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Assessment of endemic fish (*Mogurnda clivicola*) and native vegetation at springs in the northern Flinders Ranges

Dale McNeil, Melissa White and David Schmarr

ASSESSMENT OF ENDEMIC FISH (*MOGURNDA CLIVICOLA*) AND NATIVE VEGETATION AT SPRINGS IN THE NORTHERN FLINDERS RANGES

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Report to the South Australian Arid Lands Natural Resources Management Board

Government of South Australia
Department for Water

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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Cover images:

Mudlapena Spring, Finke Creek at Angepena Station (photo: Melissa White) and the Flinders Mogurnda, *Mogurnda clivicola*, (male) guarding eggs in Nepouie Spring, northern Flinders Ranges, South Australia (photo: Dale McNeil).

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EXECUTIVE SUMMARY

Fish Survey

The Flinders Ranges Mogurnda (*Mogurnda clivicola*) is one of South Australia's most critically endangered fish species. To ensure the continued survival of this species more recent information was needed, as the available literature was limited and did not account for the species' current distribution, population status and biological health. This project provides strong links and information to the South Australian government's State-wide 'No Species Loss' conservation strategy; a strategy that aims to protect the State's diverse ecosystems and their associated native plants, animals and habitats (DEH, 2007).

Prior to this study, three known locations of *M. clivicola* were recorded in the Northern Flinders Ranges (South Australia), although two of these populations are believed to be translocated populations. The current status of the source/native population and the survival of the two translocated populations were unknown. In addition, literature from the late 1990's reported that individual fish within the Weetootla population were in poor condition; showing signs of discolouration and possible evidence of cancerous melanomas.

This project was initiated by the South Australian Arid Lands (SAAL) Natural Resources Management (NRM) Board with funding from Department of Environment and Natural Resources (DENR) to determine: *i*) the current status of previously recorded populations of *M. clivicola* populations, *ii*) to assess habitat variables associated with *M. clivicola* populations, *iii*) to survey other sites for possible populations of *M. clivicola,* and *iv*) to identify key threats, knowledge gaps and research and management requirements pertaining to the protection of *M. clivicola* populations.

A rapid assessment of vegetation and habitat variables was also undertaken at spring sites where *M. clivicola* occur, in order to provide a consistent approach in evaluating the condition of aquatic ecosystems. This assessment builds upon previous assessment work and adds to information that has already been collected at springs within the Flinders Ranges (for the SAAL NRM Board). For this reason, the report is presented in two sections: the first detailing the fish assessment and the second detailing the vegetation habitat assessment.

The fish survey revisited the three previously recorded sites (Nepouie Spring, Weetootla Spring and a man-made stone tank at Balcanoona Ranger Station) plus another 14 sites that were potentially populated with *M. clivicola*. After extensive surveys, only two populations of *M. clivicola* were found to exist in the Northern Flinders Ranges. Specifically, one of the previously translocated populations no longer existed (i.e. within the man-made stone tank at Balcanoona Ranger Station) and no new populations were found to occur at the other sites.

The study revealed that the current status of the *M. clivicola* in the Northern Flinders Ranges remains stable. The total population estimate made from this survey, was close to previous population estimates of ~4,000 individuals, made in assessments undertaken a decade ago. At the time of this survey the distribution of the species was restricted to the natural population at Weetootla Spring and the translocated population at Nepouie Spring, where both populations are dependent on the permanency of spring flow to maintain surface water habitats.

During the survey, a range of size classes from larval fish (<15mm) to large adult fish (142mm) were recorded, suggesting recent recruitment and spawning. Fish generally appeared to be in good physical condition with very low incidence of obvious parasitisation and an absence of bacterial and/or fungal infections. Of significant concern however, was the very high proportion of fish displaying advanced levels of discolouration and growths, which were assumed to be symptomatic of melanoma type skin cancer reported by Pierce (1996).

The current survey estimated that up to 20% of adult fish showed clear signs of the disease, which poses a significant threat to population stability and potential long term species survival. It is therefore recommended that further analytical research is undertaken to determine the cause and effect of this symptom.

The present survey recommends several areas for further research, monitoring and management, including:

- Assessment of population genetics;
- Potential for translocation to other suitable habitat;
- Confirmation of cancer and its cause in *M. clivicola*;
- Regular population and habitat monitoring;
- Further exploratory surveys;
- Pest fish exclusion, and;

- Investigation into cultural significance.

In addition to these recommendations, it is advised that a comprehensive, long term management and protection plan be developed for the protection, restoration and amelioration of threats to *M. clivicola* populations in conjunction with the various government agencies and stakeholders that are responsible for, and value, the protection of this critically endangered species.

