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Flinders Ranges frogs and fishes: pilot project

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FLINDERS RANGES FROGS AND FISHES PILOT PROJECT

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Sincere thanks to Michael Hammer for scientific and technical advice and for providing for the fish survey work to be conducted under his permit. Sincere thanks also to Ralph Foster of the South Australian Museum for scientific and technical advice, to Mark Walsh and Dylan Sortino for field assistance and to Henry Mancini and Nicki Du Preu of the SAALNRM Board for technical and other assistance in developing and undertaking this project.

SUMMARY

This pilot project sets the groundwork for understanding the distribution, diversity, relative abundance, and conservation status of the frogs, native fishes and pest fishes of the Flinders Ranges in the SAALNRM region. Some of the species also occur in the Northern and Yorke NRM region.

Frogs and fishes are important biological indicators of the health of arid zone aquatic ecosystems. Such sites are considered to be High Conservation Value Aquatic Ecosystems (as yet unspecified HCVAE's for the purposes of the Caring for Our Country Business Plan 2009-2010). They can be referred to as Desert Jewels.

All known Australian inland fishes are totally dependent on free water for their existence and persistence. Springs in the Flinders Ranges are the only places where water permanence as required by fishes is assured. Frogs are also known to be strongly associated with such sites even though they are not dependent on continuous habitation in free water.

This study provides background knowledge and a roadmap for broader and ongoing monitoring of these biological indicator organisms and the surface waters in which they occur.

An initial background review of available mapping indicates about 150 springs and about 100 other near-permanent or persistent surface waters in the Flinders Ranges and the watercourses that flow across the surrounding country. Twenty six sites were field assessed for their potential as demonstration, recovery and reference sites and assigned relative values for these uses. The sites include springs and waterholes in or associated with watercourses that flow east, north and west from the Flinders Ranges.

Eight species of frogs and 11 species of fishes are known to be extant in the Flinders Ranges. These include three endemic frog species – the more southerly Flinders Ranges Froglet (*Crinia riparia*), an undescribed and closely related froglet (*Crinia* sp. nov.) in the northern flinders Ranges, the also undescribed Flinders Ranges Toadlet (*Pseudophryne* sp. nov.), the endemic and endangered Flinders Ranges Purple-spotted Gudgeon (*Mogurnda clivicola*), the highly restricted Flyspecked Hardyhead (*Craterocephalus stercusmuscarum,* but possibly a new species), and the introduced pest fishes the Plague Minnow (*Gambusia holbrooki*) and the European Carp (*Cyprinus carpio*). The Lake Eyre Callop (*Macquaria* sp nov) has been recorded once in the Hamilton Creek following the record 1975 Lake Eyre Basin floods and the species has not been recorded since.

The Flinders Ranges species of frogs and native fishes have a high degree of combined endemism of about 30%. (Frogs alone 3 of 8 species = 38%, fishes alone 1 or 2 of 8 native species =13 to 25%).

Voucher specimens of three species of frogs and six species of fishes were lodged in the South Australian Museum.

Field conditions for detecting many species of frogs and in particular the Flinders Ranges Toadlet *Psuedophryne* sp nov were too dry during this study.

The distribution range of the Northern Flinders Froglet (*Crinia* sp. nov.) was extended northward to Walparindina Springs (MacDonnell Creek) on Mount Freeling Station.

The Flinders Ranges Purple Spotted Gudgeons in the creek-bed outflow of Nepowie Spring were as abundant in 2009 as in 2002. This translocated thriving second known population is an ideal reference and demonstration site for this species.

Most if not all of the 11 fractured-rock springs examined were significantly diminished in flow and water levels (one was extinct) due presumably to prolonged drought and water table deflation. One of the 10 Great Artesian Basin springs examined was extinct, many showed some signs of declined flows, and one appears not to have diminished in the recent past.

A thorough field assessment of up to 50 of the approximately 250 identified surface waters will need to be made to get a reasonable inventory of the springs and waterhole dependent frogs and fishes of the Flinders Ranges.

To comprehensively understand and manage the frogs, fishes and springs (=Desert Jewels) of the whole of the Flinders Ranges will require complimentary field evaluations in the Northern and Yorke NRM region of the Flinders Ranges.

Follow-up assessments at many of the sites examined during this study as well as additional sites are recommended to monitor frog and fishes population trends, to evaluate the various impacts including abnormal drought (?climate change), habitat loss, feral animals and changed water flow, land use and grazing practice, and to improve the quality of distributional and trends data that can inform ongoing management actions.

Additional recommendations are made for community engagement and pro-active management options at Aroona Dam and the Retention Dam (both near Leigh Creek).

INTRODUCTION

General

The northern Flinders Ranges have eight species of frogs including three endemic species – the more southerly Flinders Ranges Froglet (*Crinia riparia*), an undescribed and closely related froglet (*Crinia* sp. nov.) in the northern Flinders Ranges, and the also undescribed Flinders Ranges Toadlet (*Pseudophryne* sp. nov.). Population and status assessments are urgently needed for these three species. The species are listed in Table 1.

There are 11 known species of freshwater fish including the endemic and endangered Flinders Ranges Purple-spotted Gudgeon (*Mogurnda clivicola*), the highly restricted Flyspecked Hardyhead (*Craterocephalus stercusmuscarum,* but possibly a new species), and the introduced pest fishes the Plague Minnow (*Gambusia holbrooki*) and the European Carp (*Cyprinus carpio*). The species are listed in Table 1.

At least eight native species from the Cooper Creek have been translocated into the Retention Dam at Leigh Creek (see **Other native species** account in **Discussion – Fishes** for species details) with unknown success. Only two of the known eight species (Bony Bream and Lake Eyre Callop) are included in Table 1 because they are also known from other sites in the study area.

Table 1 The eight frog species and 11 fish species in the Flinders Ranges and associated watercourses

Status "Uncertain" is used for species that have limited occurrence or are unconfirmed in the Flinders Ranges

Species (scientific name)	Species (common name)	Status in Flinders Ranges	Remarks
Frogs			
Crinia riparia	Flinders Streams Froglet (proposed alternate name)	Secure	Widespread along streams and near other long-term water in the southern half of the Flinders Ranges (south of Warren Gorge); shelters in deep cool refuges; winter breeder; restricted to ranges
Crinia sp. nov	Flinders Springs Froglet. (proposed name)	Probably Vulnerable	Occurs mostly at springs and other near-permanent waters in cooler gullies of the northern half of the Flinders Ranges (north of Warren Gorge); shelters in deep cool refuges; winter to (?)opportunistic breeder; restricted to ranges
Limnodynastes tasmaniensis	Spotted Marsh Frog	Secure	A widespread species that shelters in deep well-shaded refuges; opportunistic breeder with preference for cooler months; more reliable watercourses in the ranges and some adjacent plains sites
Neobatrachus centralis	Desert Trilling Frog	Secure	An arid adapted burrowing species widespread in softer homogeneous soils esp. sands; opportunistic breeder; on plains and footslopes

Neobatrachus pictus	Painted Trilling Frog	Uncertain in Flinders Ranges	A temperate burrowing species occurring in softer homogeneous soils esp. sands; its occurrence in the Flinders Ranges is restricted to the very south; winter breeder; on footslopes
Pseudophryne sp. nov.	Flinders Ranges Toadlet	Vulnerable, possibly Endangered	Occurs mostly at springs and other persistent surface waters with suitable dense ground vegetation in the central and northern parts of the Flinders Ranges (north of about Mookra Towers); shelters in deep cool refuges and can burrow into moist soil; winter to (?)opportunistic breeder; in ranges only
Litoria caerulea	Green Tree Frog	Uncertain in Flinders Ranges	A single report of a calling male at a northern Flinders Ranges waterhole, shelters in deep well-shaded tree hollows, caves and deep soil crevices; opportunistic breeder with preference for warmer months; presence needs to be confirmed
Litoria rubella	Desert Tree Frog	Secure	A widespread arid-adapted species that shelters in deep well-shaded tree hollows, deep recesses and under bark; opportunistic breeder with preference for warmer months; associated with substantial watercourses with larger trees in and surrounding the ranges
Fishes			
Nematolosa erebi	Bony Bream	Secure	A widespread arid arid-adapted mid-water and near-bottom species, occurs in many deeper waterbodies that are flow-linked to refugia waterholes during rains, established in Retention Dam
Craterocephalus eyresii	Lake Eyre Hardyhead	Secure	A widespread arid-adapted mid-water schooling species that can tolerate a wide range of salinity and temperature, occurs in many waterbodies that are flow-linked to refugia waterholes during rains
Craterocephalus stercusmuscarum taxonomic status uncertain	Fly-specked Hardyhead	Vulnerable	A very restricted mid-water schooling species; in South Australia known to date only from the Saint Marys Pool group of waterbodies in MacDonnell Creek. Probably has narrower ranges of tolerance for temperature and salinity than *Craterocephalus eyresii*; further field and laboratory work is needed in this catchment and on this species to better inform its status
Melanotaenia splendida tatei	Desert Rainbow Fish	Secure	A generally widespread arid-adapted mid-water species, but known only from two waterbodies of the Flinders Ranges (Saint Marys Pool waterbodies and Myrtle Springs)
Macquaria sp nov	Lake Eyre Callop	Uncertain in Flinders Ranges	A widespread deeper water species in the Lake Eyre Basin, Pearce *et al* 2001 report photographic evidence of this species' occurrence in the Hamilton Creek (on Moolawatana or Mount Freeling Stations) soon after the 1975 floods; presence has not been confirmed since, introduced to Retention Dam
Leiopotherapon unicolor	Spangled Grunter	Secure	The most widespread of all arid-adapted mid-water species that is very aggressive towards other species, occurs in many waterbodies that are flow-linked to refugia waterholes during rains; it has remarkable capacities to disperse in rain-flooded country

