Conservation and Management of River Blackfish in Rodwell Creek, 2011-12

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Report to the Foundation for Australia's Most Endangered Species Inc (FAME), Goolwa to Wellington LAP and the South Australian Murray-Darling Basin NRM Board

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Cover photos Changes in the condition of pool 6 on Rodwell Creek between October 2011 (top) February 2012 (bottom).

Disclaimer

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Summary

The remnant River Blackfish population in Rodwell Creek represents a significant ecological asset in the EMLR and, more broadly, South Australia. Yet, critical water shortages over the past five years would have undoubtedly lead to the loss of this population without management intervention (that has occurred since 2008). This management has been intensive with regular monitoring, environmental watering, aeration and fish transfer, and allowed River Blackfish to persist in Rodwell Creek. Continued management over the 2011-12 critical period ensured the short-term survival of the species. Furthermore, establishment of the refuge location has secured the medium-term future of the species in the creek. Whilst the species persists, the observed extent of occurrence and population demographics coupled with a limited dispersal ability highlight the vulnerability of the species. Management attention should seek to maintain the species but emphasis must turn to the enhancement of the population through the provision of environmental water requirements as part of broader catchment-wide management.

It is, therefore, recommended to maintain and enhance the River Blackfish population in Rodwell Creek by:

- Annual monitoring of the condition of known pools (and refuge location) over the critical period (2012-13 is currently unfunded)
- Annual fish surveying to detect temporal changes in presence, distribution and population structure (2012-13 is currently unfunded)
- Determination and provision of environmental water requirements
- Investigate flow management, such as low-flow bypass of instream dams, including community based projects
- Continued broader catchment management, including control of weed species and revegetation.

1.0 Introduction

The River Blackfish (*Gadopsis marmoratus*) is a threatened nocturnal species endemic to south eastern Australia (Lintermans 2007). A 'northern' form of the species occurs patchily across the Murray-Darling Basin (MDB) and the south-east of South Australia/Glenelg River system. The species was once widespread across the Eastern Mount Lofty Ranges (EMLR) in South Australian section of the MDB. The species has undergone a significant (and continuing) decline in distribution and is now considered locally endangered (Lloyd and Walker 1986; Hammer *et al.* 2009). The River Blackfish now persist as four distinct sub-populations in large spring-fed pools in separate catchments (Hammer 2004; Hammer *et al.* 2009). In the Bremer Catchment, the species survives in pools along a 500m section of Rodwell Creek, having been rediscovered in 2004 following over 50 years of no records (Hammer 2006; Hammer 2010).

This section of Rodwell Creek was historically perennial (due to refilling from ground water through springs), but catchment water abstraction has resulted in these pools now receiving only intermittent surface water flow. This is most apparent in dry years, and over the last five years there have been critical water shortages with receding water levels over summer and autumn seasonally threatening the remnant River Blackfish population. Indeed during summer and autumn of dry years (referred to as the 'critical period'), water levels drop to decrease habitat area and disconnect from emergent vegetation, and dissolved oxygen concentrations diminish considerably (Hammer 2010). Extreme drought over 2007 and 2008 led to severe water stress in the catchment and there were no seasonal surface water flows in the creek. The lack of flow resulted in declining water level and deteriorating water quality (e.g. increasing salinity, declining dissolved oxygen concentrations) and it was predicted that the creek section would dry completely toward the end of the 2007-08 critical period. Emergency invention was initiated as part of the Drought Action Plan for Lower Murray Freshwater Fish (DAP), a collaborative project between multiple agencies lead by the SA DENR (Hall *et al.* 2009; Hammer 2010).

Since autumn 2008 a variety of management interventions have occurred in an attempt to maintain suitable conditions for River Blackfish in the main pool (as well as other known pools), which was the last pool to dry in the creek section and has good structural integrity and shade from rock and cliffs :

- **Environmental water**: deliver water to maintain pool height and dilution of salinity and low dissolved oxygen.
- **Aeration**: oxygenate the main pool as watering alone was not sufficient to maintain dissolved oxygen above critical thresholds let alone sustain a normal level (above alarm) to promote a healthy localised population (i.e. avoid sub-lethal effects of oxygen stress such as reduced conditioning). Also, necessary to combat dramatic impact of cumulative build up of organic matter on dissolved oxygen concentrations (e.g.

blackwater through high biological oxygen demand from bacteria).

- **Fish transfer**: relocate a sub-sample of the fish from the main pool (n= 8) to captive holding facilities (SARDI) as a safeguard in case of catastrophe and to initiate a captive breeding program (see Westergaard and Ye 2010). As conditions deteriorated during the 2010-12 some smaller pools began to dry leaving stranded fish and fish were relocated to a nearby (<50m) pool which held water at reasonable depth.
- **Regular monitoring**: assess status of population and evaluate the condition of pools environmental (alarm and critical) thresholds to inform management.

Long-term monitoring data indicates River Blackfish have been persisting at Rodwell Creek with steady low recruitment observed as the presence of successive 1+ fish cohorts most years (Hammer 2009; Bice *et al.* 2010; Hammer 2010; Bice *et al.* 2011). The population is dynamic - restricted to pools that hold water (in 2007 and 2008 only the main pool) during dry years, but expanding throughout the section during wet years. In 2010, above average rainfall across the EMLR lead to increased flow and water levels and subsequently decreased salinity and increased habitat and connectivity through the section. Encouragingly, significant recruitment and expansion in population size and local distribution were realised (Hammer 2009; Hammer 2010). These is little doubt that the management interventions during the extreme drought conditions of 2007-2008 maintained the population so that population expansion could take place. Whilst the status of the population had improved by the beginning of the 2011-12 critical period, the continued threat posed by hydrological alteration in the catchment ensures that active management remains necessary.

1.1 Project objectives

At the beginning of the 2011-12 critical period, a multi-facet monitoring project was initiated to assist the medium-term management of River Blackfish in Rodwell Creek. The specific objectives of the project were to:

- Assess the status of River Blackfish in known pools.
- Continue active management of known pools, through regular water quality monitoring and the provision of environmental watering and aeration.
- Investigate the range of River Blackfish in additional pools in Rodwell Creek.
- Survey and assess potential refuge locations (to allow emergency transfer, if necessary).
- Provide recommendations for the future management of the species in Rodwell Creek.

The 2011-12 project was jointly funded by the Foundation for Australia's Most Endangered Species Inc (FAME), Goolwa to Wellington LAP and the South Australian MDB NRM Board.

2.0 Methods

2.1 Study region

Rodwell Creek occurs within the Bremer catchment within the Eastern Mt Lofty Ranges (EMLR) (Figure 1). The creek is a small (5-10m wide), shallow (1-2m deep) stream, rising east of the Bugle Ranges and flowing in a south-easterly direction through a small catchment area to the Bremer River near Woodchester. The main land use in the catchment is livestock grazing, along with some horticulture, dairying and urban development. The creek is considered to be in poor condition with the input of high nutrient loads and fine sediments from adjacent agricultural land and the severely affected riparian zone (South Australian EPA 2008). The catchment (as part of EMLR region) experiences a Mediterranean type climate with mild to warm and dry summers and cool wet winters (Figure 2); overall it has relatively high rainfall (e.g. average annual rainfall for nearby Mount Barker since 1860 is 764mm, Bureau of Meteorology, unpublished data).

