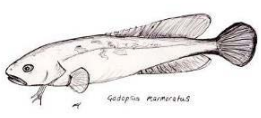
Identification and assessment of surrogate refuge dams as part of the Drought Action Plan for Lower Murray threatened fishes






Michael Hammer, Leanne Piller & Dylan Sortino
Aquasave Consultants, Adelaide

October **2009**



Government of South Australia
Department for Environment and Heritage

Citation
Hammer, M., Piller, L., and Sortino, D. (2009). Identification and assessment of surrogate refuge dams as part of the Drought Action Plan for Lower Murray threatened fishes. Report to the South Australian Department for Environment and Heritage. Aquasave Consultants, Adelaide. 34 pp.

Correspondence in relation to this report contact
Dr Michael Hammer
Aquasave Consultants
Tel: +61 429 098 920
Email: michael@bold.net.au

Contents

1.0 Introduction

Extended drought conditions in the Murray-Darling Basin (MDB) have seen unprecedented threat to freshwater habitats and species in the Lower Murray region, including nationally and state threatened fishes (Hammer 2007a; Hammer 2007b, 2008a). Urgent conservation measures have been developed for five key native fish as part 'Drought Action Plan for Lower Murray Fishes' being coordinated by the of the Department for Environment and Heritage (DEH) (Hall *et al.* 2009) and fitting in with broader recovery recommendations of the Action Plan for South Australian Freshwater Fishes (Hammer *et al.* 2007).

The five key species are:

- Southern Purple-spotted Gudgeon (*Mogurnda adspersa*) – known from only one wetland in the southern MDB.
- Yarra Pygmy Perch (*Nannoperca obscura*) – a genetically distinct MDB population occurring in western Lake Alexandrina.
- Southern Pygmy Perch (*Nannoperca australis*) – five genetically distinct populations in small areas of Eastern Mount Lofty ranges streams and Lake Alexandrina.
- River Blackfish (*Gadopsis marmoratus*) – last remnant SA MDB populations in small areas of four catchments.
- Murray Hardyhead (*Craterocephalus fluviatilis*) – an MDB endemic known from only a few localities in Victoria and SA, including the Lower Lakes, Rocky Gully, and Berri and Disher evaporation basins.

Each species has one or more populations under imminent threat of local extinction, with some species or key populations rescued. The goals for rescuing and maintaining fish in captivity addresses risk management (or last resort), and consider the projected time period of severe environmental stress and the lifespan of the species in question. Different goals include:

- **Temporary captive maintenance** – fish are held temporarily until suitable conditions occur and are then returned to the point of capture.
- **Support population** – fish are maintained, spawned and reared in captivity or artificial habitats as a backup in case of catastrophe and as a resource for conserving the wild population (e.g. understanding environmental tolerances).
- **Captive breeding program** – local major declines or extinctions place the onus on captive breeding to re-establish a population with fish bred in captivity from original broodstock (reintroduction program).

The scale and severity of habitat change in the Lower Murray has dictated the need for longer-term captive responses as primary options for species conservation (especially for Southern Purple-spotted Gudgeon and Yarra Pygmy Perch). A goal for a support program or captive breeding program should include breeding sufficient fish to establish artificial refugia (e.g. suitable surrogate dams) with the advantages of spreading risk, increasing the scale of operations (and available fish for reintroduction), and providing more natural behaviour and selection pressure to increase chances of successful reintroduction.

This report presents information to identify refuges for Lower Murray threatened fishes as part of the Drought Action Plan (Hall *et al.* 2009). Private dams, ponds or artificial wetlands in various catchments in the Mount Lofty Ranges were assessed as a potential means to incorporate this action into regional natural resource management. The integration of dams owned by local landholders or housing developments into this project also functions to address the need to improve knowledge and awareness of native fish and the Lower Murray for individuals, community groups and government organisations.

2.0 Methodology

The process for identification and selection of potential refuges was undertaken by a range of people/organisations in three key stages:

- **Stage 1** (late 2007/early 2008): initial calls for involvement and dam selection, development of project ideas and refuge criteria (Waterfind, DEH and Native Fish Australia (SA)).
- **Stage 2** (2008): DEH undertook site screening and the first major round of field surveys.
- **Stage 3** (May 2009-present): Aquasave was contracted to collate previous information into a cohesive and transparent assessment process, and to undertake a second major round of phone and field surveys with new enquiries and outstanding previous items.

2.1 Review of surrogate success & captive details

A few previous attempts have been made to establish surrogate refuges in the Lower Murray region. A review of available information on the status of these examples was made to identify any factors of success or failure to feed into the current process. The current holdings and capacity of captive breeding programs was also reviewed as context for available fish for stocking into surrogate refuges.

2.2 Dam identification

Identifying dams for local assessment involved a range of communications that called for volunteers or knowledge of suitable sites:

- Stage 1: Waterfind Environment Fund (now Healthy Rivers Australia) in conjunction with Native Fish Australia (SA) and DEH developed a media campaign which included a call for interested landholders to get in contact (Appendix 1).
- Stage 2: Additional DEH media attracted further responses from the community (2008/2009) (Appendix 2).
- Stage 3: Ongoing responses were received from targeted enquires with NRM Boards and community groups, opportunistically during Aquasave field monitoring, and word of mouth about the program which generated enquiries for involvement.

2.3 Basic screening

Enquiries were logged and responded to as soon as possible via phone calls, emails or in person. A basic screen was applied to identify sites with potential as surrogate refuges that then warranted a site inspection for assessment of environmental and physical characteristics. A specific phone survey was developed to help gather information in this process (Appendix 3). The focus was on identifying sites with permanent water, reasonable levels of cover and no introduced fish.

2.4 Field assessments

Site inspections were arranged to assess parameters that could be linked to the potential success of the site for establishing threatened species, and any risks to the receiving environment. Field assessment included (see Appendix 4 for more detail):

- Physical aspects: site photos, GPS location, size, depth, location and overflow point.
- Water security (hydrology): water source of the dam (e.g. local catchment, spring), level of annual fluctuation, and permanency through time.
- Water quality: salinity, pH, temperature, dissolved oxygen, transparency and nutrient levels.
- Habitat type and availability: measures of underwater cover including submerged aquatic plants, physical structure such as snags or rock, and biological cover (e.g. aquatic plants, current emergent vegetation, such as reeds), and edge vegetation as indication for cover at higher water levels.

- Communication with landholders/managers was made regarding any previous stockings, water quality events/issues and general commitment to site maintenance and involvement (also part of phone surveys).

2.5 Rapid fish and macroinvertebrate assessment

During Stage 3 if a dam seemed broadly suitable for threatened fish stocking, a rapid first cut fish survey was undertaken with a 7m seine net (7m), dip net, and/or angling to help quickly rule out dams with introduced fish (e.g. Gambusia, Redfin and Goldfish).

An increasing focus on food resources in potential refuge sites saw the development of macroinvertebrate surveys as part of the site inspections (mid Stage 3). To better interpret this data, comparative assessments were made at remaining wild sites, or the best proxy, for each of the threatened species under consideration: Southern Purple-spotted Gudgeon habitat in the main channel of the River Murray adjacent to Jury Swamp; Murray Hardyhead habitat at Rocky Gully (post environmental watering); Southern Pygmy Perch pools on the Angas River; and a River Blackfish pool on Rodwell Creek. Yarra Pygmy Perch were excluded due to a lack of remnant habitat.

Macroinvertebrate surveys were a simple assessment of coarse diversity and abundance, being sampled with a standard AusRivAS 250µm mesh dip net through the major habitats present (i.e. edge, open water, reed stems, snags), each sampled intensively for 30 seconds. Contents from the net were emptied into a white tray with most of the litter/debris discarded after shaking well to dislodge macroinvertebrates. Samples were identified and counted on site after 20-30 minutes of sorting, recording all taxa at a broad level (family generally) using a modified 'Water Watch' catalogue (specimens were taken for later identification in some cases).

2.6 Data collation and analysis

A database was developed in Stage 3 to store the large amount of information collected during the project (Appendix 5). This had three fields, one for enquiry and phone survey details, a second to include all field assessment information, and a third field to document actions undertaken, interpretation of results and recommendations which could be searchable for each species.

Each site received scores for different components to determine its broad suitability as a surrogate refuge, based on interpretation of raw environmental data, and in the case of dam overflow, additional scrutiny with GIS mapping (see criteria in Table 1). This system was adaptive as any new information was gathered or site improvements made (e.g. see Section 2.6)

A match or recommendation for potential stocking of a specific threatened species was then made against a summary of biological parameters (Table 2). Biological parameters were based on a summary of local observations of wild habitat and the general literature (Hammer *et al.* 2007).

2.7 Follow up works

For sites that appeared suitable, follow up detailed fish surveys were undertaken or recommended to accurately determine the presence of other fish species. Several dams which were suitable or nearly so were identified as targets for restoration works to improve their function as surrogate refuge and general biodiversity conservation value.

2.8 Workshop

Preliminary results and recommendations of surrogate site assessment to the end of Stage 3 were presented at a workshop involving multi-agency stakeholders involved in the Drought Action Plan on the 1st of October. Feedback was subsequently incorporated into the final report.

Table 1. Scoring system used to rank raw data from field assessments of potential refuge dams.