Chlamydogobius eremius	Desert Goby	Secure	A widespread arid-adapted bottom dwelling species that can tolerate a wide range of salinity and temperature, occurs in many lowland waterbodies that are flow-linked to refugia waterholes during rains; not found in the ranges
Hypseleotris klunzingeri	Western Carp Gudgeon	Secure	An arid-adapted near-bottom dwelling species that occurs in a few low-gradient waterbodies around the Flinders Ranges; known from Saint Marys Pool and the Leigh Creek Retention Dam
Mogurnda clivicola	Flinders Ranges Purple-spotted Gudgeon	Vulnerable	A very restricted mid-water and bottom dwelling species; in South Australia known to date only from the Balcanoona Creek and tributaries in permanent spring-fed waterbodies. A second translocated population is well-established in the outflow of Nepowie Springs. Two interstate occurrences of this species are based on a single specimen record from the Bulloo River and several from the Barcoo River in Queensland; further field and laboratory work is needed to better inform the status of the interstate occurrences
Gambusia holbrooki	Plague Minnow	Introduced pest	Aggressive surface schooling fish that can tolerate wide fluctuations in temperature and oxygen availability, highly invasive and almost useless as a mosquito larvae control species; mistakenly introduced to some accessible sites (Aroona Dam, Leigh Creek Retention Dam) from which they may be dispersed further by uninformed human agency
Cyprinus carpio	European Carp	Introduced pest	Prolific bottom and mid-water fish that can tolerate wide fluctuations in temperature and oxygen availability, highly invasive and almost useless as a food species; deliberately and illegally introduced to the Leigh Creek Retention Dam, from which the species may be dispersed further by uninformed human agency

As introduced fishes can have important negative impacts on native fishes and frogs, the occurrence and abundance of the Plague Minnow was also assessed in this pilot study. The European Carp is known to have persisted in the Leigh Creek retention Dam but was not specifically targeted in this study.

Springs in the Flinders Ranges are the most likely places where water permanence is assured. Such sites are known to be the refuges of fishes and frogs in a landscape that experiences long episodes of general surface dryness and drought. Australian arid zone frogs can and do take refuge in deep, cool, and sometimes higher humidity burrows, crevices and sandy soils.

All known Australian inland fishes are totally dependent on free water for their existence and persistence. For these reasons this pilot study focused on springs in the Flinders Ranges and in watercourses flowing from the Ranges.

Why are frogs and fishes important?

For a general overview of the frogs and fishes of the South Australian Rangelands see the *South Australian Rangelands and Aboriginal Lands Wildlife Management Manual* (Ehmann 2006). The following information includes a short summary of the general points in that Manual and additional information which is specific to the Flinders Ranges.

Frogs and fishes are important biological indicators of the health of aquatic ecosystems. As arid zone surface waters are mostly relatively small point habitats in vast areas of a mostly dry landscape they are indeed aquatic habitats and ecosystems of high conservation value. The biota in such Australian arid surface waters, including several species of frogs and fishes, can be localised and even highly endemic to one to five sites. Such sites can be truly referred to as Desert Jewels.

The frogs and native fishes of the Flinders Ranges have a high degree of endemism (about 30%). Due to the as-yet undetermined taxonomic status of the Flyspecked Hardyhead the combined percentage endemism falls into the range of 27 to 33% (total 4 or 5 of 16 native species = 25 or 31%). For frogs alone the percentage endemism is 38% (3 of 8 species = 38%). For fishes alone the percentage endemism is 13 or 25% (1 or 2 of 8 extant native species =13 or 25%).

The study of frogs and fishes in a generally arid environment can provide key background knowledge and a roadmap for broader and ongoing environmental trends monitoring, particularly of aquatic ecosystems and therefore water quality and water usage limitations. Understanding the trends in the occurrence, abundance and health of frogs and fishes can inform a framework for further on-ground field assessments, and for management and conservation actions if needed at the many surface waters in the Flinders Ranges.

Threats to frogs and fishes

Decreased water flows are likely to reduce the availability of breeding and refuging sites. Increased severity of waterflows associated with extreme flooding events (as is predicted by climate change models) is also likely to generally impact negatively on breeding and refuging, particularly if animals are water-dispersed to sites that have more extreme water and temperature conditions.

Extreme flooding events can result in some native species dispersing beyond their ranges (see Green Tree Frog and Lake Eyre Callop in the Discussion section). Such events may also result in the potential incursion of pest species such as the Cane Toad, European Carp and Plague Minnow from relatively long distances away.

Some changes in land use such as mining, water-harvesting, altered grazing species, feral animals depleting and fouling the Desert Jewels, and increased total grazing pressures are likely to result in habitat loss for frogs and fishes.

The release and establishment of introduced competitor and predator species presents a real risk to frogs and fishes, the known species include the Cane Toad (which is likely to eventually get to the Flinders Ranges), the Plague Minnow (which is already widely established), and Carp (which is established in the Leigh Creek Retention Dam). Aquarium fishes with a high capacity to survive harsh arid conditions climate change are also considered a risk.

The threats posed to the frogs and fishes of the Flinders Ranges by climate change will probably compound the risks already outlined, with potentially even more substantial negative impacts.

The susceptibility and sensitivity of frogs and fishes to habitat changes makes them highly suitable indicator organisms for monitoring environmental health.

Pilot project objectives

1. To provide background knowledge for a broader and ongoing monitoring and management program of the frogs and fishes in the Flinders Ranges, including impacts resulting from decreases and increases in water flow, changes in land use, habitat loss, introduced animals and climate change.

2. To compile data and data sources for the frogs and fishes of the study area, including a comprehensive base-line study of the distribution and abundance of the Flinders Ranges Purple-spotted Gudgeon and the Flyspecked Hardyhead.

3. To develop and test a protocol for base-line studies of the distribution and abundance of the three species of endemic Flinders Ranges frogs, the other fishes and frogs, and the Plague Minnow.

4. To inform the development of a prioritisation framework for management and conservation actions that may be needed at surface waters in the Flinders Ranges.

5. To recommend the course and scope of ongoing frog and fishes monitoring in the Flinders Ranges, including the potential for complimentary monitoring work in the Northern and Yorke NRM region.

MATERIALS AND METHODS

The three major phases of the pilot project

1. Baseline data collection, the selection of at least 12 pilot study sites, and the development of a field study and sampling protocol

2. Field assessment of the pilot study sites, data and voucher specimen collection, and

3. Data analysis, project evaluation, recommendations for improved follow-up monitoring and improved survey work and outcomes, and final report preparation.

Base-line data: the springs and other significant surface waters in the Flinders Ranges and associated watercourses

Available maps, publications and other sources were checked for locations and information about springs and suitable waterholes in the Flinders Ranges. The most significant source of information was older Pastoral property paper-based mapping originally compiled with significant local information and knowledge of the pastoral value of the springs and other natural surface waters and therefore their likely permanence.

Many of these spring-fed surface waters are in creek lines that intersect their feed aquifers, with a few in headwater sites and some in watercourses on plains country surrounding the northern Flinders Ranges. See Results, Table 2.

These sites were plotted onto the regional pastoral properties map to determine the most effective and cost efficient field work and road travel arrangements given the limited funding available and the pilot nature of the study. See Appendices, Map 1.

Property owners and managers were contacted by telephone and also in person for current information about the springs identified on mapping. Information was sought about the permanence and flow rate of each spring, the quality and use made of the water, the nature of fringing and in-water vegetation, and whether any frogs, tadpoles or fish had ever been seen or caught.

Of about 50 potential sites (desk-top evaluation) 26 were visited and examined for their potential as demonstration, recovery and reference sites. All the visited sites are outside DEH Reserves as the permitting processes required for work in Reserves was beyond the resources scope for this project. Furthermore the wider environmental health of frogs and fishes in the Flinders Ranges will be significantly dependent on their environmental health in non-reserve areas.

The two field trips focused on springs and waterholes in or associated with watercourses that flow east, north and west from the Flinders Ranges. The sites were chosen from eastward flowing watercourses to Lakes Frome and Callabonna from Chace Range in the south to Moolawatana Station (11), northward flowing watercourses to Lake Blanche on Moolawatana, Murnpeowie and Freeling Heights Stations (13), and westward flowing watercourses to Lake Torrens south to Aroona

Dam (2). Four artificial water bodies sites namely in Aroona Creek below the Aroona Dam (2), the retention Dam at Leigh Creek (1) and Deans Bore wetland (which flows to MacDonnell Creek) are included in these counts.

Sites were field-assessed and scored for their value as frog or fishes sites and as demonstration, recovery and reference sites. See Table 3. When possible sites examined were also photographed. A standard fishes site data sheet was completed at most sites (see Appendix 1), and supplementary field notes were also recorded.

Base-line data: distribution and ecological records for the frogs and fishes of the Flinders Ranges and associated watercourses

The distribution information for the fish and frog species from the Flinders Ranges held in the collections of the South Australian Museum were obtained, the South Australian Biological Survey reports relating to the Flinders Ranges were extracted, and local and personal knowledge was sought and utilized.

For ecological and conservation information all available publications were reviewed and researchers with up-to-date knowledge of the taxonomy and ecology of the fishes and frogs were consulted (see References with annotations).