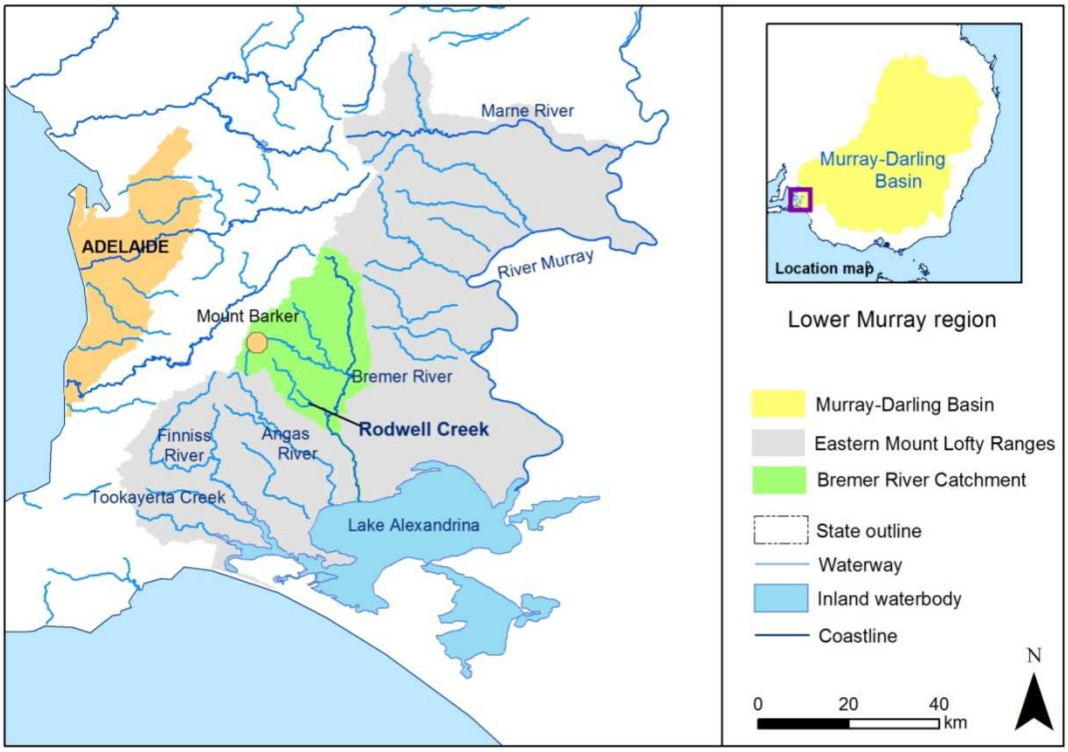

Figure 1 Location of Rodwell Creek in Eastern Mt Lofty Ranges.

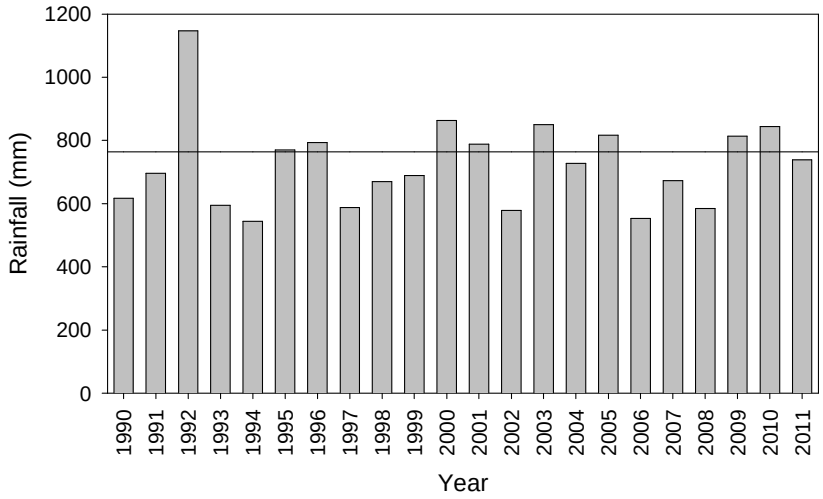

Figure 2 Representative rainfall data at Mount Barker between 1990-2011 with long-term average, 1860-2011 (black line) (Bureau of Meterology, unpublished data).

2.2 Fish monitoring

Fish monitoring was conducted on several occasions between October 2011 and May 2012 under a *Section 115 permit* in accordance with the *Fisheries Management Act 2007* (PIRSA Fisheries No. 9902425). Monitoring of the six known pools occurred during October 2011, additional upstream pools/dams were sampled during December 2011 and long-term sites (main monitoring and Highland Valley b) were sampled in April-May during 2011 and 2012 as part of EMLR annual condition monitoring (Figure 3 and Table 1). Sampling was designed to determine if the species remains in known pools (presence), map distribution in additional habitats (population extent) and provide information on the demographic structure of sampled populations. In additional sampling aimed to evaluate the suitability of any additional upstream pools/dams as refuge locations should emergency transfer from known pools be required. Specific sampling methods and effort matched prevailing environmental conditions at each site (see Appendix 2 for sampling effort). Sampling utilised the following:

- Large fyke net: single 6m wing, D shaped entrance (0.7m wide x 0.7m high), 3 compartments and 6mm half mesh.
- Small fyke net: single 3m wing, D entrance, 2 compartments and 4mm stretch mesh.
- Bait trap: rectangular 0.5m long x 0.25m square, 60mm entrance and 1mm mesh.
- Backpack electrofishing (Smith-Root LR24): with settings: 250-300V, 70Hz, 7% duty cycle and ~1000 seconds.

All sampled fish were identified to species, counted and observed to obtain general biological information (size range, reproductive condition and external disease or parasites). Length-frequency information (as Total Length, TL) was gathered for River Blackfish. Records of other fauna sampled opportunistically were maintained. At each sampled site, environmental descriptors, covering differing aspects of underwater cover, edge vegetation, pool condition, flow and water quality (see full details in Appendix 1), were recorded to aid the interpretation of results and assist with broader stream condition assessment.