Criteria/Score	5	3	0	Notes
Location	Isolated dam, no overflow	Isolated dam, minor overflow but not into a waterway	Instream dam or well linked to natural waterway	
Size	Small (100-200m^2)	Medium (200-1000m^2)	Large (>1000m^2)	Large dams may be useful in later stages
Hydrology	Spring fed, little summer draw-down	Only minor summer draw-down	Large water level fluctuation	Some flow is even better (natural or artificial)
Habitat	Dense cover across multiple types: emergent plants, submerged plants, physical	One good habitat component: emergent plants, submerged plants or physical	No underwater cover	There are subtle differences in habitat requirements for different small native species (see Table 2)
Water quality	Low salinity, not turbid, low nutrient input and high oxygen levels	Moderate salinity, turbidity, nutrient input and high oxygen levels	High salinity, turbidity, nutrient input	Salinity may be a positive for Murray Hardyhead refuges
Other fish	No fish present or historically occurring	Some fish previously but removed	Predatory or competitive fish occur	

Table 2. Indicative suitable conditions for consideration in refuge site selection of Lower Murray threatened fishes.

Species	Code	Water quality	Depth	Plants	Physical cover
Southern Purple-spotted Gudgeon	SPSG	Fresh, warmer areas preferred	Likes shallow shelves (warmer water)	Ideally dense beds of *Vallisneria* and reeds	Areas of rocks or snags
Yarra Pygmy Perch	YPP	Cool, well oxygenated	Moderate to deep	Dense submerged and emergent plants	Snags are good, but not essential
Southern Pygmy Perch	SPP	Cool, well oxygenated	Moderate to deep. Ok in shallower wetlands	Dense submerged or emergent plants	Snags are good, but not essential
River Blackfish	RBF	Cool, very well oxygenated	2.0m+	Reed lined edges	Snags and edge leaf litter
Murray Hardyhead	MHH	Slightly to moderately saline	Can be shallow	Needs some submerged plants	Not essential

3.0 Results & recommendations

3.1 Previous surrogate refuge attempts

Southern pygmy perch

In the Lower Murray, southern pygmy perch have undergone a widespread decline and now remain in three small catchments of the EMLR and patchy wetlands fringing Lake Alexandrina. These four populations are all genetically distinct and represent separate management units (Hammer 2001, 2002). The Tookayerta Creek sub-population was the focus of translocation to artificial refuges (~0.3ha farm dams) during the late 1980s. The sub-population, one of only two Lower Murray populations known at the time (Lloyd and Walker 1986), was considered at risk due to the progressive invasion of Gambusia. Between 70 and 110 Southern Pygmy Perch were transferred to farm dams selected based on their small size, permanency, limited consumptive water use, invertebrate populations and habitat components. At one site successful removal of a resident carp population was undertaken prior to stocking and emergent macrophytes were planted in shallow areas to improve cover diversity (Lloyd 1991). The stockings were considered successful initially based on survival of the stocked fish, however recruitment was limited. A follow up assessment in 2001 failed to find any evidence of established populations: one dam was dry and another had little cover (Hammer 2001).

Another translocation of fish from Tookayerta Creek was made to Warrawong Sanctuary which comprises a series of large recirculated dams on a tributary to the Onkaparinga River (SA Gulf Drainage Division). This attempt is poorly documented but likely occurred in the early 1990s and was undertaken by private individuals. It was however, successful with large numbers of Southern Pygmy Perch established in several dams for a sustained period (1995-2005: M Hammer pers. obs). More recently catches have dwindled after the introduction and establishment of Flathead Gudgeon which have reached high densities.

A specific research program initiated in 2000 investigated the distribution and ecology of Southern Pygmy Perch in the SAMDB (Hammer 2001). This research identified drying pools in the Angas River catchment (Middle Creek) containing high numbers of Southern Pygmy Perch (the species is now locally extinct from this location). A refuge dam was located post haste with criteria of being free of predatory fishes, permanency (spring-fed), high levels of cover (in this case dense beds of *Vallisneria* and *Potamogeton crispus*) and being located in the same sub-catchment but isolated from natural waterways. Under PIRSA permit, 111 fish (26/1/01) and a further 25 fish (3/3/01) were collected and transferred to the refuge dam. Fish in the first transfer were quite healthy and active, and 11 of the 111 fish were retained as genetic material. Survivorship from the second transfer later in the year was likely quite low as fish were stressed by poor pool conditions of low water level and warm temperatures: 18 were dead on arrival to the dam. Most of the fish stocked were 0+ (young-of-year) fish, with a few larger adults. The first follow-up monitoring in 2001 revealed positive signs of recruitment and high numbers of 0+ fish (25-35mm). Subsequent visits have, however been less successful with low numbers captured with increased effort: 1, 0 and 5 in autumn 2003, 2004 and 2005 respectively with little sign of recent recruitment (Hammer 2005). The same climatic influences impacting the wild population have influenced the water level in the dam. In autumn 2007 a better indication of long-term establishment was noted. Although still in relatively low numbers, recruitment had occurred in spring 2005 and 2006 which were slightly wetter years (Hammer unpublished data). The dam has been the target of ongoing restoration efforts of a local catchment group and like-minded landholder (fencing and revegetation) with the benefits of this habitat improvement beginning to show with increasing levels of emergent vegetation and shade.

Murray Bridge Army Range

The Murray Bridge Department of Defence training area (firing range) is located 5km east of the River Murray within Mallee habitat. The Army Range contains a wetland complex which receives wastewater from the Murray Bridge Treatment Plant with a basic configuration of two large rectangular dams (~1.0ha) which are deep and have narrow margins lined with *Typha*. The wetland was the site of translocation for two species that at the time were presumed locally extinct in the SA MDB – the Southern Purple-spotted Gudgeon and Agassiz's glassfish (*Ambassis agassizii*). A media article relating to the effort indicates that fish were introduced into the wetland in 1997 from unspecified remnant populations in the upper MDB in Queensland (*The Advertiser, 22/2/1999*). The same article suggests that monitoring in 1999 provided indication of the initial success of the translocations. A 2008 assessment indicated low population levels but continued survival of the Southern Purple-spotted Gudgeon, no Agassiz's Glassfish, and the establishment of Gambusia (Hammer 2008b). SA Water is currently looking to divert a large proportion of current flow to the Army Range away from other uses and a reconfiguration of the wetland is intended. There are also implications for the Queensland source of Southern Purple-spotted Gudgeon considering the recent re-discovery of a genetically distinct wild population in SA (Hammer 2008c).

River Blackfish

This species was also introduced to Warrawong Sanctuary by private individuals in the late 1980s, comprising fish from two separate locations – the Angas River (Dawson Creek) and Mosquito Creek South East. These represent two major genetic lineages (Hammer 2008c) which thus compromises the value of the refuge. Survival was assessed as positive in the late 1990s, but only large fish were ever found, and numbers seemed to dwindle in the early 2000s (M Hammer pers. obs).

River Blackfish were rediscovered in the Angas Catchment after a ~30 year absence in an instream dam on a small tributary, Dawson Creek (Lloyd 1987). They have since become locally extinct from this site (Hammer 2004). Following the initial rediscovery in the early 1980s, Lance Lloyd undertook some captive breeding trials at Adelaide University. Some juvenile fish were eventually produced and stocked into a farm dam – the success of the stocking remains to be determined.

Yarra Pygmy Perch

As part of urgent conservation measures 20 wild fish were transferred to a dam at Pembroke School in December 2007 adjacent to a known Yarra Pygmy Perch site (Hammer 2008a). While initially suitable, the same issue affecting the wild population in Lake Alexandrina (water shortage) eventually led to the drying of the dam and failure for this attempted refuge population.

Summary

While limited in replication, resources and strategic effort, the previous attempts to establish refuge populations indicate some general patterns. Firstly, dams need to be selected carefully for suitable conditions and modification may be required. The value of refuge locations appears to be best suited to short-term utility (< 5 year) as there was little indication of the successful maintenance of populations for longer time periods, especially without ongoing monitoring and intervention.

3.2 Current captive fish availability

A summary of threatened fish species and major conservation units in the Lower Murray which are the focus of the Drought Action Plan are shown in Table 3. The status of the different conservation units is also indicated with a matching capacity for reactive (High risk) and proactive (Medium and Lower risk) surrogate refuge actions (stocking) also shown. See Appendix 6 for detailed information pertaining to fish rescued from the wild and currently held in captive facilities and offspring from captive breeding programs.

Structured captive breeding programs (i.e. dedicated facilities with capacity to produce moderate-large numbers of first generation juveniles) exist for Southern Purple-spotted Gudgeon and Murray Hardyhead, more ad hoc or small-scale programs for Yarra Pygmy Perch and River Blackfish, and there is limited capacity for spawning of Southern Pygmy Perch. In terms of different at risk SA MDB conservation units represented, the single conservation unit of both Southern Purple-spotted Gudgeon (Lower Murray) and Yarra Pygmy Perch (Lower Lakes) is maintained, the two Murray Hardyhead conservation units (Lower Lakes and Riverland) are maintained, but only two of five Southern Pygmy Perch (Angas and Lower Lakes) and one of four River Blackfish (Rodwell Creek) are maintained. A few populations have sufficient fish remaining in the wild for attempts at proactive stockings.

Table 3. Details of the threatened species and conservation units that are the focus of the Drought Action Plan, with information on status and capacity for refuge stocking. Species codes as per Table 2.