Voucher specimen and field methods

Representative voucher specimens of frogs, tadpoles and fishes were taken at each site where these were found. The specimens included live animals (tadpoles and frogs) for tissue sampling (cyto-taxonomy), field-processed whole reference specimens, and tissue samples (cyto-taxonomy) ie fish fin clippings in alcohol. Most species were also photographed for reference purposes. All specimens were processed as prescribed by the South Australian Biological Survey Guidelines for Fauna Surveys and lodged in the South Australian Museum with all standard specimen data.

Site visits involved:

1. in most cases a pre-visit discussion by telephone or sometimes in-person with the property owner or manager
2. an evaluation of the site's suitability for further monitoring work, the measurement and recording of standard site variables (see Table 3 and Appendix 1),
3. the use of a site-specific and conditions-specific range of detection techniques for frogs (night-time and day-time searching and aural detection, netting of tadpoles) and fishes (night-time and day-time searching and visual detection, dip and fyke netting and bait trapping)
4. the recording of a comprehensive set of site data on environmental impacts and site conditions
5. when possible recording the abundance of fishes, tadpoles and frogs with either specimen counts or counts per unit area
6. when possible the taking of site and specimen images

This has resulted in the generation of a protocol for base-line studies of the distribution and abundance of the frogs and fishes of the Flinders Ranges (see Recommendations for the Protocol outline).

RESULTS

Base-line and field data: the springs and other significant surface waters in the Flinders Ranges and associated watercourses

The number of mapped springs and other surface waters that are potentially suited to frogs and fishes in the Flinders Ranges and its environs are summarised in Table 2. These numbers should be used only as guide and with caution as mapping may not be correct or reflect current conditions. The overall numbers are relatively accurate (probably within 10%) and are indicative of the task involved in adequately assessing these Desert Jewels in the Flinders Ranges and their environs.

Figure 1 Site 1, Parawilia Waters. This was the only surface water at this site.

Figure 2 Site 2, Prelinna Hut Spring at the time of visit. Reduced to depression in the creek bed.

Figure 3 Site 3, Angaroonoy Springs, upstream and north of the main deeper cliff-base pools.

Figure 4 Site 4, Angaroonoy Springs, deeper cliff-base pools downstream and south of the extensive in-stream springs.

Table 2 The number of mapped springs and other surface waters that potentially have frogs and fishes in the Flinders Ranges and its environs.

Most but not all Flinders Ranges and environs leases are included and some of the named leases have changed their tenure status and in some cases their boundaries since the maps used for this desk-top compilation were drafted.

Note that the spring and waterbody types are not mutually exclusive, nor are the types necessarily differentiated on mapping.

The numbers of both types of springs may be estimates due to their varied sizes and clustering patterns

Property or lease	**Mound spring groups**	**Fractured-rock springs**	**Spring-fed waterholes in creekline**	**Creekline waterholes**
Alpana	0	8	4	0
Angepena	0	6	1	3
Arkaroola	0	8	1	4
Artimore	0	2	0	0
Balcanoona (now the Vulkathana National Park)	0	9	20	10
Burr Well	0	7	1	1
Gum Creek	0	9	2	2
Mannawarra	0	11	3	0
Martins Well	0	3	1	0
Moolawatana	5	4	3	3
Mooloolloo	0	7	0	2
Moorillah	0	6	0	0
Mt Falkland	0	2	2	0
Mt Freeling	0	10	5	10
Mt Havelock	0	1	0	0
Mulga View and Pinda Springs	0	2	0	0
Murnpeowie	10	2	4	4
Nantawarrinna (now an Aboriginal Land)	0	3	1	0
Narrina	0	10	2	0
Oratunga	0	6	2	0
Prelinna	0	1	1	0
Saltia	0	2	0	0
Wertaloona	0	3	0	3
Willow Springs	0	5	3	0
Wooltana	0	6 (?all GAB)	0	0
Totals	**15**	**133**	**55**	**42**

Figure 5 Site 5, Narrina Spring and deep rock pools. Searching for *Crinia* sp nov.

Figure 6 Site 6, Bora Bora Spring in background, with rain filled pools in foreground.

Figure 7 Site 7, Big Spring creek bed with extensive tree dieback and death probably due to sustained water stress.

Figure 8 Site 7, Big Spring creek bed with massive natural concrete associated with past sustained waterflows. Pool of recent rainwater.

Figure 9 Site 8, Moro Gorge Creek (nearby spring fed) at vehicle crossing.

Figure 10 Site 9, Nepowie Spring creek pool looking downstream to the east.

The 26 visited sites and their field-assessments are given in Table 3. Most sites examined were also photographed and some of these are in Figures 1 to 27.

Most if not all of the 11 fractured-rock springs examined were significantly diminished in flow and water levels (one was extinct) due presumably to prolonged drought and water table deflation. One of the 10 Great Artesian Basin springs examined was extinct, many showed some signs of declined flows, and one appears not to have diminished in the recent past.

Table 3 Springs and other surface waters examined in access and date order

***Assessment of sites**:

demonstration means the site is reasonably accessible, relatively safe and suited to supervised visits by small teaching groups

recovery means the site can be used for long-term and opportunistic trends monitoring by specialist workers and access may be difficult and/or dangerous

reference means the site can be used for regular monitoring by specialist workers and access may be difficult and/or dangerous

value is a three level ranking of the usefulness of the site for the designated assessment (high, medium and low)

Spring or water body name AMG drainage	**Name of property or lease**	***Assessment of site** demonstration, recovery, reference value: high, medium, low	**Remarks** visit date (ddmmyyyy) nature of surface water frog species recorded during field work fishes species recorded during field work
1. Parawilia Waters 54 J 291231 X 6494527, Lake Frome drainage	Mt Havelock lease	Drought recovery value: medium	21042009 Fractured rock spring, base of Chace Range, in a pass watercourse *Limnodynastes tasmaniensis* No fishes
2. Prelinna Hut Spring 54 J 288314 X 6499735, Lake Frome drainage	Mannawarra lease	Drought recovery value: low	21042009 Waterhole in Wilpena Creek bed *Limnodynastes tasmaniensis* No fishes
3. Angiroonoy Springs 54 J 298368 X 6502710, Lake Frome drainage	Mannawarra lease	Demonstration, and reference value: high	21042009 Fractured rock springs, in creek bed in half gorge *Limnodynastes tasmaniensis* *Crinia* sp nov No fishes
4. Angiroonoy Springs 54 J 298550 X 6501700 (approx, no satellite access) , Lake Frome drainage	Mannawarra lease	Demonstration, and reference value: high	22042009 Fractured rock springs and waterbody, in creek bed in half gorge *Limnodynastes tasmaniensis* No fishes
5. Narrina Spring 54 J 285316 X 6579889, Lake Frome drainage	Narrina lease	Drought recovery and reference value: medium	23042009 Fractured rock springs and rockpools, in creek bed in open gorge *Crinia* sp nov No fishes
6. Bora Spring 54 J 297186 X 6579436, Lake Frome drainage	Narrina lease	Drought recovery value: low	24042009 Fractured rock spring and rockpools, in basement rock creek bed at an escarpment No frogs

			No fishes
7. Big Spring 54 J 323543 X 6601814, Lake Frome drainage	Nantawarrinna Aboriginal Land	Aquifer recovery value: indeterminate	24 & 25042009 Extinct fractured rock spring (?), in rocky creek bed. Substantial natural concrete in creek line indicating long-term seepage and flows in the recent past. Some pooled water present from very recent rain *Litoria rubella* No fishes
8. Moro Springs 30° 41' 00"S X 139 ° 13'04"E, Lake Frome drainage	Nantawarrinna Aboriginal Land	Reference value: medium	25042009 Fractured rock springs and rockpools, in basement rock creek bed in an open gorge *Crinia* sp nov (visit in 2000) No fishes
9. Nepowie Spring 54 J 343330 X, Lake Frome drainage 6628000	Wooltana lease	Demonstration, and reference value: high	25042009 Strong flowing warm natural spring of Great Artesian Basin in creek bed in gorge through a rocky range No frogs *Mogurnda clivicola*
10. Aroona Creek pools to 250m downstream of Aroona Dam wall 54 J 246589 X 6613207, Lake Torrens drainage	Puttapa lease?	Reference value: low	08082009 Isolated pools in rock and gravel creek bed presumably fed by fractured rock aquifer from Aroona Dam No frogs *Gambusia holbrooki*
11. Aroona Creek pools near picnic sites approx. 800m downstream of Aroona Dam wall 54 J 246418 X 6612855, Lake Torrens drainage	Puttapa lease?	Demonstration, recovery and reference value: high	08082009 Con-joined slow-flowing pools in rock and gravel creek bed presumably fed by fractured rock aquifer from Aroona Dam No frogs *Gambusia holbrooki*
12. Leigh Creek Mine Retention Dam 54 J 249869 X 6620529, Lake Eyre drainage	coal mine area	Reference value: high	08082009 Artificial large surface area dam on Leigh Creek watercourse filled by rain runoff and pumped water from coal mine. At least eight native species from the Cooper Creek have been translocated into the Retention Dam (see Other native species account in Discussion – Fishes). No frogs *Hypseleotris klunzingeri* *Craterocephalus eyresii*
13. Leigh Creek waterholes in creek	Myrtle Springs lease	Drought recovery and	08082009 Non-permanent waterholes