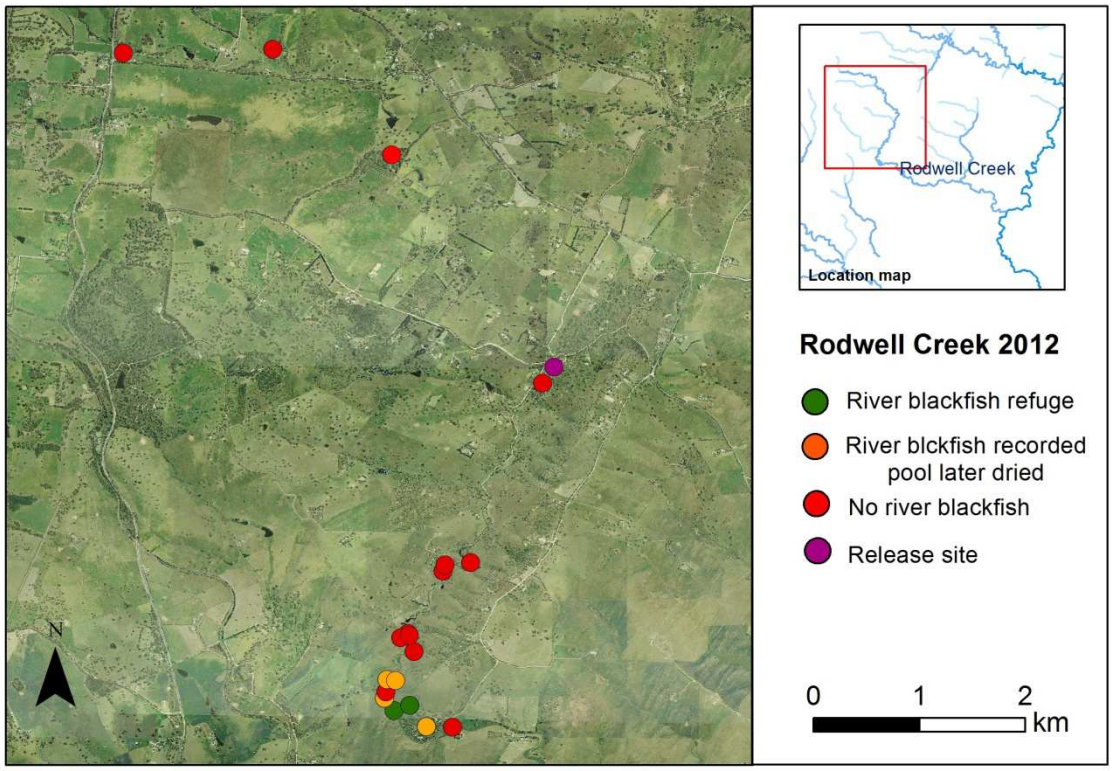

Figure 3 Sampling sites and River blackfish status as of autumn 2012.

Table 1 Summary of fish monitoring sites on Rodwell Creek over 2011 and 2012 (in downstream to upstream order).

Site Code	Date	Waterway	Location	Easting	Northing
ML11-46	05-May-11	Rodwell Creek	Highland Valley (b) pool	310340	6103956
ML12-11	12-Apr-12	Rodwell Creek	Highland Valley (b) pool	310340	6103956
ML11-72	21-Oct-11	Rodwell Creek	Pool 1 (house pool)	310137	6103954
ML11-73	21-Oct-11	Rodwell Creek	Pool 2 (main pool)	310003	6104156
ML12-12	12-Apr-12	Rodwell Creek	Pool 2 (main pool)	310003	6104156
ML11-74	21-Oct-11	Rodwell Creek	Pool 3	309881	6104103
ML11-75	21-Oct-11	Rodwell Creek	Pool 4	309806	6104217
ML11-76	21-Oct-11	Rodwell Creek	Pool 5	309815	6104274
ML11-77	21-Oct-11	Rodwell Creek	Pool 6 (border pool)	309820	6104394
ML11-82	12-Dec-11	Rodwell Creek	Pool 11	309983	6104814
ML11-83	12-Dec-11	Rodwell Creek	Pool 12 (Rodwell Creek farm)	310234	6105427
ML11-84	12-Dec-11	Rodwell Creek	Pool 13 (Rodwell Creek farm)	310249	6105483
ML11-04	08-Feb-11	Rodwell Creek	Pool 14	310445	6105510
ML11-85	12-Dec-11	Rodwell Creek	Pool 15	310968	6107216
ML11-86	12-Dec-11	Rodwell Creek	Pool 16	311054	6107371
ML11-78	13-Dec-11	Rodwell Creek	Pool 7	309886	6104384
ML11-87	13-Dec-11	Rodwell Creek	Pool 17	309752	6109348
ML11-88	13-Dec-11	Rodwell Creek	Pool 18 (Wildlife Corridor)	308810	6110329
ML11-89	13-Dec-11	Rodwell Creek	Pool 19 (Analla)	307652	6110267
ML11-90	13-Dec-11	Rodwell Creek	Pool 20	310137	6103954

2.3 Condition monitoring & management of pools

The condition of the six known River Blackfish pools was monitored from 15 September 2011 to 21 June 2012. Monitoring predominately focused on the main pool (16 trips) with regular checking of the remaining five pools (six trips). Monitoring of all pools involved measurement of select environmental descriptors - water level (using existing depth stake), water quality (EC, pH, temperature, dissolved oxygen) and an assessment of aquatic habitat (see Appendix 1). The condition of pools was evaluated against ***alarm*** and ***critical*** thresholds linked to the tolerances of the species (Hall *et al.* 2009; Hammer 2010):

- **Water level** - above alarm (1.5m) and critical (1m) thresholds to maintain sufficient aquatic cover and buffer against high air temperatures.
- **Temperature** - below alarm (20°C) and critical (24°C) thresholds to limit direct (survival) and indirect (dissolved oxygen concentrations) impacts to species.
- **Salinity** - below alarm (5000µScm^{-1}) and critical (7500µScm^{-1}) thresholds to limit direct (survival) and indirect (sub-lethal growth and conditioning or stress) impacts to species.
- **Dissolved oxygen** - above alarm (4 mgL^{-1}) and critical (2 mgL^{-1}) thresholds to limit direct (survival) and indirect (sub-lethal growth and conditioning or stress) impacts to species.

Management invention of the main pool was initiated when prevailing conditions reached alarm thresholds and involved aeration and environmental watering using pre-existing infrastructure and emergency fish transfre (Hammer 2010). Environmental water is gravity fed from two rainwater tanks (total volume 30000L) via a spray bar at the top of the pool to reduce velocity and increase aeration. A water tanker delivers bore water with suitable water chemistry (low salinity, sulphides, and trace metals) to the rainwater tanks via a commercial supply. An aeration system was developed via a commercial pond aerator (Pond One 12000, 6600L hour^{-1}) located at the property residence and piped to the pool some 400m through 12mm poly pipe carefully trenched and configured to avoid damage during property maintenance and by natural means. Delivery to the pond was to three large airstones at 0.5m depth tide to star pickets.

Summary of the management inventions at Rodwell Creek: environmental watering (top) and aeration (bottom).

3.0 Results

3.1 Fish monitoring

Status of populations in known pools

In October 2011, a total of 91 River Blackfish were sampled from the five of the six pools were the species has been previously recorded (Table 2). Numbers were greatest in pool 6 (45 fish), pool 3 (37 fish) and to a lesser extent the main pool (7 fish) with only single individuals recorded in pools 1 and 4. Fish monitoring in April 2012 indicated that the species remained present in the main pool. Downstream of the pools 1-6, the species is largely absent (1 individual in May 2011, none in April 2012).

Table 2. Catch summary of fish species recorded in the Rodwell Creek catchment (in downstream to upstream order). Alien species in red.

