveys to identify potential high conservation value sites that may require management protection.

4.1.10. Onkaparinga River

The Onkaparinga Catchment was sampled at four sites along its main channel as well as on three tributaries.

Kangarilla and Scott Creeks each supported small populations of *G. olidus* in environments free from exotic fish species. One site along the edge of Scott Creek Conservation Park lacked any fish despite a seemingly ideal habitat. This patchy distribution is suggestive of connectivity issues along Scott Creek.

Cox Creek supported a large stable (since 2009 Waterwatch sampling) population of *G. olidus* free from exotics. Waterwatch sampling in 2009 also identified *G. brevipinnis* further downstream which were not identified on this occasion.

The main channel was more variable than its tributaries supporting a total of four native and two exotic fish species. Notable is the confirmed presence of all three galaxiid species, although in very low numbers. Aside from Charleston which supported 374 *G. olidus*, no more than nine individuals of any native fish species was located at any other site. Likewise, although exotic fish were caught at every main channel site, five was the most individuals of any species that was identified at any one site. Although this trend would seem encouraging in exotic populations it appears instead that the habitat quality in the Onkaparinga main channel is so poor as to discourage healthy populations of any species, even exotics.

Onkaparinga sites typically ran through agricultural land (primarily grazing) with dark water indicative of large amounts of organic matter in the channel. Channels were typically simple with eroded banks. Riparian zones were sparse throughout and, although eucalypts are recorded as dominant for most Onkaparinga sites, there was usually only one or two remnant trees existing in isolation.

Silverlakes was a noteworthy site on the Onkaparinga main channel. While recent significant effort has been put into removing weeds from the site, no steps have been taken to revegetate, leaving the banks vulnerable to erosion. At the time of sampling significant underbank erosion was apparent along one bank and scouring along the other. Without immediate intervention to stabilise the banks this site will rapidly degrade, probably resulting in a homogenous channel of the type that favours exotic fish species.

4.1.11. Patawalonga River Catchment

The Greater Patawalonga Catchment contained a total of six native and six exotic species. The native *G. olidus* was the most dominant fish in the system occurring at nine of the 12 sites sampled with a total almost double that of all the other Patawalonga fish species combined.

Brownhill Creek (and its tributary Ellis Creek) was in good condition above Mitcham Reserve with all sites supporting populations of *G. olidus* in the absence of exotic fish. The good condition of this reach raises concerns over the potential impacts resulting from proposed Brownhill Creek flood retention dams and any construction in the area should consider impacts upon *G. olidus* and *G. brevipinnis* (identified in past surveys).

Minno Creek and an unnamed upper tributary of Sturt Creek (site name Sturt Tributary) likewise contained healthy populations of *G. olidus* with no exotic fish present. These sites have been surveyed in the past with no records of fish (Michael Hammer *pers. com*.). This result proves the importance of smaller and often ephemeral creeks and tributaries in the Adelaide Hills as refugia for native minnow species. Future surveys should strive to include unsurveyed, or data poor tributaries and creeks, as these sites possibly contain strong remnants of native biodiversity lost to the main channel habitats through various deleterious impacts.

Immediately downstream of Sturt Tributary, Willowglen contained *S. trutta* and no other fish species. Both of these sites have remained stable over the last six years (Hammer, 2005). In the remainder of Sturt Creek exotic species were ubiquitous and diverse. Native fish appear at these sites as part of a mixed community but numbers were never high.

Despite it's highly modified channel structure, the Patawalonga site had the second highest native diversity observed in this study (five native species) as well as the highest overall fish diversity (eight species which it shared with Yaldara). An exciting find at this site was a rare *A. australis*, the first record for this catchment. This find is suggestive of some - obviously limited - access to the ocean which has allowed upstream migration. This cannot be confirmed as this species is known to display phenotypic plasticity with regards to oceanic migration (Arai *et al*., 2003) and purely freshwater morphs are common in other anguillid species (Daverat *et al*., 2006). Regardless of this possibility, given the rarity of this species and the presence of two other fishes with diadromous lifecycles, facilitations should be made to support oceanic access for these species. There is also scope for marked habitat improvement at this, surprisingly significant, site.

4.1.12. Pedler Creek

Waterwatch data from 2009 at the Nashwauk site used two small fykes to locate *G. maculatus* and *P. olorum*, as well as *G. holbrooki*. The current study used more nets and also identified *P. urvilli*. It is likely this species was present but unidentified during the previous study. Despite the more limited number of nets in 2009 the overall catch was dramatically higher than in 2011.

Immediately upstream of Commercial Road three artificial dams have been constructed. While these dams provide sedimentation services and contribute to a picturesque park, they also provide an ideal lentic habitat for cyprinids and *G. holbrooki* to proliferate and dominate (Gehrke 1995, Costelloe *et al.* 2010). It is anticipated that during times of connectivity these ponds have the capacity to swamp downstream environments with exotic species. It is suggested that a system of periodic drying be implemented for the dams to lower the numbers of exotics in the system if surface-water connections are likely to occur at any stage.

4.1.13. Torrens River

A total of ten sites were sampled within the Torrens Catchment; three on the main channel and seven sites along five of its tributaries.