Vegetation Survey

Overall, the vegetation assessment found that most surveyed sites were in good condition and largely unmodified. The two springs that had a high investment priority rating both had populations of the critically endangered fish species, *Mogurnda clivicola*, and also saplings of an important tree species to the local Adnyamathanha People, *Capparis mitchelli*, Iga / Native Orange tree. The high investment priority rating of these two sites both recommend further investment into understanding the ecological function of these springs and their importance in the landscape. Due to the sites being assessed as being in good condition, current management should be maintained but monitored to ensure future disturbance does not impact the springs.

The three sites with a moderate investment priority rating were also highlighted as sites with unique features they were also considered to be in good condition. It is also advised that current management is maintained but monitored to ensure future disturbance does not impact these springs. Those sites with a low investment priority would only need future management if required for a specific purpose.

It is recommended that evaluation of the vegetation condition within the Flinders Ranges springs be continued. This will then allow for a consistent and comparative approach that can assist with prioritising specific springs that may require either on-ground intervention and/or future monitoring.

Furthermore, during this present survey Traditional Owners at Iga Warta expressed concern that they had not observed recruitment of wild *Capparis mitchelli*, Iga / Native Orange tree within the area. This particular tree species is of high local cultural significance to the Adnyamathanha people. Five saplings were found during this trip; one at Weetootla Spring and four at Nepouie Spring. It is therefore recommended that as a next step, a mapping project is undertaken with community assistance to gain a better understanding of the current distribution and recruitment rate of *Capparis mitchelli* within the Northern Flinders Ranges area.

SECTION 1: FISH SURVEYS

Authors: Dale McNeil and David Schmarr. SARDI (Aquatic Sciences)

The Flinders Ranges Mogurnda (*Mogurnda clivicola*), also known as the Flinders Ranges Purple-spotted Gudgeon, is one of South Australia's most critically endangered fish species (Hammer *et al.* 2010). The SA Museum Adelaide (SAMA) has recorded the species at three locations in the Northern Flinders Ranges (namely Weetootla Spring, Nepouie Spring and a man-made stone tank at Balcanoona Ranger Station). The Weetootla Spring is thought to be the original source/native population for the area, while the other two locations are recorded as being translocated populations. However, the details of these two translocations have never been published or described. In addition Pierce *et al.* (2001) also alludes to other translocations of this species into "other Flinders Ranges waters" however, no details or explanation of these potentially significant translocations have been adequately provided.

Similar specimens from the Bulloo River in south-west Queensland have been provisionally identified as the *M. clivicola* (SAMA 2009/10; Allen and Jenkins 1999) although the authors acknowledge that a rigorous assessment and collection of specimens are required before the species can be positively attributed to this locale. Wager and Unmack (2000) suggest that a remnant population may also exist in the upper Barcoo River catchment in Queensland (Peter Unmack *pers. comm.)* although the genetic and taxonomic affinity of these populations to the Flinders Ranges *M. clivicola* again remains undetermined (Pierce *et al.* 2001). Without conclusive evidence it must be assumed that the only extant population of the *M. clivicola* exists within the Northern Flinders Ranges. As the scientific name denotes (*Mogurnda* = Purple spotted gudgeon; *clivicola* = hill-dwellers) are found within the upper reaches of Balcanoona and Nepouie Creeks in the Northern Flinders Ranges.

Typically, springs in the Flinders Ranges are located in ephemeral streambeds. The associated creeks within these streambeds flow after seasonal or episodic rainfall events, however, groundwater fed springs continue to flow once creek levels have subsided. Permanent springs like Weetootla and Nepouie are most likely supplied from a large regional groundwater aquifer that allows the springs to continue to flow and withstand dry seasons and droughts, thus attributing to the continued survival of this fish species at springs within ephemeral creek-beds.

The published information pertaining to the population status and biology of *Mogurnda clivicola* at Weetootla Spring is limited. Estimates of the population size have been recorded as low as 150 individuals (Mackay 1985) and as high as 4,000 individuals (Pierce *et al.* 2001). Thus far there has been no published estimate of the population size of the translocated populations. *Mogurnda clivicola* are believed to spawn in spring and summer (water temperatures >20°C), spawning over hard substrates, with mass spawning events occurring in response to surface water flows in summer (MacKay 1985, Hammer *et. al*. 2010). Of significant biological concern, is the observation in the late 1990's by SARDI researchers (acting on reports from locals and Park Rangers) of discoloured individuals within the Weetootla population. The discoloured blotches were identified as a cancerous melanoma by Pierce (1996), and the cause of the melanomas attributed to the hole in the ozone layer; however no analytical testing was performed at the time to confirm this hypothesis.

The aim of this report was to determine the current status of *M. clivicola* populations within the Northern Flinders Ranges and to identify current and future threats to the sustainability of the population. Recommendations for research and management strategies that may reduce the impact of threats and protect the remaining populations of this critically endangered species will also be outlined and discussed.