Site code	Date	Location	Carp gudgeons	Mountain galaxias	River blackfish	No fish	Gambusia	Yabby	Shrimp
ML11-46	05-May-11	Highland Valley (b) pool			1				
ML12-11	12-Apr-12	Highland Valley (b) pool				x		x	
ML11-72	21-Oct-11	Pool 1 (house pool)	156		1		97	x	x
ML11-73	21-Oct-11	Pool 2 (main pool)	130		7			x	
ML12-12	12-Apr-12	Pool 2 (main pool)			4				
ML11-74	21-Oct-11	Pool 3	215		37			x	
ML11-75	21-Oct-11	Pool 4			1			x	
ML11-76	21-Oct-11	Pool 5	14						
ML11-77	21-Oct-11	Pool 6 (border pool)	40		45			x	
ML11-78	13-Dec-11	Pool 7			1				
ML11-79	12-Dec-11	Pool 8				x			
ML11-80	12-Dec-11	Pool 9				x			
ML11-81	12-Dec-11	Pool 10				x			
ML11-82	12-Dec-11	Pool 11				x		x	x
ML11-83	12-Dec-11	Pool 12 (Rodwell Ck farm a)				x		x	x
ML11-84	12-Dec-11	Pool 13 (Rodwell Ck farm b)				x		x	x
ML11-04	08-Feb-11	Pool 14	3						
ML11-85	12-Dec-11	Pool 15				x		x	x
ML11-86	13-Dec-11	Pool 16		1			20	x	x
ML11-87	13-Dec-11	Pool 17					81	x	x
ML11-88	13-Dec-11	Pool 18 (Wildlife Corridor)					50	x	x
ML11-89	13-Dec-11	Pool 19 (Analla)					100		x
ML11-90	13-Dec-11	Pool 20					150	x	x

Figure 4 shows the length-frequency distribution of individuals sampled from pool 3 and 6 overlaid with the size ranges for age classes (up to 3 years old) obtained from the River Blackfish EMLR population model of Hammer (2006). Pools 3 and 6 contained mid-sized individuals (e.g.1+ and 2+ fish) with pool 6 also containing older individuals (e.g. >3+ fish). The absence of individuals below 98mm in these pools indicates a lack of recent recruitment,

yet four of the seven individuals collected from the main pool were clearly new recruits (e.g. 42-75mm).

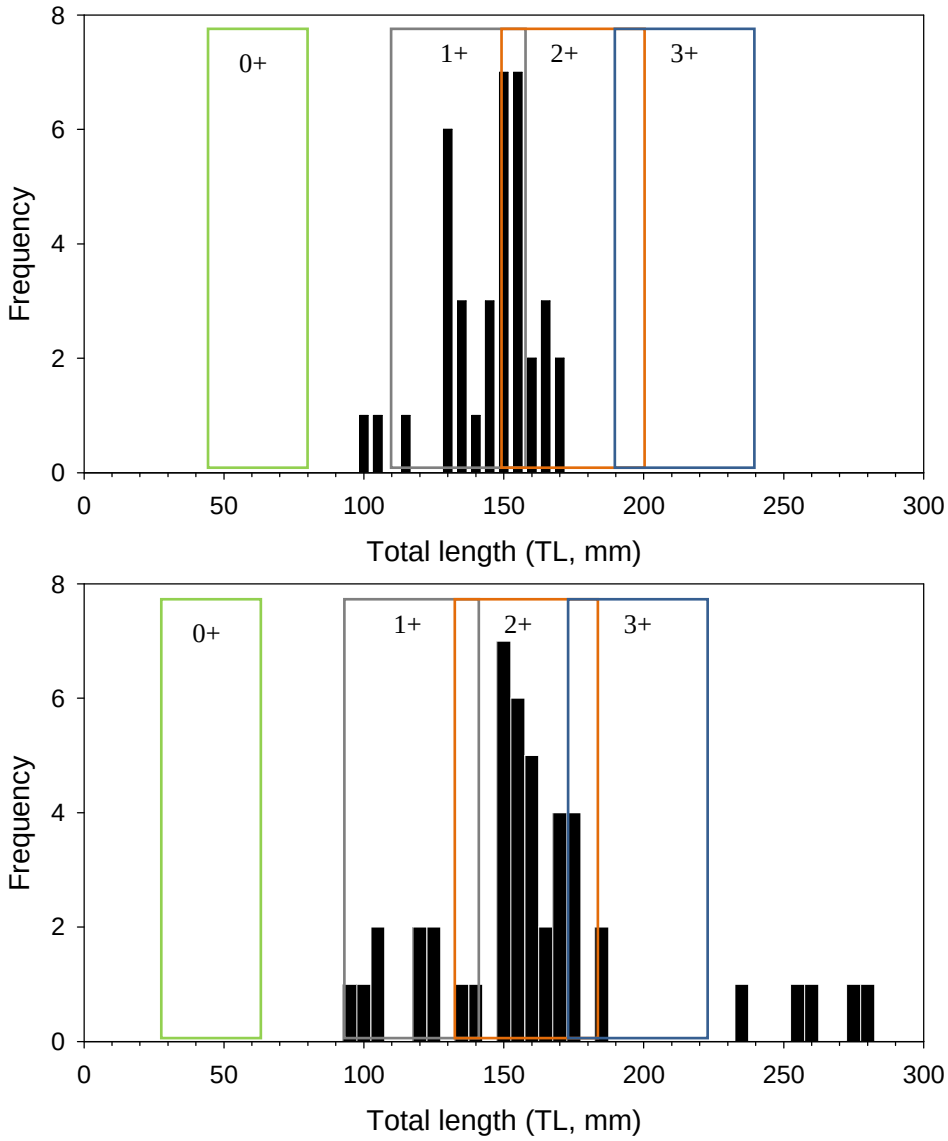

Figure 4 Length-frequency distribution of River Blackfish in pool 3 (top) and pool 6 (bottom) of Rodwell Creek during October 2011.

Range mapping

A total of 14 additional pools/dams were visited during December 2011 with fish sampling conducted in 12 (see appendix 4 for site photos). Sampling of 12 upstream pools was able to only detect one River Blackfish (169 mm) located in pool 7, which appears to be annually connected to pool 6 (Table 2). Pools 8-13 did not contain any fish species (although yabbies and shrimp were present in three of these pools. From pool 16, a single Mountain Galaxias was recorded, a species which have been previously recorded in this pool. Carp Gudgeon were recorded in high numbers across the majority of the pools and Gambusia were recorded only in pool 1 (house pool) and those further upstream (pools 16 to 20) indicating that colonisation of the mid-reaches of the creek by this introduced species may not be possible due to limited

connectivity.

Assessment of the suitability of these pools as refuge habitat for River Blackfish was made on the basis of pool connectivity (and flow), aquatic habitat (and edge vegetation) and water quality (Table 3). At the time of assessment, the creek had ceased flowing and all pools were beginning to recede, with depths ranging from 0.4 to 1.5 m. The majority of pools assessed were discounted as irregular connection ensured that water would not persist over the whole year. Of the remaining six pools with assumed permanent water, two were removed due to either insufficient aquatic habitat (pool 13) or poor water quality, namely alarmingly low dissolved oxygen (pool 21, approaching 2 mg^{-L}). Four suitable pools were identified (pools 16-19), with pool 16 deemed most suitable due water permanency, adequate aquatic habitat and water quality.