Species	Cons Unit	Extinction risk	Captive wild fish	Current capacity for refuge stocking
SPSG	Lower Murray	High	55	Yes - dedicated hatcheries ready to produce
YPP	L. Alexandrina	High	100	Yes - ponds producing juveniles
RBF	Rodwell	High	8	No - few wild fish, breeding trial under way
	Marne	High	-	No - few wild fish, no captive breeding
	Angas	Medium	-	Yes - proactive stocking of wild fish
	Tookayerta	Low	-	Yes - proactive stocking of wild fish
SPP	Angas	Medium	50	Yes - proactive stocking of wild fish
	Finniss	High	-	No - few wild fish and no captive breeding
	Inman	Medium	-	Yes - proactive stocking of wild fish
	L. Alexandrina	High	40	No - few wild fish and no captive breeding
	Tookayerta	Low	-	Yes - proactive stocking of wild fish
MHH	Lower Lakes	High	90	Yes - some wild fish for stocking and captive breeding underway
	Riverland	High	100	Yes - some wild fish for stocking and captive breeding underway

3.4 Summary of surrogate refuge data

During 2008 and 2009 some 80 enquiries were received, logged in the database and acted against with at least a phone survey. Some enquiries resulted in multiple site assessments (i.e. one or more dams on a property), with a total of 74 site assessments undertaken. Some follow up activities included specific fish surveys, temporal inspection (i.e. in wetter periods) and advice on refuge improvements. A copy of the searchable database is held by DEH and Aquasave but contains sensitive landholder information making it not suitable for wider public release.

The distribution of field assessment sites is shown in Figure 1, the suitability of sites is summarised in Appendix 7 and discussed in subsequent sections.

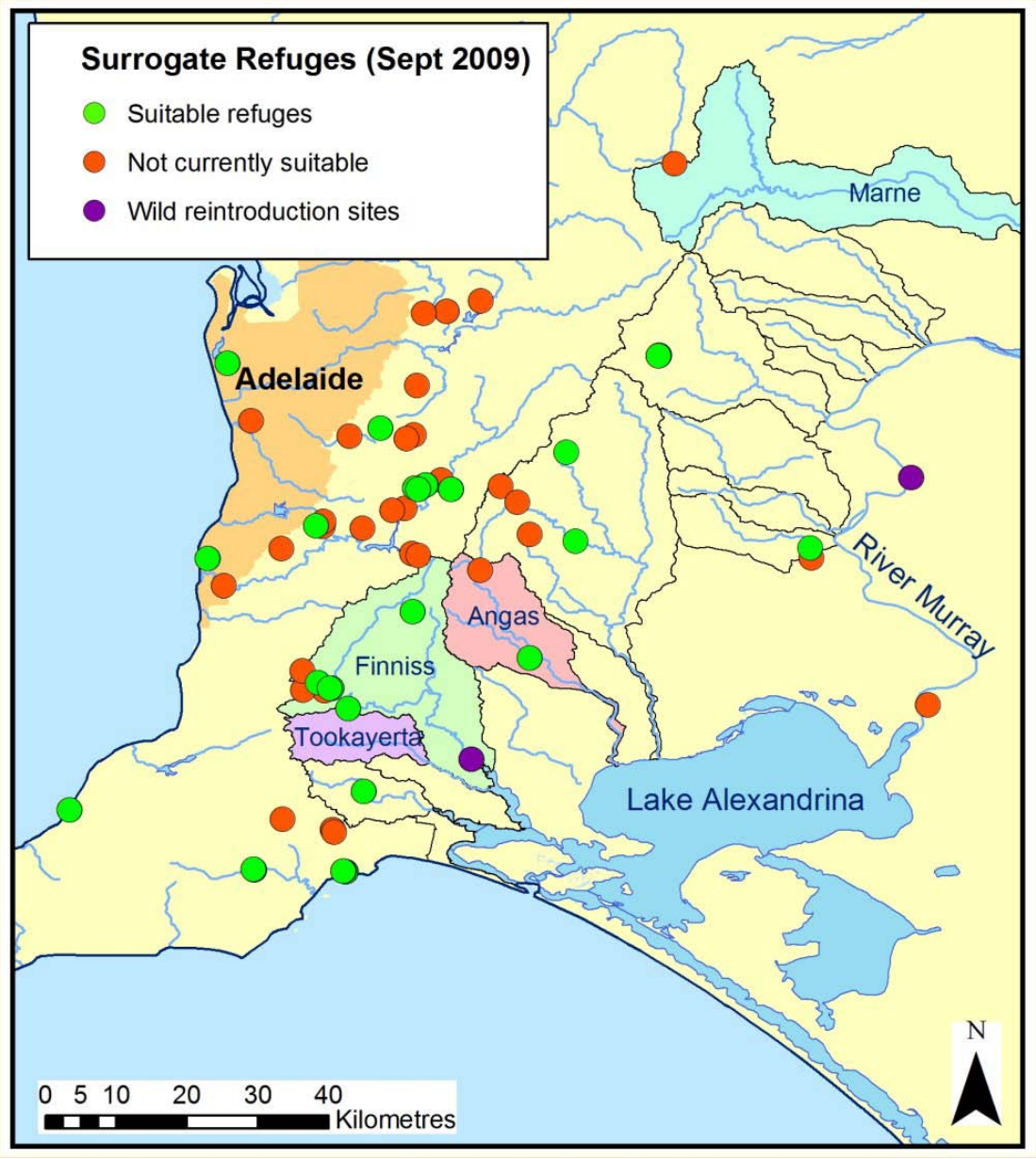


Figure 1. Location of field assessment sites for surrogate refuges including sites currently considered suitable for one or more of the target species. The Eastern Mount Lofty Ranges catchments are marked with black outline and those with wild populations mentioned in the text shaded.

3.5 Food resources

The qualitative macroinvertebrate assessment aimed to identify the general food availability for fish in surrogate refuge sites as a measure of site suitability and targets for site improvement. Data from wild sites for four of the five target species is shown in Appendix 8 (Yarra Pygmy Perch are excluded). This data is reinforced by diet data from the literature (Table 4): specific diet studies of three of the five species have received some attention in the Lower Murray, namely River Blackfish, Southern Pygmy Perch and Murray Hardyhead (Lloyd 1987) with other supporting information available (Sanger 1978; Curmi 1996; Ellis 2006). Basic assessment was undertaken for Lower Murray Southern Purple-spotted Gudgeon prior to wetland drying supported by information for other regions (Pusey *et al.* 2004); and Yarra Pygmy Perch information needs to be extrapolated from studies in Victoria (Sanger 1978) and studies targeting similar species (Pen and Potter 1991).

In summary, diet is variable across the different species and hence ideal food resources in refuge sites will vary. Some form of food for larval fish (i.e. good levels of zooplankton) and a diversity and abundance of macroinvertebrate prey items will likely offer the best chances of successful stocking. The River Blackfish site in particular showed a high diversity in macroinvertebrate prey items and high abundance of freshwater shrimp which suggest refuge sites should have similar characteristics. Southern Purple-spotted Gudgeon appear to need higher abundance of larger prey items, and the pygmy perches and Murray Hardyhead require smaller food items varying from zooplankton to insect larvae colonising underwater surfaces (benthos or aquatic plants).

Targeted macroinvertebrate surveys were undertaken at 36 refuge sites (mainly sites assessed in Stage 3 but some revisitation of earlier sites) and helped to inform site recommendations (next sections).

Table 4. Indicative diet of the five target species.

Species	Mode	Diet	Source
SPSG	Microphagic carnivore (benthic)	Crustaceans, small fish, larval may flies, beetles, terrestrial items & tadpoles	Hammer (2007), Pusey *et al.* (2004)
YPP	Microphagic carnivore (nektonic)	Diptera, mobile insect larvae, Ostracods, Copepods	Sanger 1978; Pen & Potter (1991)
SPP	Microphagic carnivore (benthic)	Beetles and chironomid larvae, amphipods	Lloyd (1987); Sanger (1978)
RBF	Macrophagic carnivore (benthic)	Aquatic insects, crustaceans and small fish	Lloyd (1987); Curmi (1996)
MHH	Omnivore (nektonic)	Zooplankton, insect larvae, detritus and algae	Lloyd (1987); Ellis (2006)

3.6 Trial sites (fish released)

Stage 1 & 2 identified two outstanding candidate refuge dams, which matched the requirements for Yarra Pygmy Perch; namely Refuge 5 (Crouch) and Refuge 28 (Oster) (Appendix 6 & 7). The dams were subsequently the site of release for captive bred juvenile Yarra Pygmy Perch. A total of 70 juvenile Yarra Pygmy Perch (20-35mm) were released at Oster Dam (50 fish in November 2008 and a further 20 in December 2008) and 90 into Crouch Dam (20 fish in December 2008 and a further 70 in April 2009). Field assessment using fyke nets in October 2009 (~1 year after fish release) indicated good to very good survivorship and fast growth of the Yarra Pygmy Perch (Figure 2), with fish about to spawn.

Two priority sites identified in Stage 1 of the project – Oster (top) and Crouch which have subsequently been stocked with Yarra Pygmy Perch (Photos A. Hall).