The specific aims of the fish survey were to:

- Conduct a survey of the three previously recorded locations of *M. clivicola* in the Northern Flinders Ranges (Weetootla Spring, Nepouie Spring and Balcanoona stone tank)
- Survey nearby waterholes, springs and streams for possible populations of *M. clivicola.*
- Estimate the total number of *M. clivicola* remaining and their range within the Northern Flinders Ranges.
- Assess habitat variables associated with *M. clivicola* populations
- Determine the abundance, size structure, reproductive status and prevalence of disease in identified populations
- Identify key threats, knowledge gaps and research and management requirements pertaining to the protection of *M. clivicola* populations.

- Formulate a monitoring program incorporating community participation.

Methods

A broad geographical survey was conducted across a variety of stream reaches, waterholes and isolated springs to determine the distribution of *M. clivicola* in the Northern Flinders Ranges, the detail of which is outlined in the following sections.

Identifying Fish

Given the clarity of the water and shallow nature of stream habitats, it was possible to conduct visual surveys and counts of individual fish from the stream beds. This methodology was preferred since it allowed an appropriate and sensitive means of ensuring minimal sampling impacts upon the restricted and threatened fish species (e.g. capture and handling of fish may cause stress and/or disturbance to the target population).

Initial visual surveys rapidly identified the presence of fish at sites. Following on from the initial visual identification a combination of backpack electrofishing and detailed visual estimations of abundance (depending on the sampling requirements at each site) were conducted. Backpack settings were determined *in situ* according to the specific water quality conditions and attempted to capture all fish in a pool to provide unbiased size frequency distribution, sex ratio, disease prevalence data, as well as a confirmation of initial visual estimates. At sites where visual surveys failed to locate any fish, a backpack electrofisher was used to sample a small section of the reach to ensure against false visual assessments. No fish were electrofished from any reach where visual surveys had previously failed to identify fish. Visual assessment also effectively identified fish species (allowing differentiation between *Leiopotherapon unicolour* and *M. clivicola*) which were not found to cohabit springs in the current survey. With no more than a single species present at any site and electrofishing surveys validating visual estimates, this method was considered an acceptable low impact survey method for the distribution, composition and relative abundance of fish from the clear stream habitats surveyed for this project.

Longitudinal Surveys

The two stream reaches that contained *M. clivicola* (Balcanoona and Nepouie Creeks), were surveyed using a longitudinal search along the entire length of the creek-bed (including the connected and isolated pools). Due to the remote and

difficult terrain, and the high success of visual surveys, longitudinal surveys were conducted using visual identification. Estimates of individual fish numbers were made independently by three observers and then averaged. Where streams bifurcated, both channels were assessed separately ensuring that all available areas of aquatic habitat were assessed. The maximum depth, pool size (or reach length), number of fish and habitat characteristics were determined for each section. Any break in surface water connectivity was recorded as a separation of site, with individual stream reaches and pools often separated by several metres (and occasionally ≤ 1km) of dry stream bed.

A comprehensive survey was undertaken in one single, large pool for both Weetootla and Nepouie springs, using multiple-pass backpack electrofishing. Multiple passes ensured that the vast majority of individuals within the pools were caught. Electrofishing was ceased once a single pass failed to locate any fish. All captured fish were identified, measured total length (TL mm), sexed (a triangular urino-genital papilla in males and a broad, short, striated and fringed papilla in females) and assessed for skin lesions, parasites or discolorations. Fifty individual specimens were retained from each of these two pools (n = 50 per pool) for possible future analyses of genetics, diet, age and disease.

Results

General Survey

From the 17 sites surveyed, native fish were recorded at three sites, with *Mogurnda clivicola* only recorded at two sites (Figure 1). *M. clivicola* was previously recorded at a total of three sites (SAMA), but for this survey the stone-tank at Balcanoona Ranger Station site was dry and had been for some years. The only other species recorded during the survey was spangled perch (*Leiopotherapon unicolour*) which was found at Mudlapena spring.

Longitudinal Transects

Longitudinal fish surveys were undertaken at Weetootla Spring (Figure 2) and Nepouie Spring (Figure 3) providing population assessments, observations about spawning and diet and observations of disease frequency.

Population Assessments

Visual estimates of total *M. clivicola* populations were greater in Weetootla Creek (range = 1269 - 3290 fish) compared with Nepouie (range 74 - 240 fish). From these visual estimates, the total population estimate for the entire Northern Flinders Ranges is ~ 3530 fish.

The *M. clivicola* population in Weetootla Creek appears to be reasonably well represented by individuals of various age classes (TL range = 30 to 140 mm) with, the highest frequency falling within the 70 to 80 mm range (Figure 4a).

The range of the established population at Nepouie Spring also appears relatively well represented by individuals of various age classes (TL range = 40 to 120 mm), with a higher frequency of individuals falling within the range >90 mm (Figure 4b). There appeared to be generally fewer females than males in the larger size classes, whilst the numbers were similar in the mid ranges (Figure 4b).