River Blackfish and Mountain Galaxias sampled from additional pools

3.2 Condition monitoring & management of pools

The 2011-12 critical period in Rodwell Creek was preceded by strong winter floods in 2010 and then an extended period of flow (March to October 2011), which acted to maintain water levels in each of the known pools (Figure 5). However, flows ceased at the end of October 2011 and water levels (~1.7-1.8m deep) receded rapidly to the end of January 2012 (0.92m deep) - a consistent pattern across recent years . Corresponding declines in aquatic habitat (40% → 25%) and alarmingly low dissolved oxygen (<4mgL^{-1}) and high salinities (up to 8.8 $mScm^{-1}$) were realised (Figure 6).

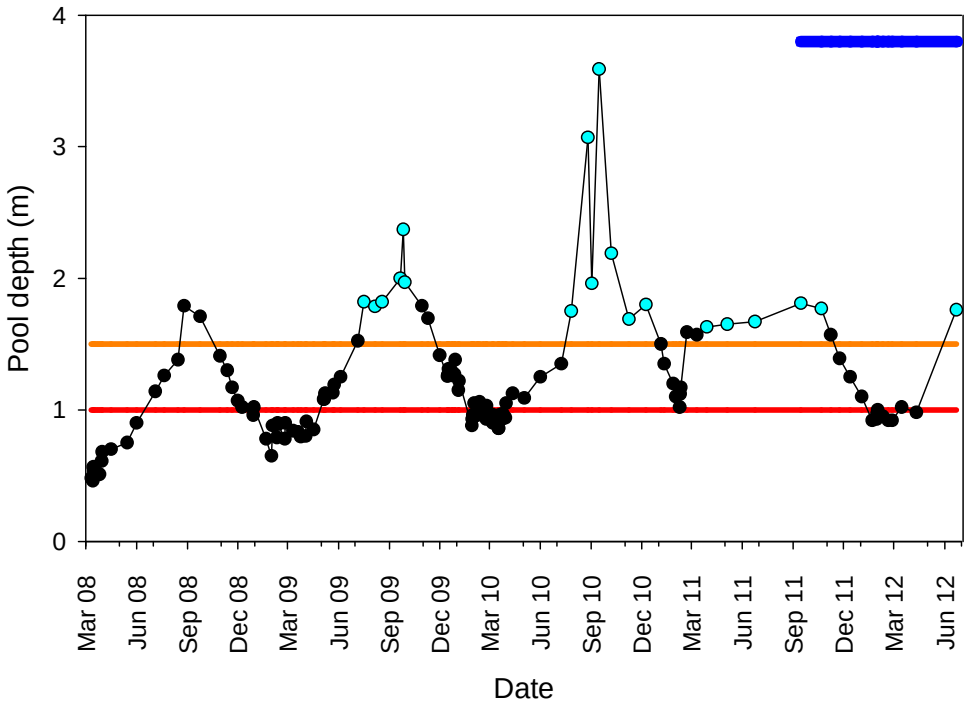

Figure 5 Pool depth at Rodwell Creek since autumn 2008 with 2011-12 sampling period (blue bar) and periods of creek flow (light blue dots).

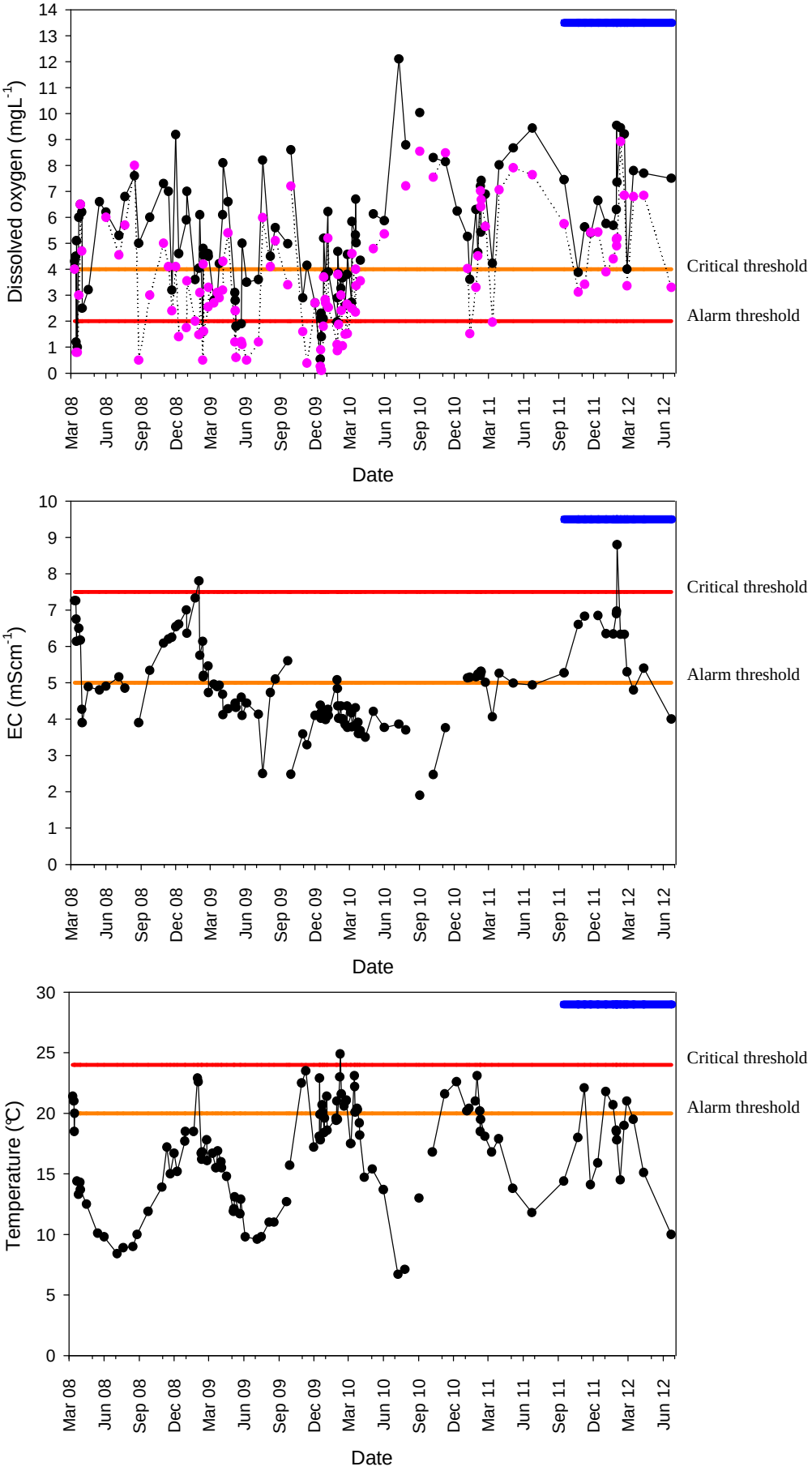

Figure 6 Dissolved oxgyen (top), EC (middle) and temperature (bottom) at Rodwell Creek since autumn 2008 with 2011-12 sampling period (blue bar) and alarm (red line) and critical (orange line) thresholds shown.

The deterioration of the known pools by the end of January 2012 prompted environmental watering (28000L) of the main pool and triggered the requirement for emergency transfer of individuals from pools 3 and 6 (Figure 7).