The main channel supported five species of native fish, though with marked variation between sites. While Breakout creek supported five native fish species in high numbers, Cudlee Creek supported only a few *P. grandiceps* and Mt Pleasant supported no native fish. The Cudlee Creek area has previously been found to contain a high number of native species including *G. brevipinnis*, *G. olidus* and *Philypnodon macrostomus.* This site however, suffered significant impacts during 2008/09 when transfer flows were ceased resulting in severe drying of refuge pools, including those at Cudlee Creek Conservation Reserve. This drying was linked to a decline in native fish species and community structure (McNeil *et al.* 2011) that appears not to have recovered since.

Breakout creek contained the most native fish of any site, supporting almost double the fish of any other site in the study. Of the five species present, three are believed to be translocations from the River Murray (Hammer, 2005). This report has chosen to consider these species (*Melanotaenia fluviatilis*, *Hypseleotris* spp*.* and *Tandanus tandanus*) as native for the purpose of scorecard calculation and recommendations.

A noteworthy point for Breakout Creek is the three artificial weirs separating the site from the ocean (Figure 8). While this site did contain the strong swimming and diadromous *G. maculatus*, only four were observed. The site also lacked the other common near-coastal diadromous species *P. urvilli*. Given that the lowest weir already contains a fish ladder which has been shown to effectively facilitate conditional fish passage (McNeil *et al*., 2010), it may be that the recently constructed weirs are blocking or impacting upon diadromous fish passage. (Waterwatch 2011, McNeil *et al*. 2011). It is also quite likely that passage into the Torrens is being blocked for rarer eels and lampreys.

Figure 8. Poorly constructed artificial weir in Breakout Creek (Torrens River).

In the upper Torrens Catchment on the main channel, the Cudlee Creek site seems stable and is dominated by exotics (Hammer, 2005). There is a notable new record of a *C. auratus* appearing at this site. This species did not appear anywhere in the Torrens in 2005 sampling or in five surveys by McNeil *et al.* (2011) between 2006-2008 and appears to be establishing itself within the system; appearing at Breakout Creek in 2006-2008 (McNeil *et al.,.* 2011) in 2010 Waterwatch sampling and again in this study.

The furthest upstream site at Mt Pleasant was visually ideal but lacked any native fish, instead being dominated by a large thriving population of *G. holbrooki*. Given the significant barriers to movement and predators that any migratory native fish would have to overcome in order to colonise this site, there may be a case for translocating a *G. olidus* population to this site.

Fox creek is an upper tributary and contained the only *G. brevipinnis* located in the Torrens catchment. As 2005 Torrens records found only two *G. brevipinnis* and McNeil *et al.* (2011) only captured 22 fish in 5 surveys at Cudlee Creek, this species appears to be struggling within the system.

Sixth Creek, and its tributary Deep Creek, contained the strongest populations of salmonids seen in this study. At the very top of Deep Creek, Collins road is positioned at the top of a large waterfall that acts as a barrier to natural salmonid movement. At this site a healthy population of *G. olidus* provides insight into the historic state of this tributary. Further downstream both *S. trutta* and *O. mykiss* were caught in a range of size classes and were all in spawning condition. Densities observed were suggestive of stocking. Salmonids were not observed coexisting with any other species of fish in this catchment.

First and Fourth Creeks are among the most frequent previously sampled sites and reveal largely stable fish communities. First Creek contained a strong population of *S. trutta* in 2005 (Hammer, 2005) which was not detected in 2009 Waterwatch sampling or in the current study. The current study did locate a single *P. fluviatilis* in the pool below first falls, the first record at this site. This may be one reason why *G. olidus* did not occur in the pool and were restricted to the streams above and below the pool. The population above first falls is stable but vulnerable due to its isolation from the channel below.

Fourth Creek currently supports a stable population of *G. olidus* at multiple sites along its length.

4.1.14. Tunkalilla Creek

Tunkalilla Creek was found to contain small populations of *G. brevipinnis* in 2005 (Hammer, 2005). Using a different sampling approach we were able to locate a large complex population of *G. brevipinnis* at the one site sampled. Given the absence of exotic species in this catchment, Tunkalilla Creek appears to be an important site for this species in the Mount Lofty Ranges.

4.1.15. Washpool Creek

Washpool Creek has poor historic records but retains a community of diadromous fish with the potential to recolonise even after local extinction. Due to its small catchment, Washpool Creek is immune to common issues like water extraction or impoundment. This site holds significant value as a source and a refuge for coastal species *G. maculatus* and *P. urvilli*. Although Washpool Creek does not require active management it must be protected from urbanisation if these values are to be retained.

4.1.16. Wirra Creek (Maslin Creek)

Wirra Creek was sampled in 2009 as part of Waterwatch fish monitoring (Waterwwatch 2011) and as an ongoing part of a study into the control of exotic fishes in the area (McNeil and Wilson 2008, McNeil *et al.* 2010a). Both studies identified healthy populations of *G. olidus*. This appears to be a stable population and will likely be the source of stocking fish for a future restocking project to be carried out in neighbouring Willunga Creek.