A large female Yarra Pygmy Perch recaptured from Crouch dam in spring 2009

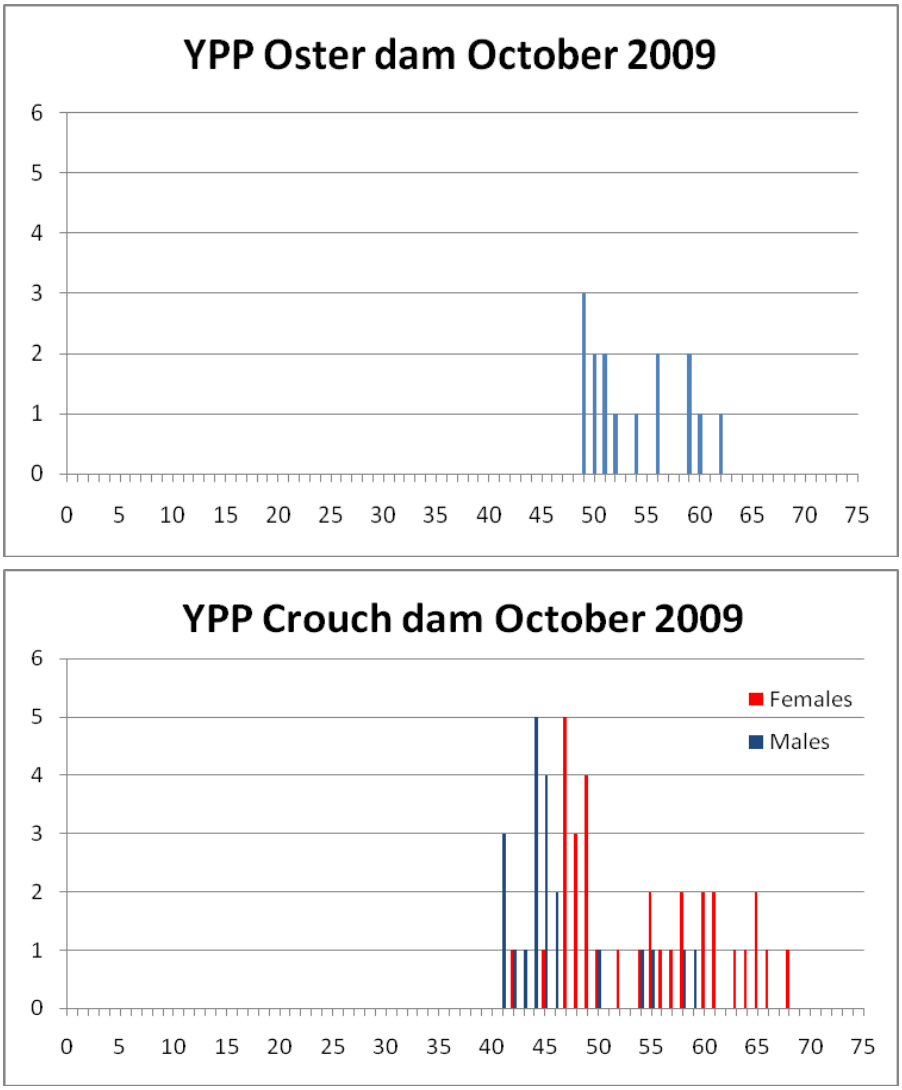


Figure 2. Length frequency data for Yarra Pygmy Perch captured (surviving) at the two trial release sites (n = 15 and 54 respectively)

3.7 Recommended release sites (ready immediately)

A further 20 high priority sites have been identified as ready stocking sites, in some cases pending final targeted fish surveys (Appendix 6). This includes a range of different types of refuges including smaller ponds, artificial wetlands and farm dams. The site conditions match a mix of species but favour Southern Purple-spotted Gudgeon, Yarra Pygmy Perch and Southern Pygmy perch (few suitable River Blackfish or Murray Hardyhead refuges were located). A brief summary of key sites is provided.

Beyond Wetlands

This site is a recently developed but established stormwater wetland in an isolated sub-catchment (housing development) just outside the MDB near Victor Harbour. It has all the basic habitat elements (rock, emergent and submerged aquatic vegetation), and vegetation is continually improving. There are three separate cells with different habitat characteristics, with low to moderate salinity 2000-5000µS. This wetland supports a moderately diverse macroinvertebrate assemblage, with very high densities of Ostracods and *Daphnia* in all three pools as well as a reasonable abundance of larger prey items such as damselfly larvae (particularly in the top pool). This wetland site could be improved with addition of local *Paratya* to increase the weighting of larger prey items and perhaps addition of pipes, snags and other habitat elements to increase habitat heterogeneity. Control of access and fishing may be required to help any released fish. Overall it is a ready stocking option for Southern Purple-spotted Gudgeon, Yarra Pygmy Perch, Southern Pygmy Perch and Murray Hardyhead.

Beyond Development wetlands.

Tupelogrove Nursery

The site is a well established series of isolated dams in the Onkaparinga Catchment near Longwood. The dams have dense aquatic vegetation being ideal for pygmy perch species. Macroinvertebrate sampling identified abundant zooplankton, and smaller macroinvertebrates including amphipods (overall a relatively low diversity). Larger food items would make the site suitable for River Blackfish (i.e. addition of freshwater shrimp).

Two heavily vegetated dams at Tupelogrove Nursery.

Grange Golf Club

One of a series of urban stormwater recovery wetlands is located at Grange Golf Course. It contains a series of three cells the first a primary treatment cell, then two subsequent cells with dense emergent and some aquatic vegetation. The site had low salinity and good water quality at the time of sampling (autumn 2009). It also supported a strong zooplankton community with moderate macroinvertebrate diversity and abundance (but again no larger prey items like freshwater shrimp). With the addition of some physical cover such as rock and snags and some larger prey items the site seems ideal for either of the pygmy perches and Southern Purple-spotted Gudgeon.

Cell 2 of the stormwater treatment wetland at Grange Golf Club.

Newham, Strathalbyn

This site comprises a large backyard pond in Strathalbyn which has been groomed as a backup site for local Angas River Southern Pygmy Perch. It has ideal dense aquatic vegetation and reasonable macroinvertebrate resources (freshwater shrimp have recently been added). The pond has filtration and is supplied by rainwater. Water cartage may be required to keep the pond topped up in very dry summers, but this could easily achieved. Suitable wild fish are currently in a holding pond and thus available for immediate stocking to the pond. Fish conditioned can be monitored and supplementary feed added if needed.

Newham Pond, Strathalbyn.

Robertson, Back Valley

This site contains two small dams adjacent to the wild Inman Catchment Southern Pygmy Perch population. Only preliminary assessments have been made, but the water permanency, habitat complexity and water quality seem suitable, with the location ideal as a nearby surrogate refuge for the aforementioned population.

One of the dams on Robertson Property, Back Valley.

Swinburne, Wistow

This potential refuge is a series of isolated ponds, previously used to house goldfish but which have been offered for native fish conservation. Following initial enquiry and inspection the ponds have been sterilised and fitted with additional rock and snag cover and aquatic plants added making them a suitable location for Southern Purple-spotted Gudgeon. Macroinvertebrate sampling in November 2009 indicated that additional food resources should also be added prior to use of these ponds as surrogate homes.

The series of ponds at Wistow.

Murray Bridge stormwater wetland

A stormwater wetland on Greenlands Drive, Murray Bridge has several positive aspects for stocking captive bred Southern Purple-spotted Gudgeon. Firstly it is under supportive management by the Murray Bridge Council (who have undertaken initial site works including adding rock and vegetation) and is in a secure (fenced) site. Water permanency appears secure even through the recent dry period and is fresh (EC 300-500µS), but quite turbid after rain (overall similar to the wild habitat). The site has only recently been augmented; however *Vallisneria* and *Potamogeton ochreatus* is already becoming established. Successful establishment of stocked Flathead Gudgeon and Carp Gudgeon suggest the general suitability of the site for fish (no exotic fish are present), and these fish form a base food resource. The site could be enhanced by the addition of simple rock piles, further establishment of submerged aquatic vegetation and addition of shrimp from the Murray (food resource).

Murray Bridge Stormwater Wetland (Vallisneria circled).

Leigh, Dawesley

This is a small, spring fed and heavily vegetated dam near Dawesley, unlikely to overflow into natural waterways due to the Brukunga Mine arrangements. The dam is fenced and managed for conservation. It has abundant Carp Gudgeon (stocked) and some shrimp, with a reasonable abundance of macroinvertebrates. There are a few larger catfish which the owner would like to remove to aid establishment of stocked fish, and areas of rock could be added. The dam was moderately saline in autumn (EC 4700µS), but overall stocking should be trialled with Southern Purple-spotted Gudgeon juveniles.

The small spring fed dam, near Dawsley.

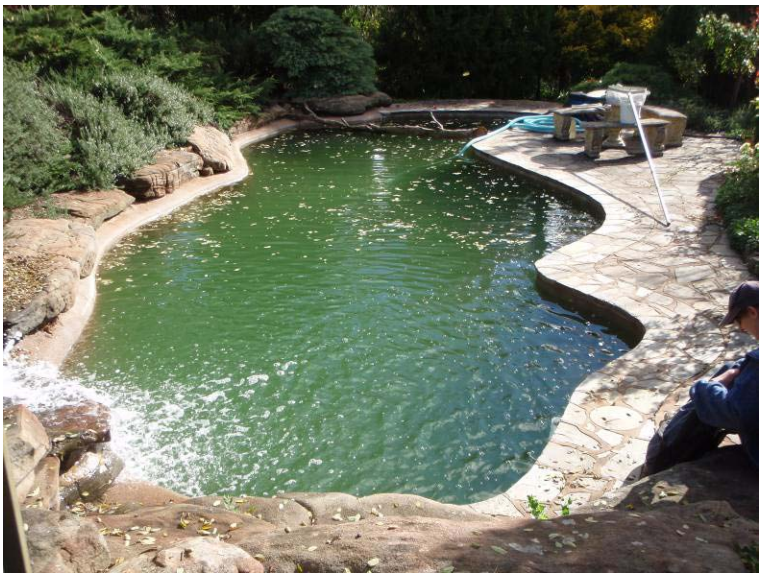
Munday Dam

This site is in upper Reedy Creek, and the dam and indeed the sub-catchment have no fish present. This dam is spring fed and has thick aquatic plants (including *Vallisneria* and filamentous algae) and abundant food resources. The site was noteworthy in June 2009 for its extremely high Ostracod density as well as the presence of *Daphnia* and some larger prey items including freshwater shrimp. Again, this water was slightly saline (EC 4500µS) and the site could be improved by the addition of sections of rock extending from reed edge cover and screening overflow. However, it is basically ready for stocking Southern Purple-spotted Gudgeon and Murray Hardyhead.