line near intercept with bitumen road north 54 J 2477590 X 6630460, Lake Eyre drainage		demonstration value: high	in creek bed fed by rainfall and seasonal springs. NO WATER PRESENT AT VISIT. No frogs No fishes
14. main upstream pool of St Marys Pool complex, in MacDonnell Creek 54 J 346546 X 6726333, Lake Blanche drainage	Murnpeowie lease	Reference value: high	08 to 10082009 Large permanent waterholes in creek bed fed by GAB springs and creek flows after rains No frogs *Nematolosa erebi* *Craterocephalus stercusmuscarum* taxonomic status uncertain *Melanotaenia splendida tatei* *Leiopotherapon unicolour* *Hypseleotris klunzingeri*
15. gauging station pool of St Marys Pool complex, in MacDonnell Creek 54 J 346770 X 6727273, Lake Blanche drainage	Murnpeowie lease	Reference value: high	09 to 10082009 Large permanent waterholes in creek bed fed by springs and creek flows after rains No frogs *Nematolosa erebi* *Craterocephalus stercusmuscarum* taxonomic status uncertain *Hypseleotris klunzingeri*
16. wetland of Deans Bore in Deans Bore Creek (tributary of Petermorra Creek) 54 J 362159 X 6719926, Lake Blanche drainage	Murnpeowie lease	Reference value: medium	10082009 Extensive and long-extant artificial wetland in creek-line fed by bore overflow No frogs No fishes
17. first Chimney Spring, to Petermorra Creek 54 J 359300 X 6706225, Lake Blanche drainage	Murnpeowie lease	Aquifer recovery value: high	10-11082009 Waterhole in creek fed by seep from ?GAB springs in creekbed No frogs No fishes
18. second Chimney Springs group, to Petermorra Creek 54 J 358432 X 6707007, Lake Blanche drainage	Murnpeowie lease	Aquifer recovery value: high	11082009 Three shallow pools below two mound springs fed by GAB in broad creek bed Eriocaulon present No frogs No fishes
19. third Chimney Springs group, to Petermorra Creek 54 J 357786 X 6707167, Lake Blanche drainage	Murnpeowie lease	Aquifer recovery value: high	11082009 Five shallow pools below five mound springs fed by GAB in broad creek bed *Eriocaulon* present on some mounds

			No frogs No fishes
20. fifth Chimney Springs group, to Petermorra Creek 54 J 356145 X 6707222, Lake Blanche drainage	Murnpeowie lease	Aquifer recovery and reference: the deepest pool near springs group AMG, lowest group of all springs seen value: high	11082009 walk to these from vehicle access point at 54 J 355900 X 6706999 Extensive shallow pools and many mound springs (30 – 40) fed by GAB for about 300m in broad creek bed *Eriocaulon* present on some mounds No frogs No fishes
21. fourth Chimney Springs group, to Petermorra Creek 54 J 356369 X 6706810, Lake Blanche drainage	Murnpeowie lease	Aquifer recovery value: high	11082009 walk to these via watercourse from deepest pool in fifth group AMG Shallow pools and many mound springs (10 - 20) fed by GAB in broad tributary of main creek *Eriocaulon* present on some mounds No frogs No fishes
22. Petermorra Spring, to Petermorra Creek 29° 46’ 08” S X 139° 32’ 54” E, Lake Blanche drainage	Murnpeowie lease	Aquifer recovery value: indeterminate	11082009 Long extinct spring at base of low rocky foothills, presumably fed by GAB and possibly also by fractured rock aquifer. Evidenced by disused rusting stock watering trough and piping from spring. . NO WATER PRESENT AT VISIT. No frogs No fishes
23. Twelve Springs group, to Yerila Creek 54 J 371037 X 6697868, Lake Callabonna drainage	Moolawatana lease	Reference value: medium	11082009 Many shallow tail pools below about twelve mound springs fed by GAB *Eriocaulon* present on some mounds No frogs No fishes
24. Terrapinna Spring and Waterhole, in Hamilton Creek 29 ° 54’ 55” S X 139 ° 39’ 59” E, Lake Frome drainage	Moolawatana lease	Reference value: high	11082009 Large single waterhole presumably fed by an in-bed fractured rock spring and by occasional rain-fed water flows in concurrent Hamilton Creek No frogs No fishes
25. Brindana Spring and Waterhole, in Hamilton Creek 54 J 367697 X	Mount Freeling lease	Reference value: high	11 - 12082009 Single waterhole fed by in-bed fractured rock springs and by occasional rain-fed

6685205, Lake Frome drainage			water flows in concurrent Hamilton Creek No frogs *Leiopotherapon unicolor*
26. Walparindina Springs and Waterholes, to MacDonnell Creek 54 J 336220 X 6689327, Lake Blanche drainage	Mount Freeling lease	Reference value: high	12082009 Two waterholes fed by in-bed fractured rock springs and by occasional rain-fed water flows, in creek bed in half gorge *Crinia* sp nov No fishes

Figure 11 Site 10, Aroona Creek pool 250 m downstream of Dam.

Figure 12 Site 11, Aroona Creek pool 800 m downstream of Dam..

Figure 13 Site 12, Retention Dam, Leigh Creek.

Figure 14 Site 14, main upstream pool St Mary's Pool complex, MacDonnell Creek.

Base-line and field data: distribution and ecological records for the frogs and fishes of the Flinders Ranges and associated watercourses

The eight species of frogs and 11 species of extant fishes known from the Flinders Ranges are listed in Table 1. Images of most of these species are in Figures 28 to 43.

The ecological and conservation information on frogs and fishes of the Flinders Ranges is in the publications listed in the References (with annotations where needed).

The Discussion section and other parts of this report includes sufficient information for the writing of community information leaflets to engage rangelands residents in opportunistic frog and fishes monitoring work following rainfall and flooding events.

A new and unexpected development was the existence of a second crypto-species of Flinders Ranges froglet which has to now been taxonomically undifferentiated from the nominate *Crinia riparia*. The new undescribed species occurs in the northern part of the published range of these now two species (S. Donnellan, *pers. comm.*).

The distribution of the Flinders Springs Froglet (proposed common name for the *Crinia* sp. nov.) was extended northward to Walparindina Springs on Mount Freeling Station.

The Flinders Ranges Purple Spotted Gudgeon population at Nepowie Spring and its long flowing tail was checked and was found to be at the same high abundance of 5 to 50 (mean = 9.7, n = 10) fish per square metre as when previously examined by the author in 2002. None were collected as this site has been well sampled in the recent past.

Voucher specimens

Twelve voucher specimens of three species of frogs (the northern undescribed taxon of Flinders Ranges froglet *Crinia* sp nov, the Spotted Marsh Frog *Limnodynastes tasmaniensis*, and the Desert Tree Frog *Litoria rubella*) and about 35 voucher specimens of seven species of fishes have been lodged in the South Australian Museum. See Table 4.

Figure 15 Site 14, main upstream pool St Mary's Pool complex, MacDonnell Creek. Clearing the fyke net into sorting bucket.

Figure 16 Site 14, Bucket with fish and hiding tubes. Hand net and measuring frame below the bucket.

Table 4 Voucher specimens lodged in the South Australia Museum in order of collection.

See Table 3 for dates.

Species	Specimen type	South Australian Museum registration number	Locality
Limnodynastes tasmaniensis	Live adult frog for whole specimen and liver for frozen tissue collection	R64538	Parawilia Waters
Limnodynastes tasmaniensis	Live adult frog for whole specimen and liver for frozen tissue collection	R64539	Angiroonoy Springs
Crinia sp. nov.	Two live adult frogs for whole specimen and livers for frozen tissue collection	R64544 & 5	Angiroonoy Springs
Crinia sp. nov.	Two live adult frogs for whole specimen and livers for frozen tissue collection	R64542 & 3	Narrina Spring
Litoria rubella	Two live adult frogs for whole specimen and livers for frozen tissue collection	R64540 & 1	Big Spring
Gambusia holbrooki	Several field preserved fish	Not available	Downstream of Aroona Dam wall
Craterocephalus eyresii.	Several field preserved fish	Not available	Leigh Creek Retention Dam
Hypseleotris klunzingeri	Several field preserved fish	Not available	Leigh Creek Retention Dam
Nematolosa erebi	One field preserved fish	Not available	St Marys Pool
Craterocephalus stercusmuscarum taxonomic status uncertain	Several field preserved fish	Not available	St Marys Pool
Melanotaenia splendida tatei	Two field preserved fish	Not available	St Marys Pool
Leiopotherapon unicolor	Two field preserved fish	Not available	St Marys Pool
Hypseleotris klunzingeri	Several field preserved fish	Not available	St Marys Pool
Leiopotherapon unicolor	Fin clip in alcohol	Not available	Brindana Spring waterhole
Crinia sp. nov.	Live adult frog for whole specimen and liver for frozen tissue collection	R64842	Walparindina Springs
Crinia sp. nov.	Live tadpole for whole specimen frozen tissue collection	EBU M048	Walparindina Springs
Crinia sp. nov.	Field preserved tadpole	R64840	Walparindina Springs
Crinia sp. nov.	Field preserved metamorph	R64841	Walparindina Springs

DISCUSSION

Springs flows and condition

The diminished flows and water levels of most if not all of the eight fractured-rock springs examined (one was extinct) is cause for concern. The reductions are presumably due to prolonged drought and also water table deflation. Clarke *et al* (2007) reported that Narrina Spring had a flowing tail of about 1 km in June 2005 while during the current study the spring flow tail had diminished to two consecutive rock pools in a total stream distance of about 25m (April 2009).