4.1.17. Willunga Creek

Previous data exists from the 2009 Waterwatch fish monitoring. Using two small fykes a dense population of the speckled livebearer (*P. caudimaculatus*) was identified. This population has been known since 2008 (McNeil and Wilson 2008) and constitutes the state's only record of this competitive, exotic species. Ongoing work by SARDI and PIRSA Biosecurity has attempted to extirpate this localised population to avoid state-wide invasion. The outcome of this project appears positive with no fish identified at last observation (treatments also appear to have successfully removed the *G. holbrooki* and *C. auratus* from the system). Future plans are to restock Willunga Creek with *G. olidus* sourced from Wirra Creek. Ongoing monitoring will be crucial in Willunga Creek to allow timely response if *P. caudimaculatus* reappear.

4.1.18. Yankalilla River

Data from 2006 exists for the two Yankalilla sites sampled (Hammer, 2005). The Chapman's site retained its population of *G. olidus*. While numbers seem to have increased this is likely an artifact of differing sampling methodologies and shouldn't be considered too heavily. Ingalalla Falls continues to support *G. brevipinnis* and *S. trutta*. The current study observed *S. trutta* inhabiting a large area of pool habitat with smaller pools supporting *G. brevipinnis*. Proportional representation appears to have shifted over the last 5 years with *S. trutta* numbers down from 54 to seven. Conversely *G. brevipinnis* numbers appear to have increased from three in 2006 to 40. As with many differences between the 2006 and 2011 studies, we are observing not only changes over time but also the differences between electrofishing and fyke netting. As such neither predation nor competitive exclusion can be reliably inferred.

4.2. Prioritising Need by Fish Health Index

The Fish Health Index was designed to provide a simple overview of the ecological stability of native fish at a given site. The numeric value assigned by the Index may be used as a quick guide as to how precarious *in situ* fish populations are. In simple terms, traffic light colours may be used as a guide for prioritising the need for interventions.

4.2.1. Stable Sites

Stable sites were largely devoid of predation and competition from exotic species. Native fish populations at Stable sites are usually large and recruitment is apparent from their community structure. These sites require no immediate intervention to safeguard their fish populations. Further to this, these sites may be used selectively as guides for rehabilitation or as a source for restocking. Stable sites are likely to act as source populations within their catchment and act as deposits of genetic diversity for the greater fish population. Although these sites do not require immediate intervention, they hold significant ecological value within their catchment and should be monitored and protected.

4.2.2. At-Risk Sites

At-Risk sites had one or more risk factors identified (competition, predation or poor recruitment). Native fish populations at these sites are in an unstable position, and at risk of further deterioration. A site that has been classified as At-Risk will probably benefit from timely intervention and should be prioritised for active management. These sites should be managed by identifying and ameliorating the site-specific risk factor. These sites are likely to degrade with time and may benefit the most from immediate intervention.

4.2.3. Disastrous Sites

Disastrous sites represent the most degraded fish populations observed. Few Disastrous sites retain any native fish and those that do are at severe risk of deterioration. In the short term, these sites should be assessed for their potential to harm surrounding areas (primarily as sources for exotic species) and their management prioritised accordingly. Disastrous sites will generally require extensive intervention in order to restore their native fish populations. Although these sites may not be a priority for immediate active management, options are available to begin the restoration process which should not be neglected long term. Restoration of these sites may not be simple and the primary causative agents should be identified and addressed. These may include poor water quality, habitat degradation or dense populations of exotic fish.

4.2.4. Limitations of the Fish Health Index

The Fish Health Index is a simple tool which assesses key characteristics of a fish population to infer native fish stability at that site. In its simplicity it fails to consider many aspects of river health and should be used with caution. In nature, fish exist within dynamic, and complex, ecosystems and may be influenced in both direct and indirect ways. The index fails to consider the influence of abiotic factors like habitat and water quality or biotic factors like macroinvertebrate community structure. As a result, a site that has been classified as Stable remains susceptible to negative influences from factors not accounted for in the Index. Managers should consider all of the data included in this report (WQ tables, land use and threats table, plant table) before implementing interventions.

The Fish Health Index is purposefully ichthyocentric. Classifications are based on fish population alone and, as such, are insensitive to ecological values beyond those reflected by fish populations. Caution should be exercised by managers as sites may hold iconic value for floral, bird or frog communities or may provide ecological services which have not been identified in this simple classification.

4.3. Management Priorities by Multivariate Analysis

Multivariate analysis of fish communities provides an objective profiling of the data. This allows significant similarities to be identified, presenting commonalities in strengths and threats within the fish communities observed. The multivariate approach outlined above may be used as an objective guide to assess the regional management priorities. In addition further management questions may be pursued using this approach, for example by looking for relationships between fish species groups, or exotic species and other management variables such as barriers, impact points for water quality and habitat clearance, or for determining aquatic resource assets or flow targets. The collection of longer term data sets will add greatly to the utility of these multivariate approaches for developing environmental management questions and solutions.

Patterns in multivariate species assemblage were borne out by fish health scorecard results. Groups dominated by native species were rated as either stable or at-risk, groups dominated by exotic species or no species were rated as disastrous or at-risk, and there were no groups that included sites rated as disastrous and stable. This result supports multiple lines of evidence that anthropogenic effects (e.g. exotic species, poor water quality) cause harm to native fish communities. These effects were observed throughout the survey area, but some geographic patterns can be inferred. Multivariate groups that had native species indicators (groups one, three and seven) dominated sites from the Torrens catchment south, while there was only one site to the north dominated by native species. Other sites north of the Torrens were dominated by exotic species or an absence of fish species. The coastal diadromous groups were largely healthy, possibly due to their general proximity to the ocean. An exception to this was the Sawpit Road site on the Hindmarsh, which had a diadromous species indicator but was far inland which was indicative of good connectivity and the absence of exotic species in this catchment.