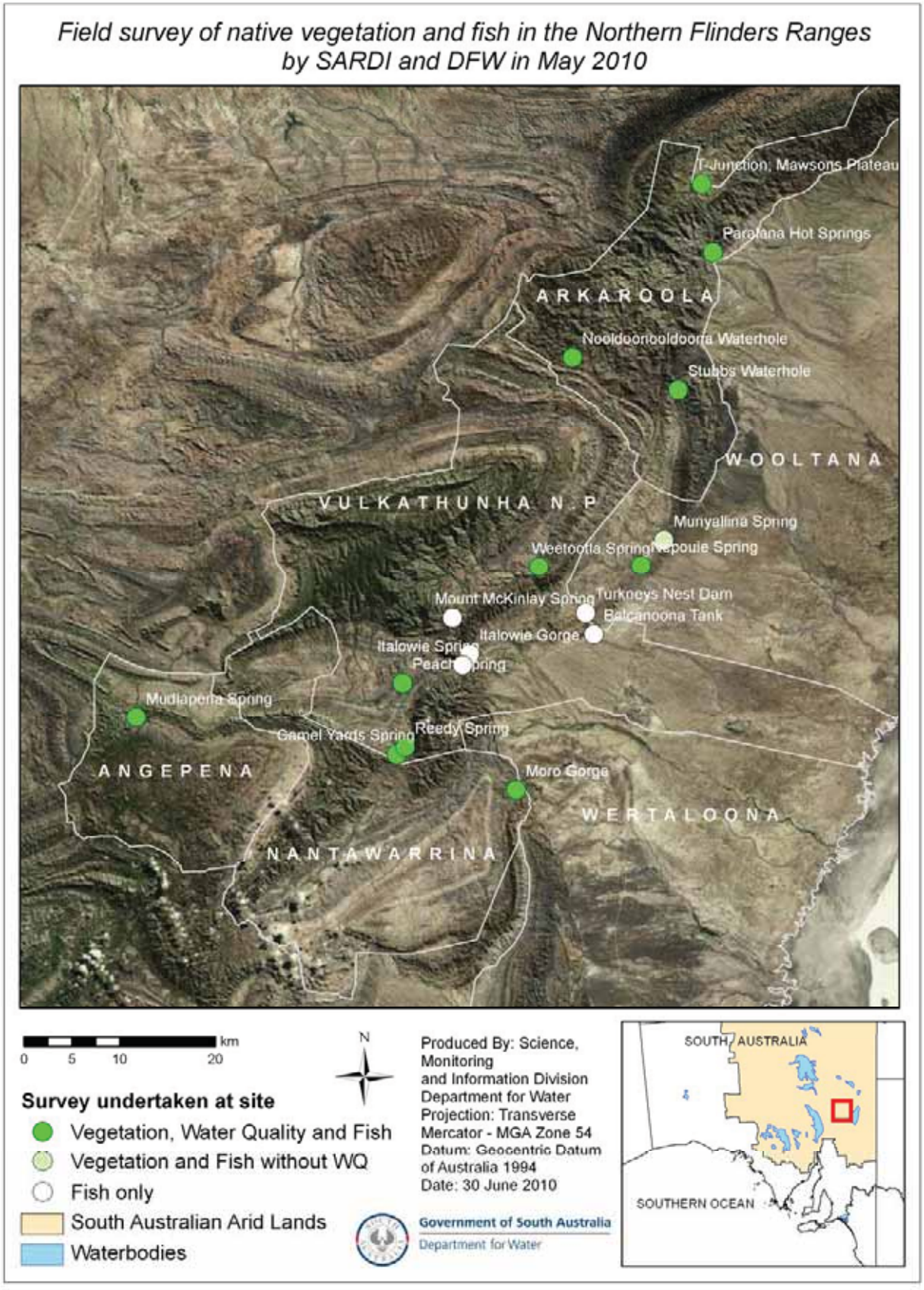

Figure 1. Field survey of sites assessed in the Northern Flinders Ranges (May 2010).