The intriguingly named Big Spring on Nantawarinna had no surface flow at all (despite the evidence of large amounts of natural stream bed concrete indicating significant flows in the historic past). It may have been rendered extinct some time ago by water extraction from nearby bores put down to supply pastoral activities. Natural stream bed concrete was also seen at other sites in the vicinity of other extinct or greatly diminished springs, indicating that there may be a general trend of diminishing flows.

Seven other fractured-rock springs (Parawilia Waters, Prelinna Hut Spring, Angiroonoy Springs, Narrina Spring, Bora Spring, Brindana and Terrapinna) all showed significant signs of depleted or no flow.

Also of concern is that many of the 11 Great Artesian Basin springs examined showed some signs of declined flows, one was extinct (Petermorra), while one appears not to have diminished in the very recent past. Nepowie Spring was the only one in which the flow rate and tail were not diminished compared to a previous visit in 2002, however its longer term (past) flow rates are not known. Other lesser springs (presumed to be GAB-fed) in the general area near Nepowie are known to have diminished or ceased in flow.

Figure 17 (left) Site 15, gauging station pool St Mary's Pool complex, MacDonnell Creek. Dense fringing *Phragmites australis*.

Figure 18 (right) Site 16, Dean's Bore wetland.

Figure 19 (left) Site 17, first Chimney Springs, Petermorra Creek. Setting fish trap.

Figure 20 (right) Site 18, second Chimney Springs, Petermorra Creek. Mound spring vent to left and another in centre of view, note salt.

Figure 21 (left) Site 19, third Chimney Springs, Petermorra Creek. Several mound springs, vehicle crossing (tracks).

Figure 22 (right) Site 20, fourth Chimney Springs, Petermorra Creek. The deepest pool seen.

Figure 23 (left) Site 23, Twelve Springs complex, to Yerila Creek. Moolawatana Station.

Figure 24 (right) Site 24, Terrapinna Springs, Hamilton Creek. Moolawatana Station.

Figure 25 (left) Site 23, Brindana Springs and pool, Hamilton Creek. Mt Freeling Station.

Figure 26 (right) Site 24, Walparindina Springs and pools, MacDonnell Creek. Mt Freeling Station.

Figure 27 Site 24, Walparindina Springs and pools, MacDonnell Creek. A small landlocked rock pool with approximately 500ml of water (shaded most of the day). It contained about 20 large *Crinia* sp nov tadpoles (two visible in water near the lens cap) in average condition but with little or no tail damage.

Frogs

The Flinders Stream Froglet (*Crinia riparia*) and the Flinders Springs Froglet (*Crinia* sp. nov.)

Figure 28 Flinders Springs Froglet (*Crinia* sp nov) Narrina Spring. Smooth back morph on left and lyrate back morph on the right.

Figure 29 Flinders Springs Froglet (*Crinia* sp nov) tadpoles. Angaroonoy Springs. Note tail damage in some due to dragonfly larvae attacks.

A new and unexpected development was the existence of a second crypto-species of Flinders Ranges froglet which has to now been taxonomically undifferentiated from the nominate *Crinia riparia* (S. Donnellan, *pers. comm.*) This discovery highlights the importance of taking voucher specimens for Museum and cyto-taxonomic research during any field work (Hutchinson 2001).

Better information is needed about the distribution of the two endemic species of the more southerly Flinders Streams Froglet (proposed common name for *Crinia riparia*) and the closely related but genetically distinct more northern Flinders Springs Froglet (proposed common name for the *Crinia* sp. nov.).

The relatively widespread Flinders Streams Froglet (*Crinia riparia*) occurs along streams and near other long-term water in the southern half of the Flinders Ranges (from about south of Warren Gorge to the Rocky River, S. Donnellan, *pers. comm.*) where it shelters in deep cool refuges during drier weather. It breeds in the cooler months. It is restricted to ranges country and is apparently Secure. Its distribution is extensive in the Northern and Yorke NRM region.

The Flinders Springs Froglet (*Crinia* sp. nov.) occurs mostly at springs and other near-permanent waters in cooler gullies of the northern half of the Flinders Ranges (from about north of Warren Gorge, S. Donnellan, *pers. comm.*) where it shelters in deep cool refuges. It is probably a winter breeder but may also be opportunistic. It is apparently restricted to ranges country and is probably Vulnerable. Its distribution is extensive in the SAAL NRM region.

The persistent drought conditions during this pilot study limited the amount of work that could be done on the Flinders Springs Froglet (*Crinia* sp. nov.). None-the-less its known distribution was extended northward to Walparindina Springs on Mount Freeling Station. This location confirms the species in the northward-flowing MacDonnell Creek which is part of the Lake Blanche/Strzelecki Creek sub-drainage of the lake Eyre Basin. This creek system is also important for fishes and highlights the need for further evaluations and better management of the biodiversity of the northward flowing watercourses.

Figure 30 (left) Site 24 two small and one large paler *Crinia* sp nov tadpoles, note distal tail damage in smaller tadpoles, due to dragonfly larvae predation attempts. From deep main pool.

Figure 31 (right) Site 24 one dark *Crinia* sp nov tadpole from small landlocked pool (see Fig 27), Walparindina Springs MacDonnell Creek. Mt Freeling Station.

Spotted Marsh Frog

Figure 32 Spotted Marsh Frog (*Limnodynastes tasmaniensis*). Parawilia Waters.

This widespread Secure species (*Limnodynastes tasmaniensis*) occurs in more reliable watercourses in the ranges and some associated lower lands and plains where it can shelter in deep well-shaded refuges. It is an opportunistic breeder with a preference to breed in cooler months.

This species is a potential indicator species of habitat change in the Flinders Ranges due to its relatively widespread occurrence and the ease with which it can be detected by aural (call) census and its easily detected and identified tadpole.

Desert Trilling Frog

Figure 33 Breeding Desert Trilling Frogs in amplexus.

This widespread arid-adapted Secure burrowing species (*Neobatrachus centralis*) occurs in areas with softer homogeneous soils esp. sands on plains and footslopes associated with the Flinders Ranges. It is an opportunistic breeder with a preference to breed in warmer months. The species is mostly cryptic and remains underground in its own vertical back-filled shaft during dry weather, but following rains many

individuals can suddenly appear on the surface (Ehmann 2006). At such times co-habiting rangelands residents frequently remark on their sudden appearance and abundance.

This species is a potential indicator species of habitat change in the Flinders Ranges due to its relatively widespread occurrence and the ease with which it can be detected following good rains.

Painted Trilling Frog

Figure 34 Painted Trilling Frogs, male on left, female on right.

This Secure burrowing species (*Neobatrachus pictus*) is largely distributed to the south of the Flinders Ranges but does get into their southern half. It occurs in areas with softer homogeneous soils esp. sandy clays on plains and footslopes. It is a winter breeder. The species is mostly cryptic and remains underground in its own vertical back-filled shaft during dry weather, but following winter rains it is active on the surface. At such times it is not as explosively abundant as the Desert Trilling Frog (Ehmann 2007).

This species is a potential indicator species of habitat change in the mid and southern Flinders Ranges due to its relatively widespread occurrence and the ease with which it can be detected following winter rains.

Flinders Ranges Toadlet

This Vulnerable and possibly Endangered toadlet (*Psuedophryne* sp. nov.) occurs mostly at springs and other persistent surface waters with suitable dense ground vegetation in the northern half of the Flinders Ranges (from about north of Warren Gorge and Moukra Towers, S. Donnellan, *pers. comm.*). It is restricted to ranges country where it shelters in deep cool refuges and can burrow into moist soil to avoid drying conditions. It is probably a predominantly winter breeder but is likely to be opportunistic if sufficient rains occur.

During the field work conditions for detecting the Flinders Ranges Toadlet (*Psuedophryne* sp. nov.) were too dry and many parts of the Ranges are still in the grip of drought. This species may have suffered significant local extinctions during the prolonged drought. Population and status assessments are urgently needed.

Green Tree Frog

This well-known tree frog (*Litoria caerulea*) is not considered to be part of the frog fauna of the Flinders Ranges. It occurs mostly in eastern Australia with inland populations associated with the many inland rivers, including the Cooper Creek (eg at Coongie Lakes). There is a single verbal report of a calling male at a northern Flinders Ranges waterhole (possibly Terrapinna on the Hamilton Creek) sometime in the mid 1970's. This has a parallel in the single detection of Lake Eyre Callop in the same creek soon after 1975 (Pearce *et al* 2002, and see below). Both these species may have come down the Strzelecki Creek in the major floods in the mid 1970's. Such dispersal events are of great interest although they may not result in successful natural colonisation of the Flinders Ranges. The species shelters in deep well-shaded tree hollows, caves and deep soil crevices. It is an opportunistic breeder with a tendency to breed in the warmer months. Its presence (persistence) in the Flinders Ranges needs to be confirmed.

During the field work conditions for detecting the Green Tree Frog were too dry and the northern Flinders Ranges were still in the grip of severe drought. This species may have persisted despite the prolonged drought if any extant individuals found suitable refuges. Play-back of recorded calls following rain is recommended at possible sites where the species may have persisted.

Desert Tree Frog

Figure 35 Desert Tree Frog (*Litoria rubella*). Big Spring.

This widespread arid-adapted Secure tree frog (*Litoria rubella*) is associated with substantial watercourses with larger trees in and surrounding the Flinders Ranges where it shelters in deep well-shaded tree hollows, deep recesses and under bark. It is an opportunistic breeder with a preference to breed in warmer months. The

species is generally cryptic and remains under cover during dry weather, but following rains individuals become more active in the open on the vertical and sloping elevated surfaces and on the ground (Ehmann 2006). At such times co-habiting rangelands residents notice their appearance.