There was a "spine" of sites running along the length of the Mount Lofty Ranges with galaxiid dominated sites. However, nested within this range were sites dominated by salmonids and *P. fluviatilis*. These interactions are discussed below.

4.4. A Note on Exotic Trout

The issue of trout stocking in South Australia is a contentious one with regular ongoing review. Whilst this study was an observational survey and lacked the rigorous design of an interaction study, some summary deserves a mention.

Three exotic species (*P. fluviatilis*, *S. trutta* and *O. mykiss*) were identified with diets that are generally accepted to include small fishes (Allen *et al*., 2003) and more specifically are linked to the global decline in galaxiid fishes (McDowall, 2006). Of these, *P. fluviatilis* was the only species that was actively observed to be predating on native fish. In one example, at Warriparinga, 35 *G. maculatus*, one *P. olorum* and two exotic *G. holbrooki* were found in the guts of 10 *P. fluviatilis*. All instances of *P. fluviatilis* predation were observed in the artificial confines of a fyke and should be considered artificially high. Regardless, it suggests a strong predatory influence exerted by this species. Of the 16 sites that contained *P. fluviatilis* 13 also contained a native fish species. Of the other three sites with *P. fluviatilis* two contained the exotic *G. holbrooki* and the third site was so degraded as to barely support any fish life. Despite this obvious predation risk presented by *P. fluviatilis*, their presence did not appear to exclude prey species from a site.

In comparison, no instances of active predation were observed in Salmonids. Salmonids were never caught in the same net as any other fish species and the opportunities for an artificial predator/prey interaction were not present. A total of seven sites contained salmonids. Of these, five sites contained only salmonids and two sites also contained a galaxiid species. At these two sites (Ingalalla and Coromandel) clear partitioning was apparent in the environment with native fish existing in microhabitats unavailable to salmonids. Although direct predation was not observed a strong exclusion effect appears to be exerted by salmonids on other fish species at the sites sampled.

A 2004 review of trout stocking in South Australia, expressed a pointed critique of salmonid interaction studies (Fulton, 2004). While the majority of studies (including this one) lack sufficient replication to prove direct harm, they do present a repeated theme of salmonids excluding other fish species (Cadwallader, 1996). The presence of trout at any site was associated with either a complete absence of native fish species, or a partitioning of habitat into trout pools and native fish pools. Trout stocking is currently permitted in the Broughton River, Wakefield River, Light River, Finniss River, Hindmarsh River and Currency Creek (SA Government Gazette August 11, 2011). The present study only surveyed the Hindmarsh and Light Rivers out of this list and no trout were captured in either river. However, trout were captured in several other catchments throughout the Western Mount Lofty Ranges. Prior to 2005, trout were permitted to be released anywhere in the state (Jonathan McPhail pers. comm. 2011). While many of the observed trout populations may be self-sustaining, it cannot be ruled out that trout have been released illegally into these catchments. A permit is required to release trout, but they are available for purchase once a year from the SA Fly Fishers Association (SAFFA) and they are also available from interstate.

The Hindmarsh River – where trout are permitted to be released but were not captured – had one of the healthiest fish communities in the survey area. It appears that trout stocking is not currently practiced in the Hindmarsh River, but is a latent threat to a very healthy native fish population. The need for trout stocking in the Hindmarsh River should be reviewed. One management direction for this river might be to consider where trout may be stocked in this catchment. As the healthiest population of galaxiid fish was found above Hindmarsh falls, it might be possible to allow trout stocking below Hindmarsh Falls as long as there is good habitat availability and connectivity available for the diadromous and estuarine species found in the lower reaches of the river. Alternatively, another river that already has a trout population and a depauperate native fish population might be considered for stocking, such as the upper reaches of the Sturt River.

From an ecological perspective sampling sites that contain salmonids alone provides poor data and expends time and resources that could better spent elsewhere. It would be far more valuable if a dialogue could be developed between the South Australian Fly Fishing Association and ecologists that would allow future sampling to avoid sites that have been stocked. This simple step would contribute significantly to a more productive system of co-management of South Australia's mixed use river environments.

4.5. Ongoing Monitoring of Fish Community Condition

Within limitations of resources for conducting surveys, there are two options to optimise monitoring efficiency: optimising *temporal replication* and optimising *spatial coverage*. Each approach will provide valuable knowledge regarding the condition of freshwater fish and provide indications for ecological stream condition.

Optimising for *temporal replication* entails repeatedly sampling the same sites over many, preferably sequential, seasons and years. This approach maximises data on the nature of fish assemblage structure and key ecological processes such as population structure, recruitment, and fluctuations in fish community dynamics. All of these aspects may fluctuate seasonally and annually depending on climate, flow, and local impacts and therefore, repeated sampling provides maximal knowledge about the condition of fish populations. Accordingly, this approach provides maximal information about the processes that are driving fish community patterns. For example, repeated sampling may reveal the flow characteristics that lead native species to recruit and migrate effectively, or determine the water quality parameters that may be impacting of freshwater fish or encouraging the dominance of more tolerant, or exotic species. Overall, this approach provides maximum information about fish communities and provides knowledge about targeting threatening processes that are driving patterns in fish community condition.