The Munday Dam as viewed from the small jetty.

3.8 Recommended further information or restoration (potential release sites)

Eight sites had characteristics that might make them suitable refuges with small levels of management input or further assessment (Appendix 7). Some of these improvements include fencing, revegetation, establishing emergent or fringing vegetation such as Clubrush or adding physical cover. A good example is a pool offered for conversion to a native fish refuge - Refuge 64 (Love).



Love swimming pool, before conversion to native fish refuge.

3.9 General biodiversity & awareness sites

Several sites were ideal habitats for native fish but failed in one or more key assessment criteria, primarily high connectivity with a natural waterway outside the range of the target threatened species/conservation units, or the presence of introduced fish. In these cases they are probably best viewed as sites that can be generally used to improve local biodiversity (especially good dams which overflow) by adding native species and/or programs to remove the exotic fish. It is recommended that follow up improvements or further assessment of these sites be undertaken to help create a general awareness of native fish conservation and requirements in the community. Appendix 7 includes the top dozen sites in this category, but any dam may be suitable if there is community interest.

Example of a site to improve biodiversity value and native fish awareness – Refuge 10 (Durnin) is otherwise ideal but overflows directly to the Onkaparinga River.

3.10 Wild reintroduction sites

A concurrent reintroduction plan for Lower Murray Southern Purple-spotted Gudgeon, identified two key wild reintroduction sites that are also stored in the database and that have clear alignment with the process of this project (and wild sites should be a priority where they are reliable).

Lower Finniss River

Accounts from the 1920s of the habitat and fishes of the lower Finniss River paint the area as an aquatic paradise. Southern Purple-spotted Gudgeon were targeted from slow flowing pools with dense submerged aquatic vegetation, where they would often sun-bath amongst the floating leaves of *Vallisneria*; pygmy perch were also abundant (Nettlebeck 1926; Blewett 1929; Rutherford 1991). This site is ideal for restoration for several reasons. Primarily it has a more reliable water supply than other Lower Murray sites including summer flowing springs. The basic habitat elements described in the 1920s also still exist – heterogeneous combination of small and large pools within Redgum lined braided channels, shaded by Teatree (now *Callistemon*) and lined by reeds and rushes. The latter has been heavily degraded by stock, but there is strong landholder commitment to local restoration, and initial contact made about completing a fenced stream corridor. Stable habitat components are still reasonable including rocky cobble, reeds and tree roots, with small remnants of former extensive submerged aquatic plants present, including the *Vallisneria*, regionally rare *Ottelia* and *Cerataphyllum*. Perhaps the most significant change is the fish community, namely the current presence of Redfin, Gambusia and Carp in different pool types. Macroinvertebrate food resources at the site were reasonably diverse and abundant.

There are clearly preparation measures to be undertaken, but the assessment suggests that re-introduction of Southern Purple-spotted Gudgeon and Yarra Pygmy Perch (also ideal for a Southern Bell Frog project).

A representative pool within the Lower Finniss braided channel habitat.

Piawalla Wetland

This managed wetland is effectively the only wetland along the ~200km of River Murray below Lock 1 through Wellington, receiving and holding environmental water to varying degrees since January 2007. Its importance as a wild refuge for fauna and flora is very high, and securing water in the wetland through future watering is a key issue for regional conservation. Edge habitat is reasonable, with some aquatic vegetation (algae, *Myriophyllum* sp and *Crassula helmsii*). The wetland is well managed and has diverse macroinvertebrates and no introduced fish (just a few gudgeons). Piawalla is only 2km upstream of the wild Southern Purple-spotted Gudgeon site at Jury Swamp and slightly further from the Rocky Gully and Riverglades Murray Hardyhead habitat (some Murray Hardyhead were also known from Jury Swamp).

At the site inspection in June 2009 it seemed ideal for reintroduction of Murray Hardyhead and juvenile Southern Purple-spotted Gudgeon (due in part to a high abundance of zooplankton). The key issue relates to future water security, as last year due to a lack of water supply, the wetland contracted significantly and became quite saline. Other improvements could be made including addition of edge rock sections and snags. Overall reintroducing threatened native fishes such as Southern Purple-spotted Gudgeon and Murray Hardyhead should be incorporated into planning, management and restoration of the wetland.

Piawalla wetland, June 2009.

4.0 Discussion

This project has generated a large body of data on potential refuge sites to spread risk for populations and species threatened with extinction due to critical environmental conditions in the Lower Murray region. Key site based recommendations are made (with more detailed supporting information provided in an accompanying database) for sites currently suitable or potentially suitable as refuges for one or more of five target species.

No refuge site is likely to be an ideal match or replacement for wild habitat, and certainly only a handful of dams met the broad criteria for serious consideration for each species. Some degree of trial and error will be required in combination with ongoing monitoring to adaptively improve the criteria and overall process. However, two trials have so far shown that positive outcomes can be achieved and justify further attempted releases.

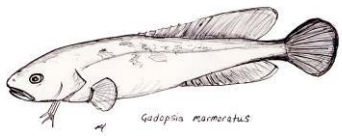
The generally low number of wild fish available and the reactive nature of fish rescues and captive breeding programs in place, means the best approach to creating refuges will in most cases be through the release of fish from short-medium term captive breeding programs. Established refuges will then form ideal stepping stones for reintroductions to wild sites once suitable habitats return driven in part by a range of other environmental actions and programs. Stockings of refuges should follow basic theory to minimise stress and maximize survival using techniques such as behavioral training, acclimation and soft release (see Brown and Day 2002).

The first concern for rescue and urgent conservation measures is the survival of conservation unit or species, but close attention should be made to the preservation of genetic diversity (Nevo *et al.* 1984), with protocols and assessment to best manage diversity and fitness of captive and refuge populations a strong priority for future research projects. Risk assessment for receiving environments (e.g. competition and disease for existing biota) should also be undertaken as part of preparations for stocking chosen sites (this forms part of the DEH translocation policy), and permit application needs to be made with PIRSA Fisheries Biosecurity Unit.

A clear message from previous attempts at creating refuges is that they can be unreliable in the long-term, difficult to establish, and that they will never replace wild habitat and evolutionary processes. Close attention of management regimes, environmental conditions and fish population trends should be made, with at least annual fish monitoring and regular communication with land holders or managers (fish monitoring could be community based after initial training). Finally, the media and community engagement in the project affords clear broader benefits to raising awareness of local threatened fishes, habitats and the overall plight of the River Murray, and ongoing follow up will thus have a double benefit.

5.0 Acknowledgments

The identification and assessment of surrogate refuge dams has been a long and involved process, with significant input from many people. Early drivers included Mark Siebentritt and Sue Keith (Healthy Rivers Australia) and Arkellah Hall and Russell Seaman (DEH). Field assessments were undertaken by Arkellah Hall, Warwick Nobble, Dylan Sortino, Leanne Piller and Tom Barnes, Jane Holland, Phillipa Wilson and Matt Pellizzare. Several sites were assessed in conjunction with a Murray-Darling Basin Authority funded project for Southern Purple-spotted Gudgeon. But most importantly the huge contribution of landholders and land managers to make their sites available, accessible and in some cases more suitable has been invaluable and provides a more positive future for currently critically threatened species and populations.



6.0 References

Blewett, C. F. (1929). Habits of some Australian freshwater fishes. *South Australian Naturalist* **10**, 21-29.

Brown, C., and Day, R. L. (2002). The future of stock enhancements: lessons for hatchery practice from conservation biology. *Fish and Fisheries* **3**, 79-94.

Curmi, T. J. (1996) Habitat use and diet of river blackfish (*Gadopsis marmoratus*) and two spined blackfish (*Gadopsis bispinosus*) in Tallangatta Creek. BSc (Honours) thesis, La Trobe University.

Ellis, I. (2006). Age structure and dietary analysis of the Murray hardyhead *Craterocephalus fluviatilis* (McCulloch), Family Atherinidae, in two lakes near Mildura, Victoria. Murray-Darling Freshwater Research Centre, Mildura. p. 44.

Hall, A., Higham, J., Hammer, M., Bice, C., and 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. (2001) Molecular systematics and conservation biology of the southern pygmy perch *Nannoperca australis* (Günther, 1861) (Teleostei: Percichthyidae) in south-eastern Australia. B. Sc. (Honours) thesis, Adelaide University.

Hammer, M. (2002). Recovery outline for the southern pygmy perch in the Mount Lofty Ranges, South Australia. Department of Environmental Biology, University of Adelaide and Native Fish Australia (SA) Inc., Adelaide. p. 32.

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. p. 104.

Hammer, M. (2005). Recovery monitoring for the southern pygmy perch in the Mount Lofty Ranges South Australia, 2001-2005 review: confidential technical document. Native Fish Australia (SA) Inc., Adelaide. p. 53.

Hammer, M. (2007a). Status report on South Australian threatened freshwater fish populations during 2007 drought conditions. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 20.