This species is a potential indicator species of habitat change in and around the Flinders Ranges due to its relatively widespread occurrence and the ease with which it can be detected following good rains.

Fishes (see also **Other native species** below**)**

Bony Bream

Figure 36 Bony Bream, St Mary's Pool, MacDonnell Creek.

This widespread arid arid-adapted Secure mid-water and near-bottom species (*Nematolosa erebi*) occurs in many deeper waterbodies that are flow-linked to refugia waterholes during rains.

This species is a potential indicator species of habitat change in and around the Flinders Ranges due to its relatively widespread occurrence and the ease with which it can be caught and identified.

Lake Eyre Hardyhead

Figure 37 Lake Eyre Hardyhead. Retention Dam, Leigh Creek

This widespread arid arid-adapted Secure mid-water schooling species (*Craterocephalus eyresii*) can tolerate a wide range of salinity and temperature occurs opportunistically in many waterbodies that are flow-linked to refugia waterholes during rains.

This species is a potential indicator species of habitat change in and around the Flinders Ranges due to its relatively widespread occurrence and the ease with which it can be seen and caught in traps and nets.

Fly-specked Hardyhead

Figure 38 Fly-specked Hardyhead, St Mary's Pool, MacDonnell Creek.

This very restricted Vulnerable mid-water schooling species (*Craterocephalus stercusmuscarum* taxonomic status uncertain) is to date in South Australia only known from the Saint Marys Pool group of waterbodies in MacDonnell Creek. It probably has narrower ranges of tolerance for temperature and salinity than *Craterocephalus eyresii*.

This species is an excellent indicator species of habitat change due to its very restricted occurrence and the ease with which it can be detected. Further laboratory work is needed to better inform its taxonomic status and relationship to closely allied forms. Further field work is needed in the environs of the MacDonnell Creek to ascertain the degree of its restricted distribution.

Desert Rainbow Fish

Figure 39 Desert Rainbow Fish, St Mary's Pool, MacDonnell Creek.

This generally widespread but locally restricted Secure arid-adapted mid-water species (*Melanotaenia splendida tatei*) is to date in the Flinders Ranges area only known from the Saint Marys Pool group of waterbodies in MacDonnell Creek and from Myrtle Springs. It is probably has narrower ranges of tolerance for temperature and salinity than other arid-adapted species.

This species is an excellent indicator species of habitat change due to its restricted occurrence and the ease with which it can be detected. Further field work is needed in the Flinders Ranges and its environs to ascertain the degree of its restricted distribution.

Lake Eyre Callop

This well-known fish (*Macquaria* sp nov) is also known as Yellowbelly. It is not considered to be part of the fish fauna of the Flinders Ranges and its associated watercourses. It is a widespread deeper water species in the Lake Eyre Basin including the Cooper Creek (eg at Innamincka) from where it can and probably has dispersed down the Strzelecki Creek to Lake Blanche and to Lake Frome during exceptional rain and flood events.

Pearce *et al* 2001 report photographic evidence of this species' occurrence in the Hamilton Creek (on Moolawatana or Mount Freeling Stations) which flows to Lake Frome soon after the 1975 floods. The species presence in or near the Flinders Ranges has not been confirmed since.

This occurrence has a parallel in the single detection of a calling male Green Tree Frog at a northern Flinders Ranges waterhole (possibly Terrapinna on the Hamilton Creek) sometime in the mid 1970's. Both these species may have come down the Strzelecki Creek in the major floods in the mid 1970's. Such dispersal events are of great interest although they may not result in successful natural colonisation of the Flinders Ranges.

Its presence (or persistence) in the Flinders Ranges needs to be confirmed, and persons visiting remote and inaccessible waterholes such as on the Mawson Plateau are well placed to make detections if the species has persisted in such a place. If one of these should be caught it would be prudent to return it as quickly as possible to the water after taking a photograph for reporting the find.

Spangled Grunter

Figure 40 Spangled Grunter, St Mary's Pool, MacDonnell Creek.

This most widespread arid arid-adapted Secure mid-water species (*Leiopotherapon unicolor*) can tolerate a wide range of water quality and is very aggressive towards other species. These characteristics help to explain its sole persistence in many drought-reduced waterbodies and why smaller species disappear. It occurs in flow-linked refugia waterholes and during and following rains and it has remarkable capacities to disperse to other water bodies in rain-flooded country.

This species is a potential indicator species of habitat change in and around the Flinders Ranges due to its relatively widespread occurrence and the ease with which it can be caught by rod fishing and trapping, and also identified.

Desert Goby

This generally widespread but locally restricted Secure arid-adapted bottom species (*Chlamydogobius eremius*) can tolerate a wide range of salinity and temperature and occurs in many lowland waterbodies that are flow-linked to refugia waterholes during rains. It is not found in the actual Flinders Ranges but in waterbodies on the surrounding foothills and plains, and in some mound springs.

This species is a good indicator species of habitat change due to its widespread occurrence and the ease with which it can be detected.

Carp Gudgeon

Figure 41 Carp Gudgeon. Retention Dam, Leigh Creek.

This generally widespread but locally restricted Secure arid-adapted near-bottom species (*Hypseleotris klunzingeri*) can tolerate a range of salinity and temperature and occurs in a few low-gradient waterbodies around the Flinders Ranges. It is known from Saint Marys Pool and the Leigh Creek Retention Dam.

This species is a good indicator species of habitat change due to its apparently restricted occurrence in the immediate vicinity of the Flinders Ranges and the ease with which it can be detected.

Flinders Ranges Purple-spotted Gudgeon

Figure 42 Flinders Ranges Purple-spotted Gudgeon (*Mogurnda clivicola*). Nepowie Spring. There are at least 10 individual fish in this photograph of an 80 X 60 cm opening in algal in-water growth.

This very restricted bottom-dwelling Vulnerable species is to date only known in South Australia from the Balcanoona Creek and tributaries in permanent spring-fed waterbodies. A second translocated population is well-established in the outflow of Nepowie Springs. Two interstate occurrences of this species are based on a single specimen record from the Bulloo River and several from the Barcoo River in Queensland.

Further laboratory work is needed in to better inform its taxonomic status and relationships with the Queensland occurrences. Further targeted field work is also warranted to ascertain whether this species occurs in as-yet undiscovered sites.

The population at Nepowie Spring is believed to have been introduced relatively recently to the spring's substantial outflow from the nearby but unconnected Balcanoona Creek system. The existence of this substantial thriving second known population in Nepowie makes it an ideal surrogate monitoring and demonstration site for this species. This is particularly the case because the Balcanoona Creek and the tributary Weetootla Creek population is dispersed throughout many small and relatively inaccessible spring-sustained rock pools within the Vulkathunha – Gammon Ranges Conservation Park.

The population at Nepowie Spring and its long flowing tail was checked in April 2009 and was found to be at the same high abundance of 5 to 50 (mean = 9.7, n = 10) fish per square metre as when previously examined by the author in 2002. None were collected as this site has been well sampled in the recent past. The species appears to be thriving in the Nepowie Springs outflow.

The monitoring of this species needs to be done by persons with appropriate expertise, well-trained persons or at least persons well supervised by an expert.

Other native species

The Retention Dam at Leigh Creek has significant potential as a refuge site for native species, and at least eight native species from the Cooper Creek have been stocked into it (Pierce *et al* 2001) with as yet unknown success. "The species include Bony Bream, … Lake Eyre Callop, … the three species of catfish [occurring in the Cooper], Glassfish, Australian Smelt, Welsh's Grunter, and other small fish species [not specified] native to the lower Cooper Creek in South Australia" (Pirece et al 2001, p 28, 29). Most of these species (except Bony Bream and Lake Eyre Callop) are not dealt with above due to their uncertain persistence and establishment in the Retention Dam. The above named species are dealt with in detail in Ehmann (2006).

Plague Minnow

Figure 43 A large number of Plague Minnows (*Gambusia holbrooki*). Aroona Creek picnic area, 800 m downstream from Dam. The black fish shapes are the fishs' shadows, actual fish are easiest to see when they directly in line with shadowed substrate (see shadows of stick and rock).

The introduced pest Plague Minnow (*Gambusia holbrooki*) seems not to be widespread in the Flinders Ranges. This aggressive surface schooling fish that can tolerate wide fluctuations in temperature and oxygen availability is highly invasive and almost useless as a mosquito larvae control species.

It has mistakenly been introduced to some accessible sites (Aroona Dam, Leigh Creek Retention Dam) from which it may be dispersed further by uninformed human activity. Actively informing the Flinders Ranges communities can reduce the risk of further spreading this species.

Any fish survey work needs to be on the look-out for this species, and the community needs to be informed and encouraged to report any occurrences or sightings.

European Carp

The introduced pest European Carp (*Cyprinus carpio*) is a prolific bottom and mid-water fish that can tolerate wide fluctuations in temperature and oxygen availability. It is highly invasive and almost useless as a food species. It was deliberately and illegally introduced to the Leigh Creek Retention Dam, from which the species may be dispersed further by uninformed human activity. Fortunately it is not widespread in the Flinders Ranges and every effort needs to be made to keep it that way and to prevent its further spread, particularly into the Lake Eyre Basin watercourses.

Actively informing the Flinders Ranges communities can reduce the risk of further spreading this species.

Any fish survey work needs to be on the look-out for this species, and the community needs to be informed and encouraged to report any occurrences or sightings.