Optimising for *spatial coverage* surveys a much higher number of sites and therefore maximises information about the distribution of species across the management region. Associated with this is the collection of data on associations of fish populations with habitat, flow patterns and geomorphic location. This focus maximises data on species' distribution, extent and range, and can pinpoint sites where exotic and native values overlap. This approach also maximises information on where threats such as land/catchment use, flow regulation, urban encroachment, barriers or water resource management issues intercept with key freshwater habitats. Broad scale prioritisation and planning of investment for management interventions will benefit greatly from this scale of monitoring effort.

The shortcomings of this approach is that reduced sampling repetition leads to a 'snapshot' view of the community that may not be representative of the site over the longer term. For example, a boom year in a key native fish species may suggest that the site is in excellent condition, whereas that presence of an exotic predator or other impact may reduce the ability of the short term recruitment event to eventuate into a robust population of that native fish in the longer term. Similarly, knowledge about the causal linkages fish community patterns with landscape or specific impacts (e.g. exotic species versus flow regulation, versus water quality thresholds) are less robust using this approach.

As a result, it is essential that future monitoring programs be clearly designed around the type of information of most value to the specific management objectives under which the monitoring is carried out. The current survey was designed to address the biodiversity 20 year Regional Condition Targets (RCTs) outlined under the Adelaide and Mount Lofty Ranges Natural Resources Management Plan (AMLRNRMB 2009). These targets include the recovery of the function and condition of ecosystems (T7), the increase in extent of functional ecosystems (T8) and to ensure against any decline in the conservation status of native species (T9).

The two approaches inform on slightly different aspects of these targets. Optimising for spatial coverage provides information on the *extent* and *condition* of functional ecosystems and allows assessment of the relative rarity of various species in the region, and therefore reports against *conservation status* of native fish. This approach therefore reports against all three of the RCTs outlined. Monitoring should therefore maximise the number of sites assessed across the region, within the limitations of funding and maintaining a comprehensive sampling methodology at each site. Targeted sites should be a mix of sites for which historical data exists (that have been sampled previously) and new sites for which no data exists (especially if there is a likelihood of finding conservation priority species). The spatial coverage should include as many separate catchments as possible across the region. Alternatively, more comprehensive surveys of individual catchments could be rotated, with a subset of areas or catchments targeted each year.

Importantly, however, the RCTs require a degree of temporal information to report against the *recovery* of condition and function, the *increase* in extent and to identify any decline in conservation status. As a result, this approach, whilst optimising for spatial coverage must include repeated sampling of sites over some timeframe. Given that the average life expectancy of most species of small bodied freshwater fish present in the Adelaide and MLR region is approximately 1-3 years, monitoring of individual populations should ideally be repeated within a three year timeframe to protect against missing widespread generational failures in population viability. Given that declines in conservation status, and ecosystem condition are often more gradual than individual species population trends, less regular re-sampling will still be highly effective in reporting against targets although repeat sampling should be carried within each five year period to detect any rapid declines in condition or conservation status that may occur.

In cases where a known impact or threat is present, however, key sites may need to be re-sampled with much higher regularity (every year or even several times a year) to report effectively against RCTs. Impacts of climate (particularly drought), bushfire, new water resource development (e.g. new pumps, weirs or farm dams), urban developments, vegetation clearance or the creation of barriers (e.g. road crossings, flood retention weirs) may all result in rapid or instantaneous declines in ecosystem condition, functionality and the conservation status of local populations and therefore, provision should be made to incorporate responsive contingency monitoring to plan for such perturbations.

This goes some way towards including aspects of the *temporal replication* approach, and therefore informing against aspects of the RCTs that this addresses. In particular, detailed information about the condition and function of ecosystems (T7) is best obtained through detailed ongoing assessment of communities and populations over time. Within the monitoring constraints, however, the approach outlined above, with some cycle of repeat sampling, and with contingencies for certain point source impacts should provide an adequate level of temporal information given a long term commitment to a consistent monitoring protocol.

Cases where temporal replication becomes more important are those that address specific issues or regions. To a large extent, this is the approach that has been adopted to inform the Environmental Water Provisions (EWP) trial assessments. This approach revealed a great deal of information about the drivers of fish community and population patterns within targeted EWP reaches. Consequently, this monitoring has enabled the development of extremely specific flow requirements for native fish in those reaches. This approach is also recommended for programs such as VWASP (Verifying Water Allocation Science for Planning) that have a limited number of sites, but where the collection of high quality integrated ecological data is required to inform on causal linkages between water resource metrics and causative ecological processes and responses to various scenarios. The use of data collected under spatial coverage monitoring approaches is not likely to be appropriate for informing specific localised planning or management issues, due to the lack of comprehensive ecological detail obtained under this approach.