Condition of pool 1 (left) and pool 6 (right) in Rodwell Creek by February/March 2012

It was decided to transfer these fish into (a) the main pool as it was being actively managed and (b) a refuge location (pool 17) further upstream to provide a medium-term safeguard and assist with the dispersal of River Blackfish above pool 7. Follow up assessment of the refuge locations revealed that pools 8-16 had dried and pool 18 was looking stagnant whilst pool 17 maintained its suitability. As such, overnight netting (31 January 2012) collected 82 fish from pool 3 and 6, which were transferred to the main pool (16 fish) and the refuge pool (pool 16, 66 fish, 110-250mm).

Release of River Blackfish (left) into pool 16 on Rodwell Creek (right)

The emergency watering during late January 2012 succeeded in stabilising water level (~1m), improving dissolved oxygen (>6mgL^{-1}) and freshening the main pool (down to 5.3 mScm^{-1}). Yet, in anticipation of the impacts of period of high air temperatures emergency watering was again undertaken toward the end of February 2012 and further improvement was realised. In

contrast to the main pool, the condition of the unmanaged pools (1, 3, 4, 5, 6) continued to decline over the critical period and by April 2012 conditions in pools 1, 4, 5, and 6 had collapsed. Indeed, pool 6 was almost dry and several dead River Blackfish were observed in the shallow, low DO and algal rich waters of pool 6 during fish monitoring in April 2012. Encouragingly, adequate conditions in pool 3 were maintained across the critical period. By June 2012, cooler weather and periods of high rainfall, and resultant creek flow, have acted to reset all pools in the section of Rodwell Creek with the main pool depth (1.76m), DO (7.5mgL^{-1}) and EC (4.0 mScm^{-1}) all at suitable levels.

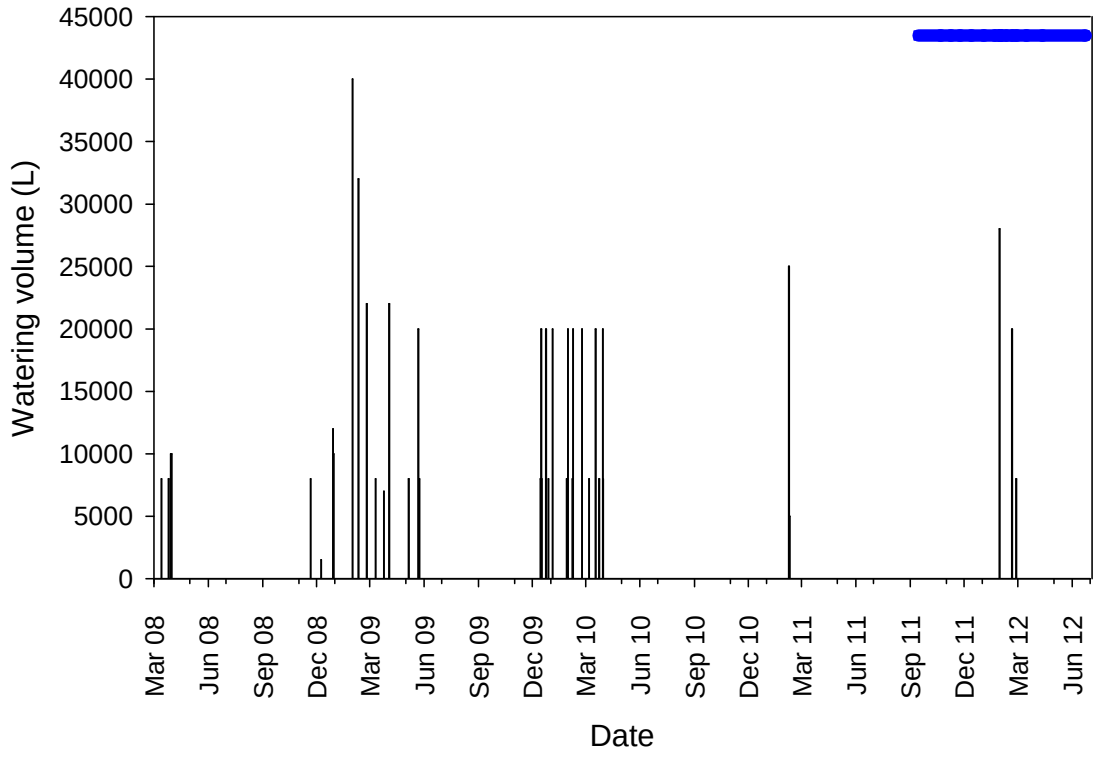

Figure 7 Environmental watering history at Rodwell Creek since autumn 2008 with 2011-12 sampling period (black bar).

The severe deterioration of pool 6 on Rodwell Creek showing dead River Blackfish spotlighted.

Status of pool 1 (top left), main pool (top right), pool 6 (bottom left) and the refuge pool (pool 16, bottom right) on Rodwell Creek in June 2012.

4.0 Discussion

4.1 Summary of 2011-12 critical period

In response to prolonged drought and increased water abstraction in Rodwell Creek catchment, active management to protect the remnant River Blackfish population has occurred since 2008. This active management has involved regular monitoring, environmental watering, aeration and fish transfer (Hammer 2009; Hammer 2010). There is little doubt that without this intervention the population would have been lost during 2008 and it is apparent that ongoing management (but with annually secured funding) is now necessary. The fact that active management in the face of prolonged drought and water over-abstraction has maintained River Blackfish in Rodwell Creek should not be understated.

The present project focused on creek management over the 2011-12 critical period (October to May). Assessment of the status of this population at this stage confirmed that the species is occurred in five known pools, at least for part of the year (i.e. refuge locations and population sinks), but lower numbers are recorded in several of these pools. The absence of River Blackfish above pool 7 indicated an inability for this low movement species to move upstream given the movement patterns of the species (Khan *et al.* 2004; Koster and Crook 2008) and the limited connectivity of the creek. As part of the status assessment, pool 16 was identified a suitable refuge location - should as emergency transfer be required - as it has permanent water (e.g. didn't dry during 2006-2009 drought period), favourable water quality and aquatic habitat (>45%).

Conditions were favourable in the known pools at the beginning of the critical period, but soon deteriorated as the creek ceased to flow at the onset of summer began. Indeed, the water depth in all pools dropped as did dissolved oxygen and salinities increased. By the end of January, critical thresholds were reached and emergency intervention (environmental watering and aeration that began in November 2011) in the main pool was necessary to protect the species - an increasing requirement over critical period (Hammer 2009; Hammer 2010). These interventions acted to stabilise the conditions in the main pool and help to ensure the short-term survival of the species. The condition of the other known pools - where environmental watering and aeration are not currently possible - was predicted to continue to decline (and ultimately were desiccated) so emergency fish transfer was initiated. Fish were moved from pool 3 and pool 6 to the main pool as active management was possible, and to a separate refuge location to spread risk and hopefully establish additional population security (pool 16). Establishment of this permanent water refuge will help to secure the medium-term future of the species in Rodwell Creek. However, regular monitoring is necessary to assess its suitability for the survival and recruitment of the species.

4.2 Future monitoring

It is apparent that ongoing management and funding is now essential to maintain River Blackfish in Rodwell Creek. Table 3 details the minimum annual monitoring requirements to provide the information necessary to manage the species. It is important to understand the extent and structure of known populations prior to the critical period each year, which should be achieved through fish surveying in spring. As the critical period approaches, regular monitoring is necessary to assess the condition of known pools (particularly the main pool) to allow management intervention to occur should conditions deteriorate. In autumn, further fish surveying should occur to confirm that the species still occurs at known pools and map any pools that have maintained water throughout the critical period.