Protocol for ongoing work

This project has been carried out under difficult seasonal conditions and with limited resources. The invariable administrative expectations from the Australian Government that appear unable to take the extreme seasonal and resources problems into account do not help.

None-the-less this pilot project has resulted in the generation of a **Protocol for base-line field studies of the distribution and abundance of the frogs and fishes of the Flinders Ranges.** This is provided in the Conclusions and recommendations.

CONCLUSIONS AND RECOMMENDATIONS

General recommendations for further frogs and fishes work

Survey and monitoring work for frogs and fishes needs to be well-timed to optimise the outputs. The timing needs to ensure optimum detections for the following reasons:

1. For frogs because in moister conditions their not-so-cryptic refuging places make them easier to detect by hand searching under cover, and they have on-going and well-established seasonal calling patterns.
2. For tadpoles because in moister conditions they are likely to be present, persistent and at optimal sizes and stages for detection and identification.
3. For fishes because after the initial flows of water laden with the heavy first-flow sediments have had a chance to settle detections and netting becomes more efficient. The time that elapses since the first significant rains in the area will also allow some breeding and recruitment to occur thus improving detection potential.

Assessments of at least 40 of the approximately 250 identified surface waters will need to be made to get a reasonable inventory of the springs and waterhole dependent frogs and fishes of the Flinders Ranges, particularly with diminished water flows and drought impacts that have occurred in the recent past.

Follow-up assessments at many of the sites examined during this study as well as additional sites are recommended to monitor frog and fishes population trends, to evaluate the various impacts including abnormal drought (?climate change), habitat loss, feral animals and changed water flow, land use and grazing practice, and to improve the quality of distributional and trends data.

There are significant overlaps in the distributions of some of the species of this pilot study into the Northern and Yorke NRM region to the SAALNRM region's south. it is recommended that to comprehensively understand and manage the frogs, fishes and Desert Jewels of the whole of the Flinders Ranges collaborative field evaluations with the Northern and Yorke NRM in their parts of the Flinders Ranges are needed.

The threats to the frogs and fishes of the Flinders Ranges are outlined under a specific heading in the Introduction (see page 13), and these need to be managed and minimised.

Translocations of native fishes to the Retention Dam at Leigh Creek have been carried out in the past (Pierce *et al* 2001) with uncertain success. Those translocations need to be evaluated and followed up with specific monitoring activities. Such evaluations and follow-ups can inform any potential future plans to utilise the artificial waterbodies as native fishes refugia as a hedge against adverse consequences of habitat and climate change. See below for further details.

Recommendations for further specific frog work

Further specialised work is recommended to more accurately determine the distribution of the two endemic species of the more southerly Flinders Streams Froglet (proposed common name for *Crinia riparia*) and the closely related but genetically distinct more northern Flinders Springs Froglet (proposed common name for the *Crinia* sp. nov.), particularly after the persistent drought conditions abate.

See also the individual species accounts in the Discussion section for recommendations of a wide range of specific further NRM work.

Recommendations for further specific fishes work

See the individual species accounts in the Discussion section for recommendations of a wide range of specific further NRM work.

The Aroona Creek below the Aroona Dam presents a unique opportunity for the improved management of fishes diversity in the Flinders Ranges and environs. The creek appears to have a slow but reliable permanent surface water flow due to leakage from the dam via minor split-rock aquifers.

This section of the Aroona Creek needs to be evaluated for its potential as a refuge for endemic native fishes, including the Lake Torrens form of the Lake Eyre Hardyhead. The presence of abundant Plague Minnows in this creek complicates the possibilities, but the potential should be determined and possibly tested with monitored trial translocations following evaluations of Plague Minnow impacts.

The Retention Dam at Leigh Creek is one of two large effectively permanent artificial waterbodies in the study area (the other being Aroona Dam). It has significant potential as a refuge site for native species, and at least eight native species have been stocked into it (Pierce *et al* 2001) with as yet unknown success. This waterbody needs to be carefully and systematically sampled to ascertain which of these species have become established and how the established species are faring.

Some of the work needed in both the Aroona Creek (below the Dam) and in the Retention Dam could be carried out with the involvement of the local community of Leigh Creek township (see below).

Recommendations for further specific biodiversity work

Further biodiversity evaluations and better management of the biodiversity is recommended in the northward-flowing MacDonnell Creek and nearby systems which are part of the Lake Blanche/Strzelecki Creek sub-drainage of the lake Eyre Basin. This creek system is important for its diversity of fishes and the presence of the Flinders Springs Froglet (proposed common name for the *Crinia* sp. nov.) in its headwaters. It is likely that there are also other species of interest to NRM in this area which is biologically relatively unexplored.

Community engagement recommendations

That the Leigh Creek community (including the school) be engaged in some of the field work (e.g. survey, sampling, data collection) needed in both the Aroona Creek (below the Dam) and in the Retention Dam. Such involvement needs to be well designed and worked out with the community to maximise positive outcomes for both NRM and the community's various interests (e.g. assisting monitoring, fishing, Landcare). Such involvement will raise community awareness of the issues relating to native fishes conservation in the Flinders Ranges (see also below).

That information signs be placed at known occurrences (eg Aroona Dam, Leigh Creek Retention Dam) of the introduced pest Plague Minnow (*Gambusia holbrooki*) to discourage further dispersal by human activity of this and other species. Information leaflets and the use of visual media are also recommended.

That information leaflets be prepared to engage rangelands residents in opportunistic frog and fishes monitoring work following rainfall and flooding events. The Discussion section includes sufficient information for the writing of community information leaflets.

Such information leaflets can include contingencies for extreme flooding events that can result in some native species dispersing beyond their ranges (see Green Tree Frog and Lake Eyre Callop in the Discussion section). Such events may also result in the potential incursion of pest species such as the Cane Toad, European Carp and Plague Minnow from relatively long distances away.

A protocol for base-line field studies of the distribution, abundance and environmental health of the frogs and fishes of the Flinders Ranges

The following protocol which needs to be informed by the South Australian Biological Survey Guidelines for Fauna Surveys is recommended:

A protocol for base-line field studies of the distribution, abundance and environmental health of the frogs and fishes of the Flinders Ranges

1. Obtain or compile a register of all surface waters that may support frogs and fishes by using any existing data bases, available maps, publications and other sources.

2. Plot the potential sites to a suitable map with property boundaries, roads, topographic data to determine the most effective and cost efficient travel and access for field work.

3. Contact property owners and managers by telephone and also in person as necessary for current information about the springs identified on mapping. Information sought should include 1) the permanence and flow rate of each spring, 2) the quality and use made of the water, 3) the nature of fringing and in-water vegetation, 4) and whether any frogs, tadpoles or fish had ever been seen or caught.

4. Rationalise the site visits to be made.

5. Field evaluate each selected site for it's suitability for further monitoring work and measure and record standard site variables.

6. Apply the complete range of site-specific and conditions-specific detection techniques for frogs (night-time and day-time searching and aural detection, netting and bait trapping of tadpoles) and fishes (night-time and day-time searching and visual detection, dip and fyke netting, and bait trapping).

7. Record a standard comprehensive set of site data including site conditions and any apparent and likely environmental impacts.

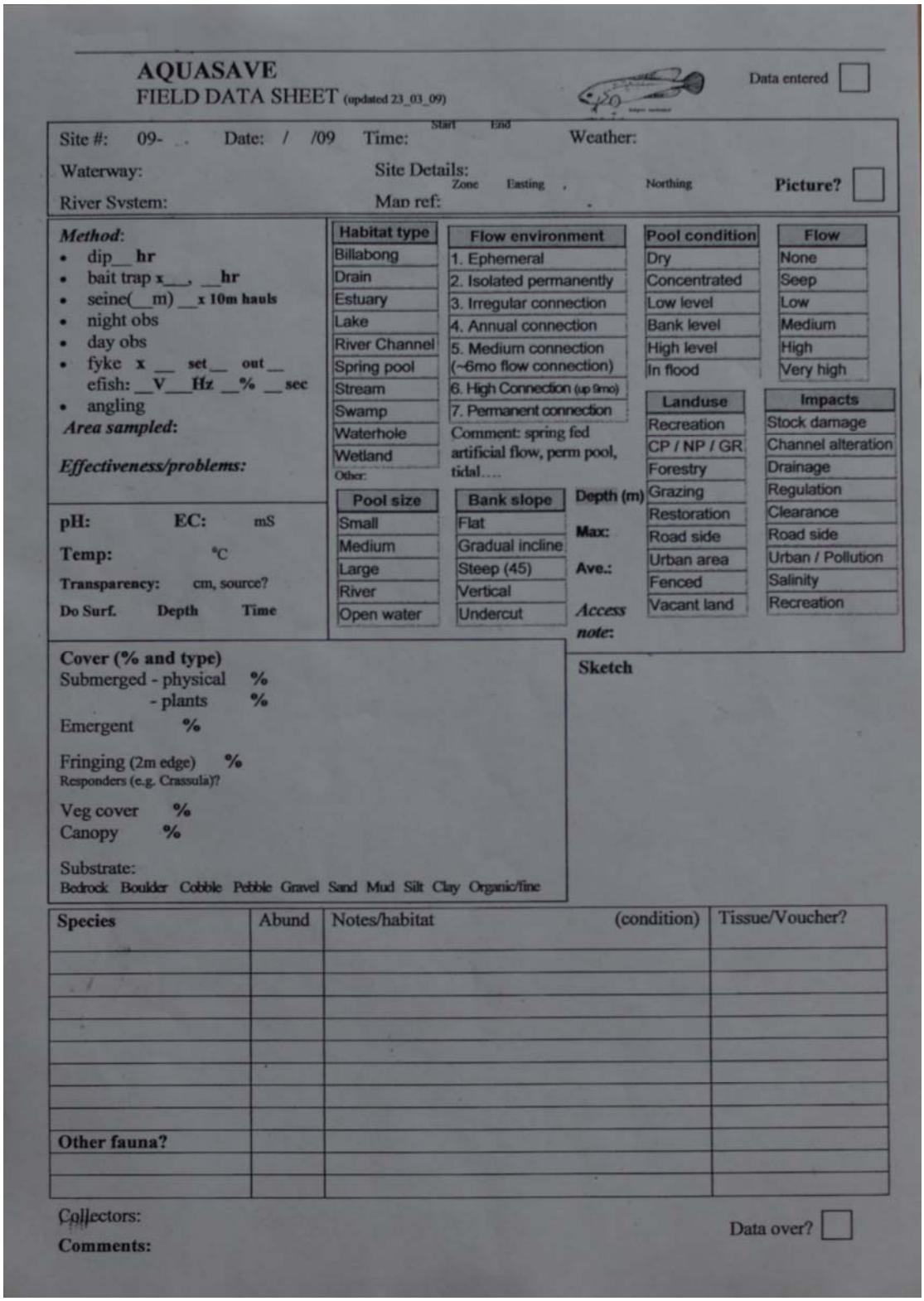
8. Record the diversity, abundance, sizes and condition of frogs, tadpoles and fishes.