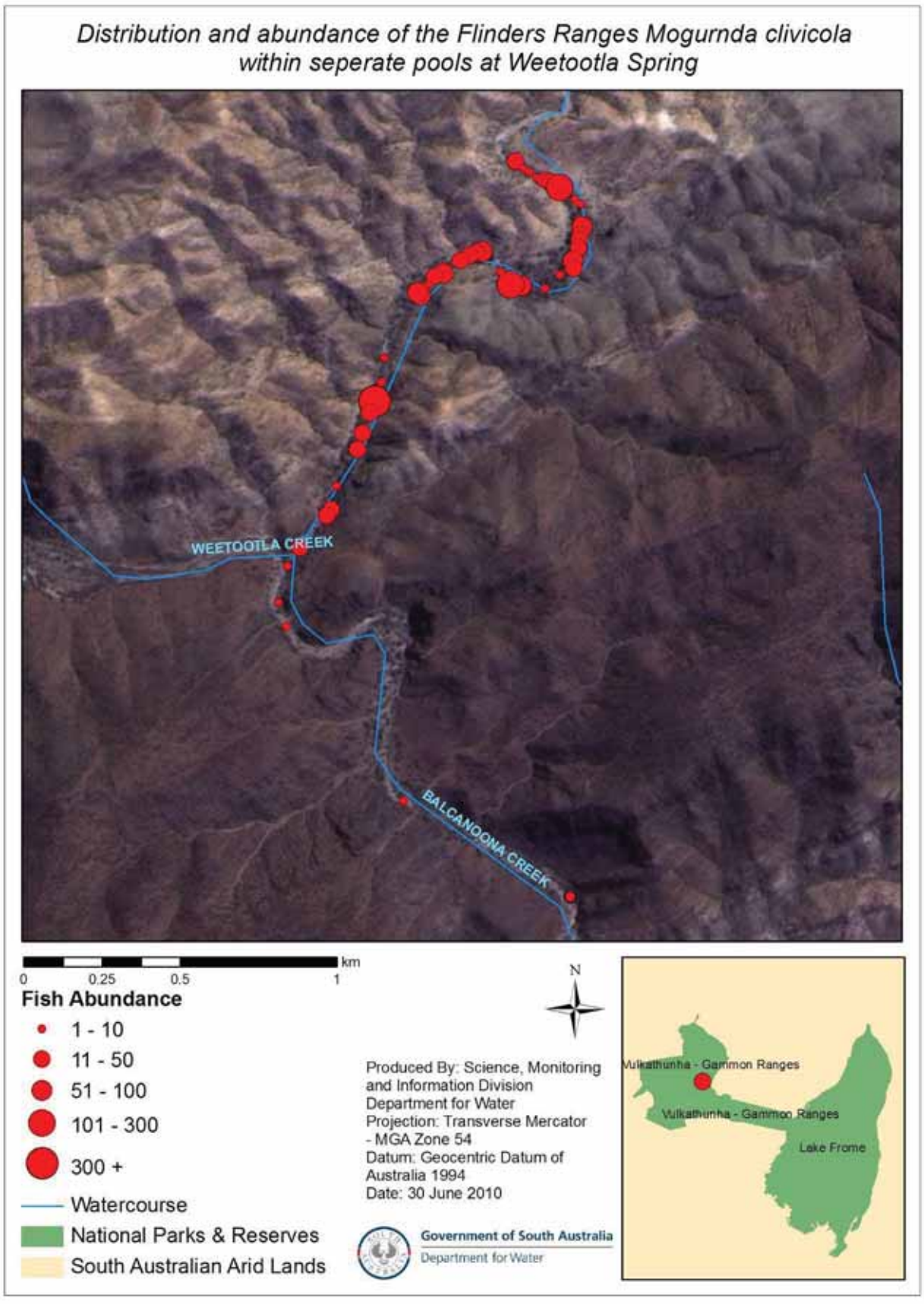

Figure 2. Weetootla Creek longitudinal transect (16th May 2010).