Hammer, M. (2007b). Report on urgent conservation measures and monitoring of southern purple-spotted gudgeon on the River Murray, South Australia. Report to the South Australian Murray-Darling Basin Natural Resources Management Board. Aquasave Consultants, Adelaide. p. 15.

Hammer, M. (2008a). Status review of wild and captive Yarra pygmy perch in the Murray-Darling Basin. Report to Department for Environment and Heritage, South Australian Government. Aquasave Consultants, Adelaide. p. 27.

Hammer, M. (2008b). Aquatic survey of the Murray Bridge Army Range wetlands, South Australia. Aquasave Consultants, Adelaide. p. 12.

Hammer, M. (2008c) A molecular genetic appraisal of biodiversity and conservation units in freshwater fishes from southern Australia. PhD thesis, University of Adelaide.

Hammer, M., Wedderburn, S., and van Weenan, J. (2007). Draft Action Plan for South Australian freshwater fishes (www.environmentsa.sa.gov.au). Native Fish Australia (SA), Adelaide. p. 170.

Lloyd, L. N. (1987) Ecology and distribution of the small native fish of the lower River Murray, South Australia and their interactions with the exotic mosquitofish, *Gambusia affinis holbrooki*. M. Sc. thesis, University of Adelaide.

Lloyd, L. N. (1991). The establishment of refugial populations of pigmy perch (*Nannoperca australis*): a native fish at risk. Department of Conservation and Environment, Shepparton. p. 12.

Lloyd, L. N., and 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* **100**, 49-57.

Nettlebeck, N. (1926). Fishes of the Finniss River. *South Australian Naturalist* **7**, 64-65.

Nevo, E., Beiles, A., and Ben-Shlomo, R. (1984). The evolutionary significance of genetic diversity: ecological, demographic and life history correlates. In 'Lecture Notes in Biomathematics No 53. Evolutionary Dynamics of Genetic Diversity'. (Ed. G. S. Mani.) pp. 13-213. (Springer Verlag: Berlin.)

Pen, L. J., and Potter, I. C. (1991). Biology of the western pygmy perch, *Edelia vittata*, and comparison with two other teleost species endemic to south-western Australia. *Environmental Biology of Fishes* **31**, 365-380.

Pusey, B., Kennard, M., and Arthington, A. (2004). 'Freshwater Fishes of North-Eastern Queensland.' (CSIRO Publishing: Collingwood, Vic.)

Rutherford, B. A. (1991). 'The South Australian Aquarium Society. 1918-1932, The First Fifteen years. An Official History.' (Brian A. Rutherford: Modbury Heights, South Australia.)

Sanger, A. C. (1978) Aspects of the ecology and evolution of the pigmy perches (Teleostei: Kuhlidae). B. Sc. (Honours) thesis, University of Melbourne.

7.0 Appendices

Appendix 1. Media from Stage 1 of the project

Adelaide Advertiser, 22nd December 2007 pg 19

Help save this species

FIGHT FOR SURVIVAL: The purple-spotted gudgeon is at risk of being wiped out.

CARA JENKIN
REGIONAL REPORTER

FARMERS are being recruited to save two fish species in danger of becoming extinct because of the drought.

Fifty southern purple-spotted gudgeons have been taken from the lower reaches of the River Murray and its backwaters and are being stored by scientists in fish tanks to prevent them dying.

Three wetland refuges for the Murray hardyhead are also drying out fast, leaving it at risk of being wiped out unless water levels can be restored.

The scientists, from the Waterfind Environment Fund, need farmers to volunteer to house the gudgeons in dams.

They also need donations of stock or domestic water to top up water levels in wetlands.

Fund chief executive Dr Mark Siebentritt said the emergency plan was the last chance to save the species before water levels fell further during summer.

He said the last remaining wetland refuge for the gudgeon in the Lower Murray had already dried out.

"These populations are unlikely to survive this summer without urgent action," he said.

"In the past, species could bounce back from drought because of the large number of wetland refuges but the wetlands are all disappearing and the picture is bleak.

"We are pulling out all stops and thinking outside the square." The southern purple-spotted gudgeon was believed to have become extinct in 1973 until the small population was found in 2002. Less than 100 fish are believed to be alive.

"Once we have successful breeding we can reintroduce these fish to the wild when the flows return, that's the ultimate aim," Dr Siebentritt said.

Dams need to be fed by springs to ensure they do not dry out during summer and must not have any other fish species living in them.

Farmers can also donate water from stock and domestic supplies to keep the Murray hardyhead alive in the wetlands.

Dr Siebentritt said only small volumes of water were needed to keep the species alive.

A Native Fish Recovery Fund is also being established to raise $150,000 to fund a specialist breeding and return-to-the-wild program.

Donations to the fund or farmer registrations can be made by calling 8211 6017 or visiting www.waterfind.org.au

Appendix 2. Media from Stage 2/3 of the project

MEDIA MONITORS

Adelaide Advertiser
02/12/2008
Page: 13
General News
Region: Adelaide
Circulation: 185633
Type: Capital City Daily
Size: 526.73 sq.cms
MTWTFS-

SPECIES RECOVERY: Environment and Heritage Department wetlands officer Ariellah Hall yesterday with endangered Yarra pygmy perch, which will be released into a private Hope Valley dam.

CARA JENKIN
ENVIRONMENT REPORTER

TINY River Murray fish rescued from the Lower Lakes are breeding so well, a population has been released into the wild.

Fifty Yarra pygmy perch were yesterday released into a dam on private property at Hope Forest, near Mt Compass, by Environment and Heritage department scientists.

The dam is more than 30km away from the species' native home in the Lower Lakes but its environmental condition is similar to that of the Lakes.

The plight of the threatened fish, which inhabit the Hindmarsh Island area near Clayton, was first identified by University of Adelaide PhD student Michael Hammer. He found the fish species was under threat of extinction from falling water levels in the Lower Lakes as a result of the drought.

He scooped up 120 Yarra pygmy perch in June, 2007, and kept them in fish tanks until the breeding program could begin.

Southern purple spotted gudgeons, another threatened fish species from the region, are also being kept in captivity and bred to protect the species from extinction. Environment department senior wetland officer Russell Seaman said yesterday's release was the first time the fish had been put into a natural environment. Several other privately owned dams had been identified as possible new homes for the fish.

"This program is a fantastic way of ensuring the survival of some of our most endangered fish species which are at risk of extinction in the wild," he said.

"It is indicative of the program's success so far that we have been able to breed enough fish in preparation for release into surrogate dams.

"Ultimately, we plan to reintroduce these fish to their natural habitat once critical drought conditions pass and river flow returns to the Murray River and Lower Lakes."

Yarra pygmy perch are now being bred and are on display at Cleland Wildlife Park.

The breeding program is being supported by Waterfind Environmental Fund and Native Fish Australia.

FISH FACTS

Yarra pygmy perch

Grow to 7.5cm long and are a gold to dusky brown-grey colour. They feed on microcrustaceans, molluscs and aquatic insects and need aquatic vegetation to live in and protect them from predators.

Southern purple spotted gudgeon

Grow to 7cm-12cm long and are dark to yellowish brown with two dorsal fins. They are sensitive to fluctuating water levels and they eat other fish.

Southern purple spotted gudgeon

Ref: 44422025

MEDIA MONITORS

Mount Barker Courier
25/03/2009
Page: 17
Section: General News
Region: Mount Barker SA Circulation: 13074
Type: Regional
Size: 128.00 sq.cms
Frequency: –W––

By **Lisa Symonds**

Hills farm dams may provide the last chance to save some of the region's native endangered fish species from extinction.

Ongoing drought has dried up creeks and water holes and devastated the Lower Lakes, dramatically cutting the available habitat for the fish.

Now environmentalists are pinning their hopes for the species' survival on private farm dams and are desperately hunting for sites that best mimic the fish's natural environment.

Arkellah Hall, a wetlands project officer with the State's Department for Environment and Heritage, said it was critical new homes were found for fish that had been rescued from their drying environment.

"At this point in time it's crucial," she said.

Two dams have already been found outside the region and are now home to Yarra pygmy perch that were bred in captivity from fish taken from the ailing Lower Lakes. But more homes are needed for the Yarra pygmy perch, as well as other species including the southern pygmy perch, river blackfish, southern purple spotted gudgeon and Murray hardyhead.

Populations of the species are being held in captivity and scientists are successfully carrying out breeding programs, but are running out of space to house the offspring.

Die out

Native Fish Australia SA representative Michael Hammer said the region stood to lose a "key part of local biodiversity" if the fish were allowed to die out in the area.

Only one population of river blackfish is left in the region and that is surviving in a managed refuge pond on private land in Rodwell Creek near Wistow that is topped up by water trucked in to keep the fish alive.

"They used to be all through Mt Barker Creek, up through to Dawesley and a few other spots in the area, but now they are down to just one pool," Dr Hammer said.

"We need to find other homes such as dams to use as a back up for them and to house fish as they breed, and so we can improve their native habitat over time."

The river blackfish and pygmy perch need permanent, spring-fed dams with reeds and logs.

The purple spotted gudgeons prefer warmer dams, suiting sites east of Mt Barker where the temperature is slightly higher.

Dr Hammer said at least five sites were needed now and called on property owners to consider offering their dams as fish refuges.

The dams must have a permanent water source, such as being spring fed, aquatic vegetation in and around the dam, good water quality, a low chance of overflow, no other fish living in the dam and no access by stock.

For more information email Arkellah Hall at hall.arkellah@saugov.sa.gov.au.