Table 1 Annual monitoring framework in Rodwell Creek.

Monitoring objectives (with indicator)	**Method**	**Objective**
Habitat condition (habitat)	Fortnightly (up to weekly if conditions deteriorate) monitoring of aquatic habitat, water quality and pool depth	Assess conditions against alarm and critical thresholds (with provision for management intervention)
Determining that a species remains (presence)	Annual fish survey of known pools (present - pools 1, 2, 3, 6, refuge location). Additionally, any opportunistic sampling as part of over projects	Confirm that the species remains
Mapping distribution during low flow periods (population extent)	Annual fish survey of additional pools (priority is downstream of known pools)	Document extent of the River Blackfish population
Snapshot of demographic structure) for (a) assessing presence of recruits and (b) assessing longer-term survivorship through presence of older size classes (recruitment)	Length-frequency measurements (including annual survey) during spring (as part of annual survey) and autumn	Assess temporal trends in population status (e.g. recruitment, only older individuals)

4.3 Long-term management

In the face of changing climatic conditions and high levels of water abstraction (farm dams), longer-term management consideration is required to ensure the long-term sustainability of River Blackfish in Rodwell Creek. Refinement and provision of the environmental water requirements (EWR) for the species at a regional level (Hammer *et al.* 2009; VanLaarhoven and van der Wielen 2009) should occur in the creek. For instance, permanent water, cool and well oxygenated conditions have not been maintained throughout the creek (with exception of actively managed main pool). Furthermore, the requirement for freshes during the low flow season, high channel forming flows in winter/spring or early summer maintenance of shallow environments is rarely achieved. For these EWRs to be to actually be realised, flow management in the catchment is necessary. Indeed, broader catchment-wide management of water abstraction needs to be addressed including the potential for low-flow bypass, especially on instream dams. Ongoing riparian zone restoration (e.g. weed control, revegetation) as has been conducted by GLWAP will improve the broader condition of the creek.

4.4 Conclusions and recommendations

Wide ranging management interventions are increasingly required to prevent the extirpation of freshwater ecological assets. The remnant River Blackfish population in Rodwell Creek represents a significant ecological asset in the EMLR and, more broadly, South Australia. Critical water shortages over the past five years would have undoubtedly lead to the loss of this population without management intervention (that has occurred since 2008). This management has been intensive with regular monitoring, environmental watering, aeration and fish transfer, and allowed River Blackfish to persist in Rodwell Creek. Continued management over the 2011-12 critical period ensured the short-term survival of the species. Furthermore, establishment of the refuge location has secured the medium-term future of the species in the creek. Whilst the species persists, the observed extent of occurrence and population demographics coupled with a limited dispersal ability highlight the vulnerability of the species. Management attention should seek to maintain the species but emphasis must turn to the enhancement of the population through the provision of environmental water requirements as part of broader catchment-wide management.

It is, therefore, recommended to maintain and enhance the River Blackfish population in Rodwell Creek by:

- Annual monitoring of the condition of known pools (and refuge location) over the critical period (2012-13 is currently unfunded)
- Annual fish surveying to detect temporal changes in presence, distribution and population structure (2012-13 is currently unfunded)
- Determination and provision of environmental water requirements
- Investigate flow management, such as low-flow bypass of instream dams, including community based projects
- Continued broader catchment management, including control of weed species and revegetation.

6.0 Acknowledgements

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7.0 References

Bice, C., Hammer, M., Leigh, S., Zampatti, B. (2010). *Fish monitoring for the 'Drought Action Plan for South Australian Murray-Darling Basin threatened freshwater fish populations: summary for 2009/10. SARDI Publication No. F2010/000647-1*. SARDI Aquatic Sciences, Adelaide.

Bice, C., Hammer, M., Leigh, S., Zampatti, B. (2011). *Fish monitoring for the 'Drought Action Plan for South Australian Murray-Darling Basin threatened freshwater fish populations: summary for 2010/11. SARDI Publication No. F2010/000647-2*. SARDI Aquatic Sciences, Adelaide.

Hall, A., Higham, J., Hammer, M., Bice, C., Zampatti, B. (2009). *DRAFT - Drought Action Plan for South Australian Murray-Darling Basin threatened freshwater fish populations*. South Australian Department for Environment and Heritage, Adelaide.

Hammer, M. (2004). *Eastern Mount Lofty Fish Inventory: distribution and conservation of freshwater fishes of tributaries to the Lower River Murray, South Australia*. Native Fish Australia (SA) Inc & River Murray Catchment Water Management Board, Adelaide.

Hammer, M. (2006). *Review of monitoring data for river blackfish in the Eastern Mount Lofty Ranges, South Australia: 2002-2006. Report to the South Australian Murray-Darling Basin Natural Resources Management Board*. Aquasave Consultants, Adelaide.

Hammer, M. (2009). *Freshwater fish monitoring in the Eastern Mount Lofty Ranges: environmental water requirements and tributary condition reporting for 2008 and 2009. Report to the SAMDB NRM Board*. Aquasave Consultants, Adelaide.

Hammer, M. (2010). *Report on in situ conservation activities at Rodwell Creek for 2009-2010*. Report to Department of Environment and Natural Resources (DENR). Aquasave Consultants, Adelaide.

Hammer, M., Wedderburn, S., van Weenan, J. (2009). *Action Plan for South Australian Freshwater Fishes*. Native Fish Australia (SA) Inc., Adelaide.

Khan, M. T., Khan, T. A., Wilson, M. E. (2004). Habitat use and movement of river blackfish (*Gadopsis marmoratus* R.) in a highly modified Victorian stream, Australia. *Ecology of Freshwater Fish* **13**, 285-293.

Koster, W. M., Crook, D. A. (2008). Diurnal and nocturnal movements of river blackfish (*Gadopsis marmoratus*) in a south-eastern Australian upland stream. *Ecology of Freshwater Fish* **17**, 146-154.

Lintermans, M. (2007). 'Fishes of the Murray-Darling Basin: An Introductory Guide.' (Murray-Darling Basin Commission: Canberra)

Lloyd, L. N., Walker, K. F. (1986). Distribution and conservation status of small freshwater fish in the River Murray, South Australia. *Transactions of the Royal Society of South Australia.* **110**, 49-58.

South Australian EPA (2008). *State of Our Environment report, South Australia, 2008*. South Australian Environmental Protection Authority, Adelaide.

VanLaarhoven, J., van der Wielen, M. (2009). *Environmental water requirements for the Mount Lofty Ranges prescribed water resources areas*. Department of Water, Land and Biodiversity Conservation & South Australian Murray-Darling Basin Natural Resources Management Board, South Australian Government, Adelaide.

Westergaard, S., Ye, Q. (2010). *A captive spawning and rearing trial of river blackfish (Gadopsis marmoratus): efforts towards saving local genetic assets with recognised conservation significance from the South Australian Murray-Darling Basin. Report to Department for Environment and Heritage. SARDI publication number: F2010/000183-1*. SARDI Aquatic Sciences, Adelaide.