The key recommendations for future monitoring under RCTs; T7, T8 and T9 are:

- Undertake a spatially optimised monitoring strategy that encompasses as many sites as possible across the region
- Ensure that sites are re-evaluated within a three year timeframe to enable reporting on trends in condition, extent and conservation status of native fish.
- Ensure commitment to long term monitoring (9 years+) of sites to enable assessment of long term trends such as increased extent, condition and species declines.
- Consider rotational surveys that focus on more detailed snapshots of specific sub-regions within each sampling season (e.g. year 1 - Fleurieu; year 2 - Adelaide and central ranges, year 3 - Northern, year 4 - Fleurieu etc. etc.)
- Maintain consistent methodology and effort across sites and years to maximise the power and utility of monitoring data.
- Develop, or be open to, contingency monitoring under circumstances of where new impacts or developments occur to protect against negative contributions to RCTs (e.g. increase in conservation status, reduced extent of functioning ecosystems).
- Maintain a *temporal replication* focus for monitoring that addresses specific site issues and require more detailed assessment of ecological processes, condition and sustainability (e.g. environmental flow responses, water planning metrics).

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APPENDIX 1 – VEGETATION OBSERVATIONS

Greater Catchment	Site Name	Dominant Aquatic	Dominant Emergent	Dominant Riparian (weeds in red)
Bungala	Bartlett's		*Typha domingensis*	*Acacia pycnantha*
Bungala	Hay Flat	Filamentous algae	*Phragmites australis*	
Bungala River	South Rd		*Phragmites australis*	
Bungala River	Stornaway		*Typha domingensis*	*Leptospermum lanigerum*
Bungala River	Yankalilla Rec Centre	Filamentous algae	*Phragmites australis*	
Deep Creek	Dog Trap Creek	*Vallisneria australis*		*Eucalyptus* sp,
Field	Field		*Typha domingensis*	*Salix* sp,
Gawler	Gawler Dam		*Typha domingensis*	*Eucalyptus* sp.
Gawler	Moculta			*Eucalyptus* sp.
Gawler	Mt Crawford		*Phragmites australis*	*Acacia* sp.
Gawler	Mt McKenzie	Filamentous algae	*Typha domingensis*	*Eucalyptus* sp.
Gawler	Nuriootpa		*Phragmites australis*	*Eucalyptus camaldulensis*
Gawler	Pony Club		*Typha domingensis*	*Fraxinus angustifolia angustifolia*
Gawler	Portuguese Bridge		*Phragmites australis*	*Eucalyptus* sp.
Gawler	Victoria Creek		*Typha domingensis*	*Betula pendula*
Gawler	Yaldara		*Phragmites australis*	*Eucalyptus* sp.
Hindmarsh	Cootamundra Reserve		*Phragmites australis*	*Eucalyptus* sp.
Hindmarsh	Hindmarsh Falls	*Persicaria decipiens*	*Juncus usitatus*	*Eucalyptus* sp.
Hindmarsh	Sawpit Rd			*Salix* sp.
Inman	Glacier Rock	*Vallisneria australis*	*Typha domingensis*	*Eucalyptus* sp.
Inman	Guaging Station		*Typha domingensis*	*Eucalyptus* sp.
Inman	Kirk Rd		*Phragmites australis*	*Eucalyptus* sp.
Light	Light Ford		*Juncus usitatus*	Allocasuarina (?obesa)
Light	Marrabel		*Phragmites australis*	*Rosa (?canina)*
Light	Rockies		*Phragmites australis*	*Eucalyptus* sp.
Little Para	Old Spot		Grass	*Eucalyptus* sp.
Myponga	Myponga Township	*Persicaria decipiens*	*Phragmites australis*	*Fraxinus angustifolia angustifolia*
Myponga	Pages Flat	*Azolla* sp.	*Typha domingensis*	*Salix* sp.
Onkaparinga	Bakers Gully	*Vallisneria australis*	*Typha domingensis*	*Eucalyptus* sp.
Onkaparinga	Charleston		*Typha domingensis*	*Eucalyptus* sp.
Onkaparinga	Cox Creek	*Persicaria decipiens*		*Eucalyptus* sp.
Onkaparinga	Hahndorf		*Typha domingensis*	*Eucalyptus* sp.
Onkaparinga	Oakbank		*Typha domingensis*	*Salix* sp.