Appendix 3. DEH Surrogate Refuge phone survey questions (condensed formatting)

DATE:

Summary:

Follow up: Yes / No / Maybe

Contact details:

1) Name & address of the landholder
2) Contact info.
3) Best contact times/avail. Times?
4) Location of the dam/pond?

Surrogate Home;

5) Type of water body (eg dam/ pond/tank)
6) Name of catchments
7) Dam location (GPS) or if not good location description
8) General Dam description (e.g. swampy spring fed dam in wet gully) & info on Rainfall, topography, soil type? (quick notes as these can be done later with GIS)
9) Is there easy access to the site?

Dynamics & Hydrology;

10) Overflow- is there usually overflow during winter?
11) Input- where may water enter the dam?
12) Size- what approx. size is the dam?
13) What is the water source for the dam (spring, catchments, pumping)
14) Does the water level fluctuate much through the year?
15) Any known leakages in the dam?
16) Additional usages of the dam, does it get pumped for stock or domestic purposes?

Habitat;

17) Are there plants around the dam such as reeds and/or rushes? Do these have submerged stems? What types (if known)?
18) Are there plants present in the water itself? (such as pond weeds/ ribbon weed).
19) Is there any physical cover such as rocks or snags?

Water Quality;

20) What is the water transparency?
21) Nutrient input?
22) What is the surrounding land use such as agriculture/ stock/ vineyards/dairy?
23) Does any stock use the dam as a drinking source?
24) What is the Salinity like?

25) Has there been or is there evidence of algal blooms or previous fish kills in the dam?

Other fish/ predators;

26) Do you know if there any fish currently or previously stocked in the dam? If yes, what species, how many, how long ago?

27) Is there fencing around the dam?

Commitment;

28) Length of time predicted at the address? (2 years or longer?)

29) Is the landholder interested in being a part of a monitoring program/ involvement with the process?

Thanks for getting involved with native fish conservation!

Appendix 4. Environmental measures taken at potential refuge sites.

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. Specific note of potential overflow was made for artificial refuges.

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.

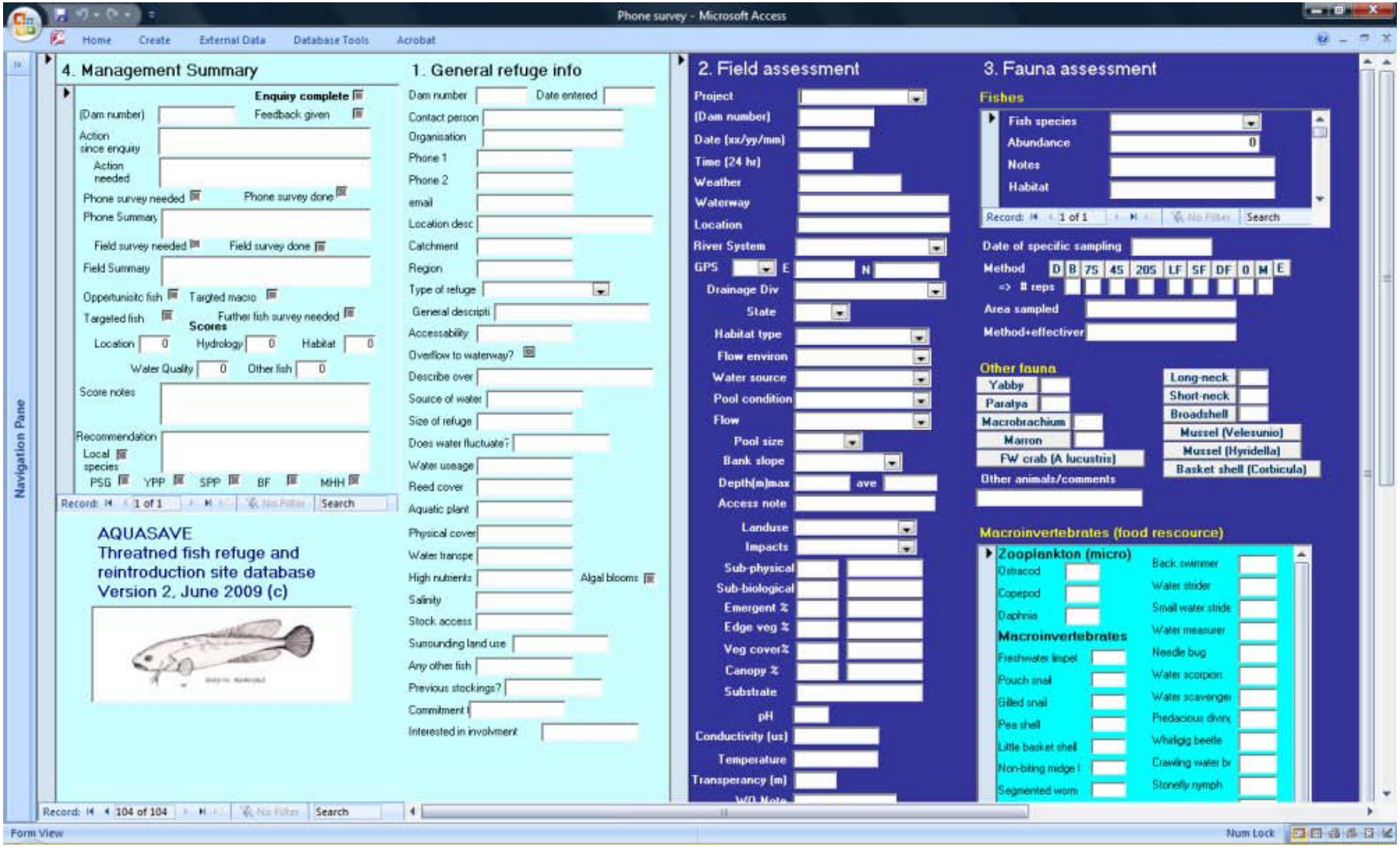
Contributions to cover (% of volume occupied and type):

- 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 overhanging 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.
- Test kits were used to assess the levels of Phosphate, Nitrate and Ammonia.
- Water transparency measured *in situ* against a white object with comments on contributions to low values such as natural tannin, colloids or algae.

Appendix 5. Surrogate refuge site database



Appendix 6. Details of number and location for (a) captive held wild fish and (b) juveniles currently available from breeding programs.

(a) Current captive holdings of rescued threatened fish from the Lower Murray region (as of end September 2009). Species codes are shown in Table 2.

Species	Source	Holding location	Housing	# fish	Capacity for production
SPSG	Murray Bridge	Aquasave	Hatchery - aquariums	33	Large - dedicated hatchery
		NFA(SA) - Berri	Hatchery - aquariums	20	Large - dedicated hatchery
		NFA(SA) - Adelaide	Hatchery - aquariums	5	Large - dedicated hatchery
YPP	Goolwa Channel	Aquasave	2500L Pond	33	Moderate - single pond
	Hindmarsh Island	Aquasave	2500L Pond	30	Moderate - single pond
	Hindmarsh Island	Cleland Wildlife Park	10000L Pond	40	Large - ideal setup
SPP	Angas River	Aquasave	2500L Pond	50	No - holding pond only
	Hindmarsh Island	SARDI - Adelaide	Small tank	42	No - holding pond only
RB	Rodwell Creek	SARDI - Adelaide	Indoor tanks	8	Possible - breeding trial
MHH	Boggy Creek	MDFRC - Mildura	Aquariums/tubs	90	Moderate - underway
	Berri	MDFRC - Mildura	Aquariums/tubs	10	Moderate - underway
	Disher Creek	MDFRC - Mildura	Aquariums/tubs	90	Moderate - underway

(b) Current (end September 2009) holding locations of captive reared fish.

Species	Broodstock source	Objective	Where located	Housing	# F1 fish
SPSG	Lower Murray	F1 backup	Aquasave	Aquaria	200
	Lower Murray	F1 production	Aquasave	Ponds	2000*
	Lower Murray	F1 backup	NFA(SA) - Berri	Aquaria	500
	Lower Murray	F1 production	NFA(SA) - Berri	Ponds	2000*
	Lower Murray	F1 backup	SARDI	Aquaria	15
	Lower Murray	F1 backup	Cleland Wildlife Park	Aquarium	15
	Lower Murray	F1 backup	Adelaide Zoo	Aquarium	20
	Lower Murray	F1 backup	Alberton Primary	Aquaria	200
YPP	Goolwa Channel	F1 backup	Aquasave	Small ponds	20
	Goolwa Channel	F1 production	Aquasave	Small ponds	200*
	Goolwa Channel	F1 backup	Cleland Wildlife Park	Aquarium	17
	Hindmarsh Island	F1 production	Aquasave	Ponds	100*
	Hindmarsh Island	F1 backup	Cleland Wildlife Park	Pond	20
	Hindmarsh Island	F1 backup	Cleland Wildlife Park	Pond	200*
	Goolwa Channel	**F1 Surrogate refuge**	Hope Forest dam - Oster	Dam refugia	70#
	Goolwa Channel & Hindmarsh Is.	**F1Surrogate refuge**	Mt Compass Dam - Crouch	Dam refugia	90#
RB	Rodwell Creek	F1 trial	SARDI	Aquaria	10
MHH	Boggy Ck, Disher & Berri	F1 backup and production	MDFRC	Aquaria	100*

*Ready for release in the next 1-6 months

F2 fish likely available for seeding other refuges in next 6 months

Appendix 7. Details of enquires and assessment sites including recommended stocking sites and further actions