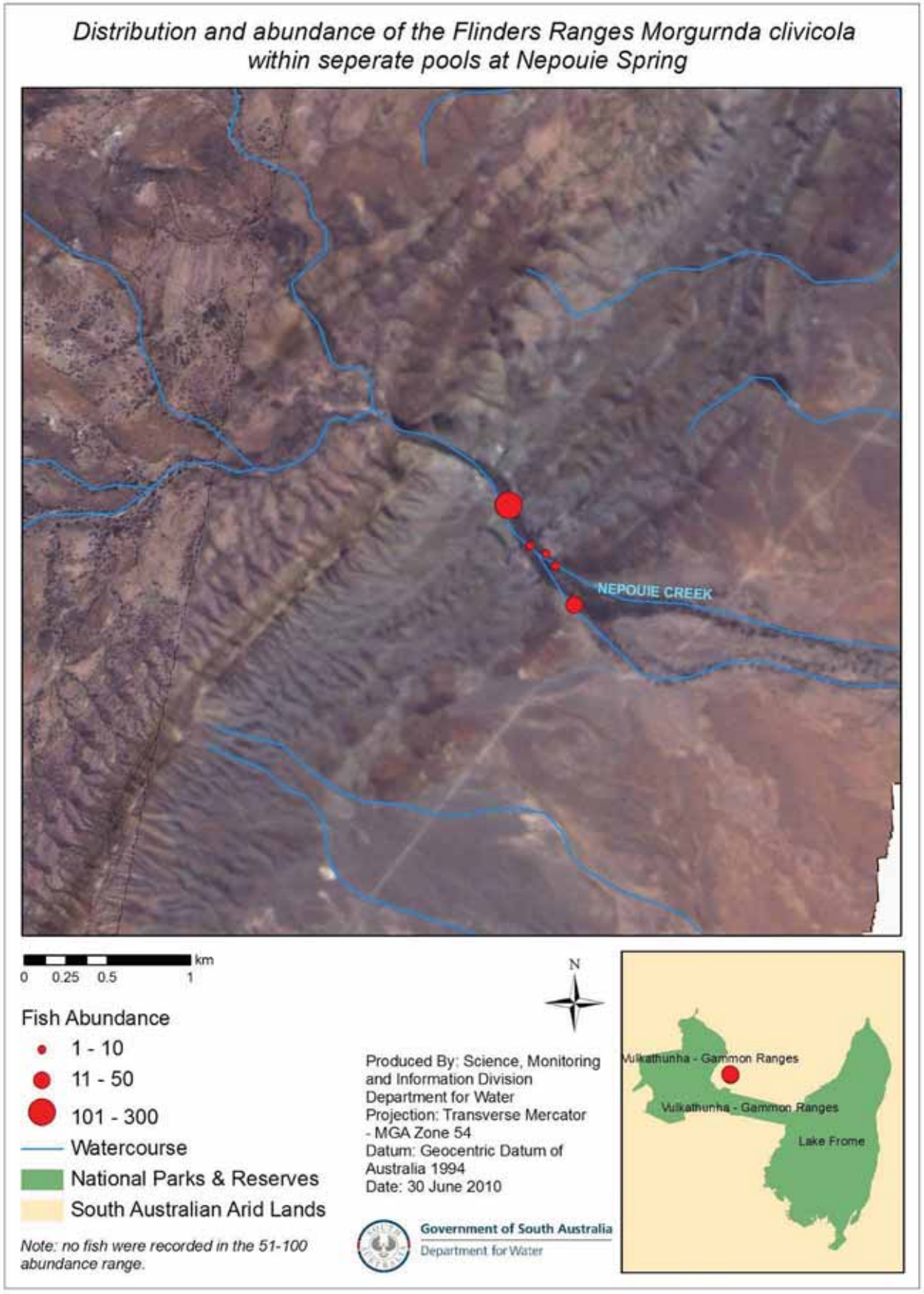

Figure 3. Nepouie Creek longitudinal transect (18th May 2010).