Greater Catchment	Site Name	Dominant Aquatic	Dominant Emergent	Dominant Riparian (weeds in red)
Onkaparinga	Scott Creek			*Eucalyptus* sp.
Onkaparinga	Scott Creek Conservation	*Vallisneria australis*	*Phragmites australis*	*Eucalyptus* sp.
Onkaparinga	Silverlakes	?*Myriophyllum*		*Eucalyptus* sp.
Patawalonga	Brownhill Ford			*Fraxinus angustifolia angustifolia*
Patawalonga	Cherry Plantation			*Rubus fruticosus*
Patawalonga	Coromandel		*Phragmites australis*	*Fraxinus angustifolia angustifolia*
Patawalonga	DS Caravan Park	*Potamogeton crispus*	*Typha domingensis*	*Salix* sp.
Patawalonga	Ellis Creek			*Rubus fruticosus*
Patawalonga	Lake Michigan		*Juncus usitatus*	*Eucalyptus camaldulensis*
Patawalonga	Patawolonga		*Typha domingensis*	
Patawalonga	Railway Dam		*Typha domingensis*	*Fraxinus angustifolia angustifolia*
Patawalonga	Riverside Reserve			*Betula pendula*
Patawalonga	Sturt Tributary			*Rubus fruticosus*
Patawalonga	Warriparinga	*Potamogeton crispus*	*Phragmites australis*	*Eucalyptus camaldulensis*
Patawalonga	Willow Glen	*Chara* spp.	*Potamogeton crispus*	*Salix* spp.
Pedler	Commercial Rd	Filamentous algae	*Phragmites australis*	*Eucalyptus* sp.
Pedler	Nashwauk		*Typha domingensis*	*Betula pendula*
Torrens	Breakout Creek		*Phragmites australis*	*Eucalyptus* sp.
Torrens	Collins	*Persicaria decipiens*		*Fraxinus angustifolia angustifolia*
Torrens	Corkscrew Bridge		*Typha domingensis*	*Salix* sp.
Torrens	Cudlee Ck		*Phragmites australis*	*Eucalyptus* sp.
Torrens	Fire Track			*Salix* sp.
Torrens	Fox Creek	*Persicaria decipiens*		*Eucalyptus* sp.
Torrens	Knotts Hill	*Persicaria decipiens*	*Typha domingensis*	*Leptospermum lanigerum*
Torrens	Morialta		*Juncus usitatus*	*Olea europaea*
Torrens	Mt Pleasant		*Typha domingensis*	*Eucalyptus* sp.
Torrens	Waterfall Gully		*Typha domingensis*	*Olea europaea*
Tunkalilla Creek	Tunkalilla	*Vallisneria australis*	*Diplachne fusca*	*Eucalyptus* sp.
Washpool	Washpool	Algal mats		Samphire
Yankalilla	Chapmans	*Vallisneria australis*	*Persicaria decipiens*	*Eucalyptus* sp.
Yankalilla	Ingalalla Falls		*Typha domingensis*	*Eucalyptus* sp.

APPENDIX 2 – LAND USE AND THREAT OBSERVATIONS

Greater Catchment	Site Name	Land Use	Threats	Comments
Bungala	Bartlett's	Grazing	Offstream Dams	No fish ever noted this high in the Bungala
Bungala	Hay Flat	Grazing and Urban	Urban Runoff, High Nutrient Runoff, Invasive riparian zone	Olives, Desert ash, Pine
Bungala	South Rd	Urban and ajoins Caravan Park	Urban Runoff, High Nutrient Runoff, Invasive riparian zone	Olives, Desert ash, Pine
Bungala	Stornaway	Native with some reveg aparent	Damming and pesticide use upstream	reports of upstream redfin in dams
Bungala	Yankalilla Rec Centre	Public use area, ajoins oval and shopping area	Urban runoff, Litter, Gambusia source population	? Gambusia source population for the Bungala, **Fish ladder needs repair**
Deep Creek	Dog Trap Creek	Deep Creek Conservation Park	Marron, trout	Pristine habitat, exotics only
Field	Field	Urban park	Weeds, Litter, Urban runoff	Reveg efforts apparent. Dog faeces everywhere
Gawler	Gawler Dam	Grazing, Flood retention dam	Carp, Barrier to movement, Grazing runoff	Highly altered section of river, turbulent flow++
Gawler	Moculta	Vineyards, Grazing	High nutrient runoff	Few isolated pools, probably impermanent
Gawler	Mt Crawford	Pine Forest	Forestry	
Gawler	Mt McKenzie	Grazing, Roadside	High nutrient runoff	Introduced fish only
Gawler	Nuriootpa	Urban park	Weeds, Poor flow and anoxic conditions, Leaf Litter	Black water
Gawler	Pony Club	Ajoins Pony club and Organic farm	Invasive riparian, nil understory or bank structure, channel	Desert Ash, Castor oil plant
Gawler	Portuguese Bridge	Grazing	High nutrient runoff	Black water
Gawler	Victoria Creek	Roadside, borders the caravan park and oval	Runoff	Healthy, well structured population of *G. brevipinnis*
Gawler	Yaldara	Vineyards, Tourism	High nutrient runoff	P. olorum quite far inland,
Hindmarsh	Cootamundra	Residential, Walking trail and	Urban runoff	First record of *M. fluviatilis* in this catchment

Greater Catchment	Site Name	Land Use	Threats	Comments
	Reserve	playground		
Hindmarsh	Hindmarsh Falls	Public reserve	Intensive yabby trapping by public	*G. brevipinnis* and *G. olidus* in high densities in the same place
Hindmarsh	Sawpit Rd	Grazing	Water extraction, Barriers to movement	
Inman	Glacier Rock	Farming, Grazing, Tourist stop	Litter, Redfin, Invasive weeds	Tourism
Inman	Guaging Station	Grazing	Water extraction, Barriers to movement	Locals refer fondly to a fishing association redfin introduction at the site
Inman	Kirk Rd	Grazing and Dairy	Stock access, Off-channel Dams, High nutrient runoff	No *Nannoperca australis*
Light	Light Ford	Grazing and Cropping	High nutrient runoff	Road crosses river
Light	Marrabel	Grazing and Cropping	High nutrient runoff	Surprisingly high fish numbers! ? Seasonal refuge
Light	Rockies	Conservation Park	Litter, Carp, Poor riparian cover, deep homogenous channel	Important social value
Little Para	Old Spot	Urban, Roadside park	Urban runoff, Litter, Poor riparian cover	Water rat destroyed 1 net, Public interference with another
Maslin Ck	Wirra	Urban, Vineyards	Water extraction, High nutrient runoff	Covered in Livebearer project, source for Willunga Creek repopulation
Myponga	Myponga Township	Grazing, Roadside, immediately upstream of reservoir	Roadside runoff, High nutrient runoff	? Opportunity to reveg for picturesque entrance into Myponga
Myponga	Pages Flat	Grazing	Weed removal without reveg	Dark water and anoxic sediment
Onkaparinga	Bakers Gully	Grazing	Erosion++, Weeds, High nutrient runoff	Landholders report recent erosion events
Onkaparinga	Charleston	Grazing	Cleared land, Weeds	Dark water, Some reveg aparent, Blackberries persist
Onkaparinga	Cox Creek	Heysen Trail, Public use area	Weeds, Erosion	Severe bank erosion apparent
Onkaparinga	Hahndorf	Grazing and Apple orchard	Runoff, Weeds along creek line	Blackwater
Onkaparinga	Oakbank	Grazing, Cropping, Public use oval	No riparian, Very deep homogenous channel	Blackwater, Redfin
Onkaparinga	Scott Creek	Grazing, some early reveg	Erosion, Weeds, High nutrient nunoff	Weed lined riparian
Onkaparinga	Scott Creek	Conservation Park	Upstream nutrient input, Logjams?	Weed removal aparent