9. Take digital images of the site and specimens seen and caught.

10. Take and lodge representative and minimal samples of frogs, tadpoles and fishes in the South Australian Museum or another similar institution for further research work.

APPENDICES

Site data form



AQUASAVE
FIELD DATA SHEET (updated 23_03_09)

Data entered ☐

Site #: 09- . . Date: / /09 Time: Start End Weather:

Waterway: Site Details:

River System: Map ref: Zone Easting , Northing Picture? ☐

Method:
- dip__ hr
- bait trap x___, __hr
- seine(__m) __x 10m hauls
- night obs
- day obs
- fyke x __ set__ out__
  efish: __V__Hz __% __sec
- angling

Area sampled:

Effectiveness/problems:

Habitat type
Billabong
Drain
Estuary
Lake
River Channel
Spring pool
Stream
Swamp
Waterhole
Wetland
Other:

Flow environment
1. Ephemeral
2. Isolated permanently
3. Irregular connection
4. Annual connection
5. Medium connection (~6mo flow connection)
6. High Connection (up 9mo)
7. Permanent connection

Comment: spring fed artificial flow, perm pool, tidal....

Pool condition
Dry
Concentrated
Low level
Bank level
High level
In flood

Flow
None
Seep
Low
Medium
High
Very high

Landuse
Recreation
CP / NP / GR
Forestry
Grazing
Restoration
Road side
Urban area
Fenced
Vacant land

Impacts
Stock damage
Channel alteration
Drainage
Regulation
Clearance
Road side
Urban / Pollution
Salinity
Recreation

Pool size
Small
Medium
Large
River
Open water

Bank slope
Flat
Gradual incline
Steep (45)
Vertical
Undercut

Depth (m)
Max:
Ave.:
Access note:

pH: EC: mS
Temp: °C
Transparency: cm, source?
Do Surf. Depth Time

Cover (% and type)
Submerged - physical %
- plants %
Emergent %
Fringing (2m edge) %
Responders (e.g. Crassula)?
Veg cover %
Canopy %

Substrate:
Bedrock Boulder Cobble Pebble Gravel Sand Mud Silt Clay Organic/fine

Sketch

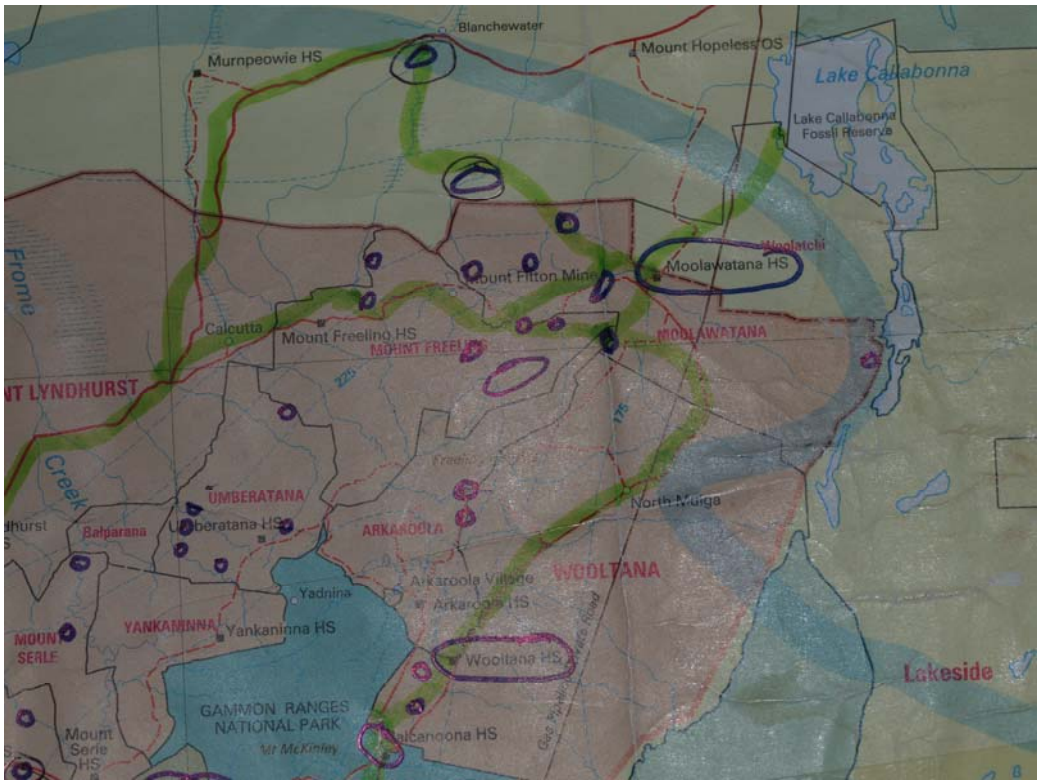
Species	Abund	Notes/habitat (condition)	Tissue/Voucher?
Other fauna?			

Collectors:
Comments:

Data over? ☐

Marked-up map used to plan field work in this pilot project

Flinders Ranges (including Gammon Ranges) area on the Pastoral map of South Australia, with mark-up showing surface waters of significance (mostly springs) transposed from old pastoral mapping (blue circles). Some property names and some towns are also encircled in blue.



Northern and southern Gammon Ranges area on the Pastoral map of South Australia, with mark-up showing surface waters of significance (mostly springs) transposed from old pastoral mapping (blue circles). Some property names and towns are also encircled in blue.

REFERENCES

Most of these are annotated, as they are of direct use in the field.

Biological Survey and Research Section 2001. *Guidelines for vertebrate survey in South Australia*. Department of Environment and Heritage, South Australia. This publication outlines the best-practice for field work involving vertebrate animals.

Brandle R (ed) 2001. *A biological survey of the Flinders Ranges South Australia 1997-1999*. Department for Environment Heritage and Aboriginal Affairs, South Australia. This publication includes comprehensive general information on the distribution of fishes and frogs in the whole of the Flinders Ranges, including frog species that occur only to the south of the present study area. It was written when only a single endemic species (*Crinia riparia*) was recognised for the Flinders Ranges (there are now three endemic species). For annotation regarding fishes in this publication see Pierce *et al* 2001 below.

Clarke I, Sharrad R and Aebi R 2007. *Groundwater resources, waterholes and dependent ecosystems in the Flinders Ranges*. A report for the SAALNRM Board by the Geoscience Research Group, University of South Australia.

Ehmann H 2006. *South Australian Rangelands and Aboriginal Lands wildlife Management Manual*. Department of Water, Land and Biodiversity Conservation, South Australia. This manual has detailed accounts of all the fishes and frogs that occur in the Flinders Ranges and surrounding areas, including identification aids, distribution information and biological/ecological information for each species. It will be particularly useful for identifying any species of native fishes that have been translocated into the Retention Dam at Leigh Creek.

Hammer M, Wedderburn S and van Weenen J 2007 (Draft). *Action Plan for South Australian Freshwater Fishes: 2007 – 2012*. Native Fish Australia (SA) Inc., Adelaide. This is available on the internet (access with Google). It covers all South Australian species that are Endangered and Vulnerable, and specifically includes the Flinders Ranges Purple-spotted Gudgeon and the Fly-specked Hardyhead from the study area. It also provides substantial details about threatening processes for fish.

Hutchinson M 2001. Issues relating to the taking of voucher specimens for biological survey work. Appendix 20 in *Guidelines for vertebrate survey in South Australia*. Department of Environment and Heritage, South Australia.

Pierce B E, Young M and Sim T 2001. Flinders Ranges Fishes. Pp 25-33 in Brandle R (ed). *A biological survey of the Flinders Ranges South Australia 1997-1999*. Department for Environment Heritage and Aboriginal Affairs, South Australia. This chapter summarises the fishes known from the mountainous parts of the Ranges and excludes species that are restricted to the waterbodies on the proximate plains around the Ranges. It also refers to the introduction of significant stocks of more than six native species from the lower Cooper Creek into the Retention Dam at Leigh Creek “in order to create artificial refugia for these species (as well as to meet other local community needs).”