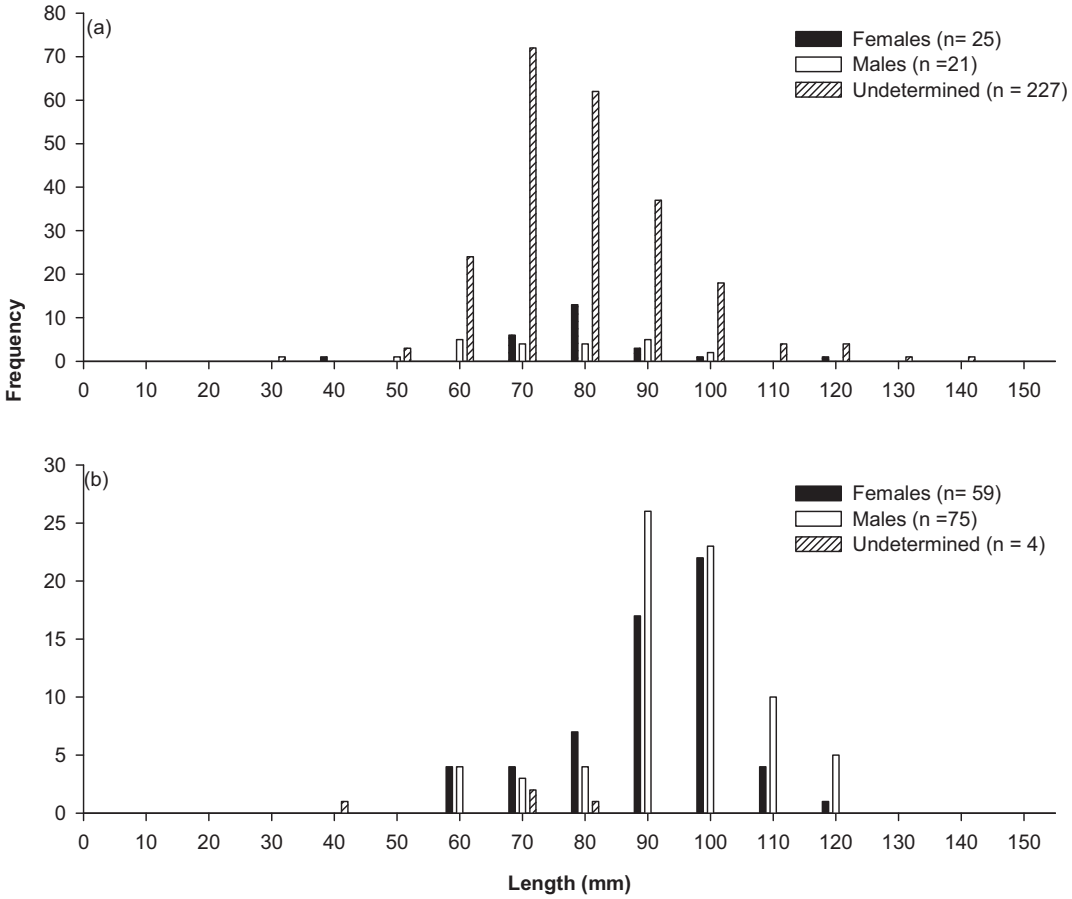

Figure 4. Length-frequency for *Mogurnda clivicola* in (a) Weetootla Creek and (b) Nepouie Creek collected using back pack electrofishing.

Spawning and Diet

Evidence of recent spawning was observed at both Weetootla and Nepouie during May 2010 (water temperatures > 20°C). At Weetootla, newly hatched larvae were observed schooling in mid-water above an adult male that was actively chasing other fish away from the area. The male displayed sign of parental care for the young. At Nepouie, two egg masses were observed, which were also guarded and fanned by an adult male fish (Figure 5). Egg numbers were estimated to be between 600-900 eggs per mass. Egg shape varied from round to capsular (Figure 6), with embryos clearly visible within some eggs.

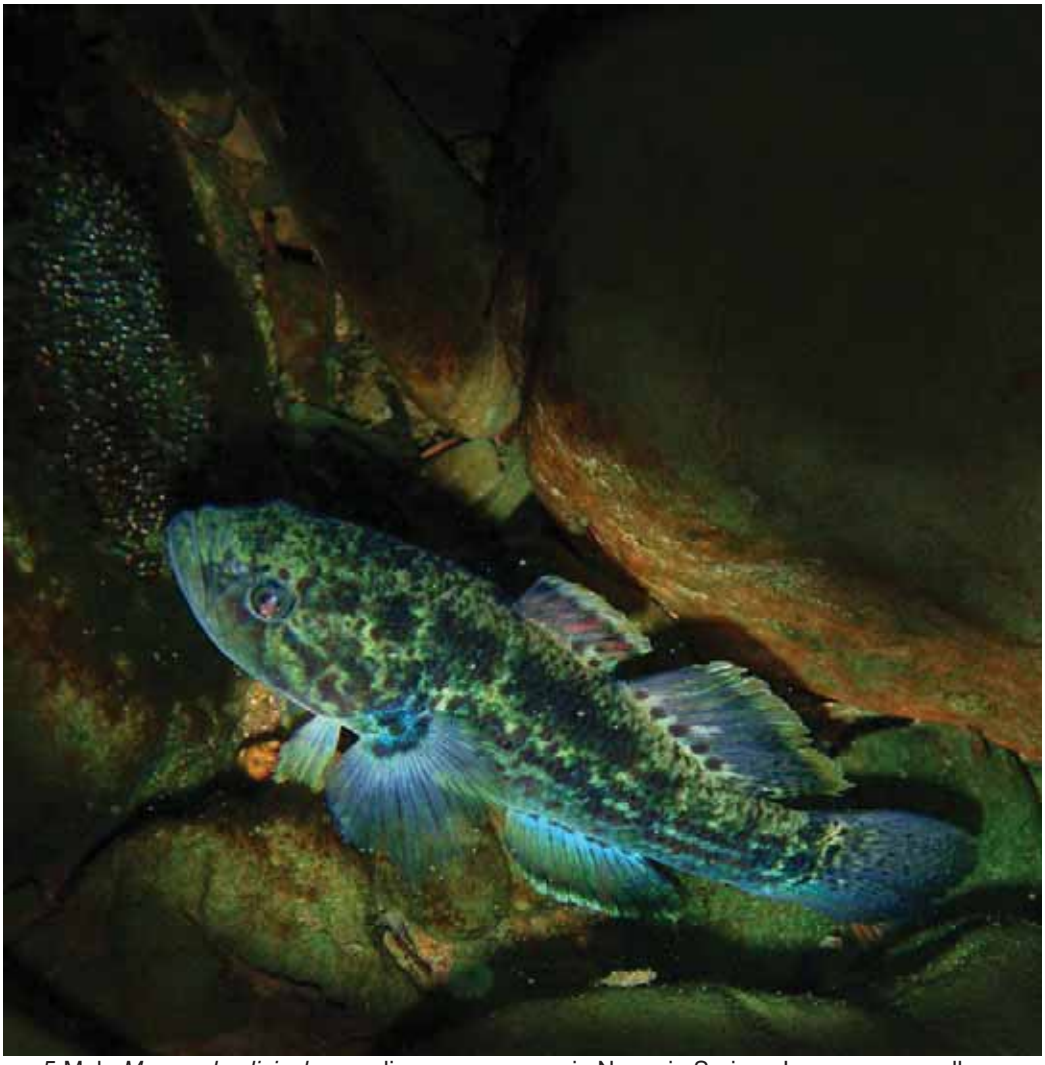

Figure 5 Male *Mogurnda clivicola* guarding an egg mass in Nepouie Spring. Larvae were well developed within eggs and amber coloured eye shine can be seen reflected from within eggs under close inspection.