8.0 Appendices

Appendix 1.Environmental descriptors recorded

Location (description and GPS-WGS 84 datum, zone 54H), waterway, weather, land use, potential impacts and environmental characteristics were recorded for each sampling site to assist with the interpretation of results and future replication. Digital photos were taken of all sites. Environmental characteristics included details of aquatic and interlinked riparian condition under the following categories:

General descriptors: Habitat type (i.e. stream, wetland, instream dam).

- Pool size as an estimation of surface area.
- Bank slope (e.g. steep = 45º, vertical 90º).
- Depth (maximum and average).
- Substrate type (e.g. sand, gravel, mud).

Flow environment:

- A temporal measure of connectivity based on seasonal conditions and local landholder input (e.g. ephemeral, six months flow connection, or permanently connected), plus comments such as whether the area is spring fed.

Pool condition and flow:

A measure of water level in comparison to the normal bank level of a pool (e.g. concentrated, bank level, in flood) and recording of *Flow* at the time of sampling ranked relative to magnitude: low = <10 L/sec; medium 10-100 L/sec; high 100-200 L/sec; very high >200L/sec.

Contributions to cover (% of volume occupied and type):

- Submerged physical (e.g. snags, leaf litter, rock),
- Submerged biological (e.g. aquatic plants, *Chara*, other algae),
- Emergent (e.g. reeds, rushes and sedges, tea tree),
- Fringing vegetation within 2 metres of the waters edge (particular note of small amphibious species on the bank such as *Crassula, Centella,Ranunculus*).
- Canopy – measure of over hanging vegetation (shade),
- General surrounding terrestrial vegetation cover.

Water quality:

- TPS meters taken at 0.3m depth recording (a) temperature, (b) conductivity (k=10 probe, range 200-200,000µS = μScm^{-1}), (c) pH, and (d) dissolved oxygen.
- Water transparency measured *in situ* against a white object with comments on contributions to low values such as natural tannin, colloids or algae.

Appendix 2.Sampling details

Site Code	Date	Waterway	Location	Large fykes	Small fykes	Bait traps	Electrofishing	Day observation
ML11-46	05-May-11	Rodwell Creek	Highland Valley (b) pool			8		
ML12-12	11-Apr-12	Rodwell Creek	Highland Valley (b) pool			10		
ML11-72	21-Oct-11	Rodwell Creek	Pool 1 (house pool)	1	1			
ML11-73	21-Oct-11	Rodwell Creek	Pool 2 (main pool)	1	1			
ML12-11	11-Apr-12	Rodwell Creek	Pool 2 (main pool)			10		
ML11-74	21-Oct-11	Rodwell Creek	Pool 3	1	1			
ML11-75	21-Oct-11	Rodwell Creek	Pool 4	1	1			
ML11-76	21-Oct-11	Rodwell Creek	Pool 5	1	1			
ML11-77	21-Oct-11	Rodwell Creek	Pool 6	2	1			
ML11-78	13-Dec-11	Rodwell Creek	Pool 7				x	
ML11-79	12-Dec-11	Rodwell Creek	Pool 8					x
ML11-80	12-Dec-11	Rodwell Creek	Pool 9					x
ML11-81	12-Dec-11	Rodwell Creek	Pool 10					x
ML11-82	12-Dec-11	Rodwell Creek	Pool 11	1	1			
ML11-83	12-Dec-11	Rodwell Creek	Pool 12 (Rodwell Creek farm a)	1	1			
ML11-84	12-Dec-11	Rodwell Creek	Pool 13 (Rodwell Creek farm b)	1	1			
ML11-04	08-Feb-11	Rodwell Creek	Pool 14	2	2			
ML11-85	12-Dec-11	Rodwell Creek	Pool 15	1	1			
ML11-86	12-Dec-11	Rodwell Creek	Pool 16	1	1			
ML11-87	13-Dec-11	Rodwell Creek	Pool 17	1	1			
ML11-88	13-Dec-11	Rodwell Creek	Pool 18 (Wildlife Corridor)	1	1			
ML11-89	13-Dec-11	Rodwell Creek	Pool 19 (Analla)	1	1			
ML11-90	13-Dec-11	Rodwell Creek	Pool 20	1	1			

Appendix 3.Environmental data for Rodwell Creek sites

Site Code	Location	Depth max (m)	Subsurface physical %	Subsurface biological %	Emergent %	Edge vegetation %	Shade %	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved oxygen @0.2m (ppm)
ML11-46	Highland Valley (b) pool	2.5	10	1	30	10	10	7.01	7630	13.5	3.59
ML12-12	Highland Valley (b) pool	2.0	5	0	40	10	0	7.99	8900	13.8	6.30
ML11-72	Pool 1 (house pool)	0.95	30	0	20	96	100	6.08	6840	17.1	7.10
ML11-73	Pool 2 (main pool)	1.5	15	0	30	80	70	6.67	6600	17.4	3.88
ML12-11	Pool 2 (main pool)	1.3	20	0	30	80	70	7.91	5430	15.1	7.70
ML11-74	Pool 3	1.2	20	0	60	95	100	7.19	-	17.5	3.40
ML11-75	Pool 4	1.2	10	1	80	70	30	7.21	6980	13.1	2.72
ML11-76	Pool 5	1.2	20	1	65	70	10	6.9	6490	16.7	4.70
ML11-77	Pool 6	1.2	15	10	10	80	20	7.67	-	17.1	6.10
ML11-78	Pool 7	0.8	35	1	10	20	100	8.11	8960	17.8	7.30
ML11-79	Pool 8	1.0	20	0	0	5	10	8.06	9060	19.5	6.51
ML11-80	Pool 9	0.2	40	0	0	5	10	Too shallow			
ML11-81	Pool 10	0.4	5	0	30	25	10	Too shallow			
ML11-82	Pool 11	1.0	20	0	45	20	45	8.12	8900	16.8	4.93
ML11-83	Pool 12 (Rodwell Creek farm a)	1.2	5	0	0	60	20	7.69	8940	16.4	4.15
ML11-84	Pool 13 (Rodwell Creek farm b)	1.3	2	0	5	20	4	7.88	9280	16.5	4.64
ML11-04	Pool 14	3.0	10	5	0	10	5	8.50	5190	22.3	8.90
ML11-85	Pool 15	1.0	10	0	0	50	30	7.83	9230	16.8	6.08
ML11-86	Pool 16	1.5	15	10	15	5	30	8.72	7440	19	9.62
ML11-87	Pool 17	1.5	2	24	5	10	45	8.29	7220	18.7	8.25
ML11-88	Pool 18 (Wildlife Corridor)	1.5	1	20	20	30	20	8.37	7020	20.4	7.82
ML11-89	Pool 19 (Analla)	2	1	10	0	10	20	8.32	5180	21	4.62
ML11-90	Pool 20	1.5	1	20	20	40	20	7.97	7480	19.6	2.13

Appendix 5. Additional pools and potential refuge locations

Pool 7

Pool 8

Pool 9

Pool 10

Pool 11

Pool 12 (Rodwell Creek farm a)

Pool 13 (Rodwell Creek farm b)

Pool 15

Pool 16

Pool 17

Pool 18 (Wildlife Corridor)

Pool 19 (Analla)

Pool 20