Refuge	Contact person	Organisation	Type of refuge	Overflows?	Catchment	Easting	Northing	PSG	YPP	SPP	BF	MHH	Local species	Phone survey needed	Phone survey done	Field survey needed	Field survey done	Oppertunisitc fish done	Targexed fish done	Further fish survey needed	Targted macro done
Ready stocking sites																					
005*	Robert Crouch		Dam		Finniss River	287060	6088347		x						x		x		x		
028*	Simon Oster		Dam		Finniss	283502	6091937		x						x		x		x		
029	Ryan Crowhurst		Pond		Christies Creek	270327	6109187	x							x		x				
032	Bruce Wright	Beyond Housing Development	Wetland - Artificial		Unnamed (Port Elliot)	287343	6065351	x	x	x					x		x	x	x		x
032-1	Bruce Wright	Beyond Housing Development	Wetland - Artificial		Unnamed (Port Elliot)	287102	6065361	x	x	x		x			x		x	x			x
032-2	Bruce Wright	Beyond Housing Development	Wetland - Artificial		Unnamed (Port Elliot)	287044	6065364	x	x	x		x			x		x	x			x
033	Chris Leigh		Dam		Bremer	311495	6125116	x							x		x	x	x		x
034-1	Natalie Hodder		Dam		Meadows Creek	284852	6091174			x	x				x		x			x	
041	Bruce Munday		Dam	x	Reedy Creek	321916	6138939	x	x			x			x		x	x	x		x
050	Jason van Weenan		Pond		Hindmarsh	270327	6109187			x					x		x				
054	Kate Mason	SAMDBRNMB	Wetland - Artificial		River Murray	339990	6112099	x							x		x		x		x
059	Damian Newham		Pond		Angas River	307898	6095941			x					x		x	x			x
069	Ian Powell	Tupelogrove Nursery	Dam		Onkaparinga	294093	6119704		x	x					x		x	x		x	x
069-1	Ian Powell	Tupelogrove Nursery	Dam		Onkaparinga	294093	6119704		x	x					x		x	x		x	x
069-2	Ian Powell	Tupelogrove Nursery	Dam		Onkaparinga	294455	6119528		x	x	x				x		x	x		x	x
071	Barry Linke	Grange Golf Club	Wetland - Artificial		Torrens	271888	6136789	x	x	x					x			x			x
071-1	Barry Linke	Grange Golf Club	Wetland - Artificial		Torrens			x	x	x					x		x	x			x
073	Allan Swinburne		Pond		Bremer	312787	6112603	x							x		x				x
80	Andrew Robertson		Dam		Inman	276779	6065354			x					x		x	x		x	
80-1	Andrew Robertson		Dam		Inman	276698	6065366			x					x		x	x		x	
Potential sites (requiring improvement)																					
007	D.J. (Barry) Barrett (Dr)		Dam	x	Currency Creek	289125	6076736						x		x		x			x	
019	Steve Busbridge		Dam	x	Onkaparinga	282748	6114090			x			x		x		x	x		x	x
022	Geoff Underwood	Cleland Wildlife Park	Dam		First Creek	289878	6128070		x						x		x				
037	Jeff Clark (caretaker)	South Shores	Wetland - Artificial		Bungala	255311	6073217					x			x		x	x			
047	Michael & Michelle Jones		Dam	x	Torrens	321952	6138984				x		x		x		x			x	
064	Andrew Love		Pool pond		Onkaparinga	298270	6119547		x	x	x				x		x				x
076	Lyn Wilkinson & Mike Dickeson		Pond		Meadows Creek	294179	6102195			x					x		x	x			
077	Graeme Doyle or Phil Coles	Urrbrae Agricultural College	Wetland - Artificial	x	Brownhill Creek			x							x		x	x			x
Wild reintroduction sites																					
055	Jon Lovejoy		Stream	x	Finniss River	301470	6081544	x	x						x		x	x	x		x
055-1	Jon Lovejoy		Stream	x	Finniss River			x	x						x		x		x		x
078	Kate Mason	SAMDB NRMB	Wetland - Natural		Piawalla	351495	6122302	x				x			x		x	x	x		x

Refuge	Contact person	Organisation	Type of refuge	Overflows?	Catchment	Easting	Northing	PSG	YPP	SPP	BF	MHH	Local species	Phone survey needed	Phone survey done	Field survey needed	Field survey done	Oppertunisitc fish done	Targexed fish done	Further fish survey needed	Targted macro done
034-2	Natalie Hodder		Waterhole		Meadows Creek	284288	6090792								x		x				
035	Robin Graham		Dam		Hindmarsh River	285688	6071242								x		x				
035-1	Robin Graham		Dam		Hindmarsh River	285680	6071243														
035-2	Robin Graham		Dam		Hindmarsh River	285829	6070891														
036	Carolyn Wastell & Martin Snee		Dam	x	Meadows Creek										x						
039	Barry Lincoln		Dam	x	Inman										x		x				
040-1	David Loveder	SA Water	Dam	x	Finniss	279891	6072557								x		x	x	x		x
041-1	Bruce Munday			x	Reedy Creek	321952	6138983								x		x				
042	Bridget Kingham	SA Water	Dam	x											x						
043	Ken Ruge	SA Water	Dam	x	Onkaparinga	293970	6110391								x		x	x			
043-1	Ken Ruge	SA Water			Onkaparinga	294636	6110127								x		x	x			
043-2	Ken Ruge	SA Water			Onkaparinga	292919	6116734								x		x	x			
043-3	Ken Ruge	SA Water			Onkaparinga	291489	6116481								x		x	x			
043-4	Ken Ruge	SA Water			Onkaparinga	288128	6113887								x		x	x			
043-5	Ken Ruge	SA Water			Onkaparinga	283498	6114009								x		x	x			
043-6	Ken Ruge	SA Water			Onkaparinga	283590	6114705								x		x	x			
044	Jeff Smith		Dam	x	Onkaparinga	278810	6110792								x		x	x			
046	Margaret Lee		Dam	x	Onkaparinga	292964	6126597								x		x	x			
048	Margaret Wilksch		Dam	x	Angas River	301913	6108201								x	x		x			x
049	Gary & Elaine Norris														x						
051	David Cooney	Mount Barker Coucnil													x						
052	Craig Kemp													x		x					
056	John Leake		Marina channel	x	River Murray	353982	6090224								x	x	x	x			
057	Paul Dalby & Michelle Freeman		Dam	x	Onkaparinga										x	x					
058	Ruth Cruickshanks		Dam		Tookayerta										x						
060	Doug Lindley		Dam	x	Finniss River	281822	6090817								x		x	x			x
060-1	Doug Lindley		Dam	x	Finniss River	281627	6093502								x		x	x			x
061	Tim Newberry		Dam		Kangaroo Island										x						
062	Melinda Barnard	Warrawong Sanctuary	Dam		Onkaparinga										x					x	
063	Lyssa Liebelt		Dam	x											x						
064-1	Andrew Love		Dam	x	Onkaparinga										x		x				
070	Graham Stephens	Glenelg Golf Club	Wetland - Artificial		Patawalonga	274880	6128697								x		x	x			x
070-1	Graham Stephens	Glenelg Golf Club	Wetland - Artificial		Patawalonga										x		x				x
070-2	Graham Stephens	Glenelg Golf Club	Wetland - Artificial		Patawalonga										x		x	x			x
074	Tony Weatherley	Manager of Garrett Property	Dam	x	Brownhill Creek	286329	6126821								x		x	x			x
075	Bill Hankin	Biopark Organic Farm	Dam	x	Bremer	307480	6113378								x		x	x			x
079-1	Tony Kaines		Dam	x	Onkaparinga										x						

Appendix 8. Macroinvertebrate survey results at wild threatened fish sites.

Species	**SPSG**	**SPP**	**RBF**	**MHH**
Wild site	Jury Swamp (main channel)	Angas River	Rodwell Creek	Rocky Gully
Date	4/06/2009	23/05/2009	21/09/2009	4/06/2009
Zooplankton				
Seed shrimp (ostracod)	18	100	175	
Copepod	5	200	10	1000
Waterflea (*Daphnia*)	8	100	30	
Macroinvertebrates				
Freshwater limpet			0	
Pouch snail		20	19	
Gilled snail				
Pea shell				
Little basket shell				
Non-biting midge larvae	3	1	11	10
Segmented worm				
Biting midge larvae				
Leech				
Roundworm				
Flatworm				
Cranefly larvae				
Mosquito larvae				2
Mosquito pupae				
March fly larvae				
Black fly larvae				
Hydra				
Soldier fly larvae				
Scud (amphipod)			96	
Isopod				
Water mite				
Fishing spider				
Water boatman				
Back swimmer				
Water strider				1
Small water strider				
Water measurer				
Needle bug				
Water scorpion				
Water scavenger beetle				1
Predacious diving beetle	1		11	200
Whirligig beetle				
Crawling water beetle				
Stonefly nymph		10		
Damselfly nymph	1		50	
Mayfly nymphs		50	36	1
Water scavenger beetle larvae			2	
Whirligig beetle larvae				
Dragonfly nymph			9	1
Predacious diving btl larvae			3	
Springtail				
Caddisfly larvae		2	3	
Decapod crustaceans & fish				
Yabby	2		1	
Freshwater shrimp (*Paratya*)	87	1	28	
Freshwater prawn	2			
Freshwater crab		1		
Small native fish	9	1		
Gambusia				1
Water Quality				
pH	8.0	7.5	7.5	8.8
EC (mS)	727	5080	5600	31200
Transparency (cm)	0.3	0.6	0.9	0.2
DO (surface)	8.6	9.1	5.0	9.7
Temperature	15.9	16.8	12.7	16.1