Greater Catchment	Site Name	Land Use	Threats	Comments
	Conservation		Obstructing movement	
Onkaparinga	Silverlakes	Grazing, Public use	Recent weed removal has left riverbank highly vulnerable	Needs immediate riparian reveg, socially important site
Patawalonga	Brownhill Ford	Conservation park	Weed lined creek, leaf litter +++, illegal stocking	reports of privately stocked dams washing into creek
Patawalonga	Cherry Plantation	National Park	Small habitat, lack of connectivity	? How much habitat remains during high summer
Patawalonga	Coromandel	Urban reserve	Urban runoff, Weeds	Willow, Desert ash
Patawalonga	DS Caravan Park	Caravan Park adjacent to Rd	Urban Runoff, Weeds, Clear riparian zone	probably ephemeral habitat
Patawalonga	Ellis Creek	Grazing	Poor Riparian Cover	reports of trout in creek?
Patawalonga	Lake Michigan	Grazing	Poor Riparian Cover	Efforts by landholder to remove weeds
Patawalonga	Patawolonga	Urban	Litter +++, High nutrient runoff, Carp spp	*A. australis*, connectivity to the ocean appears important at this site
Patawalonga	Railway Dam	National Park	Weed lined creek, leaf litter +++	reports of redfin in dam?
Patawalonga	Riverside Reserve	Public use park, Urban, Ajoins local business	Urban runoff, Weeds	Bamboo
Patawalonga	Sturt Tributary	Grazing, Remnant orchard	Trout immediately downstream, Obstructed connectivity	Obstruction is both protective and restrictive
Patawalonga	Warriparinga	Urban reserve	Urban runoff, Litter, Redfin	Huge predation of *G. maculatus* by Redfin in nets
Patawalonga	Willow Glen	Well tended private garden	Trout	Landholder protective of the resident trout
Pedler	Commercial Rd	? Sedimentation ponds, Public park	Urban Runoff, Litter, Source populations of introduced fish	Source of gambusia and goldfish in the system
Pedler	Nashwauk	Urban Reserve	Litter, Urban runoff, Source populations of Introduced upstream	?Artificial, may need periodic draining
Torrens	Breakout Creek	Linear park	Introduced and translocated fish, Urban runoff	Small patch of castor oil plants
Torrens	Collins	Grazing, native scrub	Weeds, high nutrient runoff	Above waterfalls
Torrens	Corkscrew Bridge	Roadside	Water extraction, Weeds, Roadside runoff	High densities of trout, appear stocked, All trout in

Greater Catchment	Site Name	Land Use	Threats	Comments
				spawning condition
Torrens	Cudlee Ck	Roadside linear park, opposite bank Conservation Park	Fish community dominated by introduced species	Poor fish numbers given habitat quality
Torrens	Fire Track	Ajoins firetrack and private land	Water extraction, Weeds, Trout	High densities of trout, appear stocked, All trout in spawning condition
Torrens	Fox Creek	Public access forestry	Runoff	small dam well populated, probably a source population
Torrens	Knotts Hill	Ajoins private land	Trout, Erosion	Trout in spawning condition
Torrens	Morialta	Conservation Park	Weeds	Blackberries, High rates of cysts in fish
Torrens	Mt Pleasant	Revegetated roadside	No native fish	Crustacean dominated healthy system (good vegetation, clear running water)
Torrens	Waterfall Gully	Heavily used National Park	Weeds, Litter	Main pool only 1 fish was collected (Redfin)
Tunkalilla	Tunkalilla	Pine forest, Grazing	Forestry, Nearby Marron	reports of feral pigs
Washpool	Washpool	Samphire swamp, conservation area	Upstream Pollution, Water abstraction	All nets tampered with, fish numbers much higher than reflected here
Willunga	Willunga	Urban, Vineyards	Water extraction, High nutrient runoff	Covered in Livebearer project, invasives being eradicated
Yankalilla	Chapmans	Grazing	Roadside runoff	
Yankalilla	Ingalalla Falls	Forestry	Forestry, Tourists, Trout	Natives in marginal microhabitats