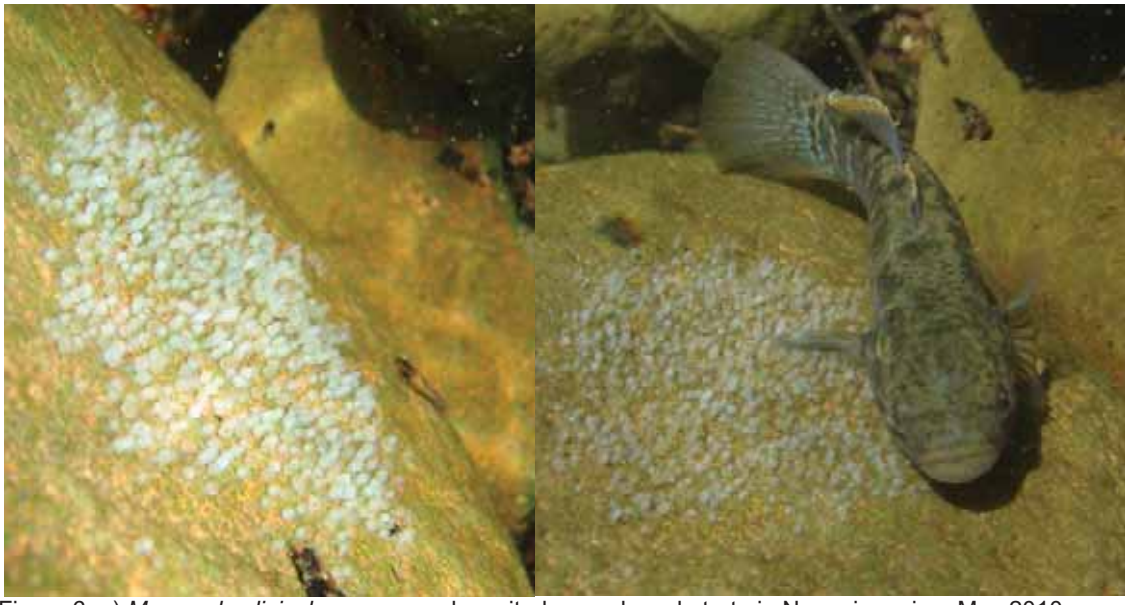

Figure 6. a) *Mogurnda clivicola* egg mass deposited on rocky substrate in Nepouie spring, May 2010. This mass was attended by a large male that fanned the egg mass constantly (b).

M. clivicola were observed eating caddis larvae and tadpoles during the survey, although no tadpoles or frogs were present in pools where *M. clivicola* occurred (with the exception of one pool where there were abundant tadpoles and frogs and only a single fish present). When ten tadpoles were added to a small pool (containing ~20 *M. clivicola*) they were rapidly consumed (within 2 minutes). Other observations were that the pools where fish were present appeared green in colour, with high densities of algae covering the substrate and forming filamentous masses. However, fishless pools tended to be clear (Figure 7). These differences were attributed to the effects of grazing from the high densities of tadpoles that were present in springs that were free of fish.

Figure 7. Dense tadpoles and lack of algae characterise fishless waters in Weetootla spring

Disease

A number of fish were noted to have abnormalities, such as pale yellowing discolouration of the fins or patches of flesh, or very black discolorations often around the head or body (Figure 8). Additionally large tumour-like growths were observed over the head and body (Figure 9). The location of discolorations and growths appeared to be random although tail and dorsal fins, the anal body region, caudal peduncle, head, lower jaw, and dorsal flanks were common areas of impact. The incidence of abnormalities was higher at Weetootla where 20 % of females, 29% of males and a total of 19.8% of the total population showing signs of abnormalities (Table 1). At Nepouie, the incidence of abnormalities was lower, with 8.5 % females and 14.6 % of males recorded to have abnormalities, with an incidence in the total population of 12.3% (Table 1). Recently dead fish with growths and discolorations were also observed, albeit in low numbers.

Table 1. Percentage of *Mogurnda clivicola* showing signs of abnormalities at Weetootla and Nepouie. * possible underestimation due to low light conditions.

Catchment	Gender	Total number of fish	Total number of abnormal fish	% population with abnormalities
Weetootla*	Females	25	5	20.00
	Males	21	6	28.57
	Undetermined	227	43	18.9
			% of Population	**19.8**
Nepouie	Females	59	5	8.47
	Males	75	11	14.67
	Undetermined	4	1	25.00
			% of Population	**12.3**

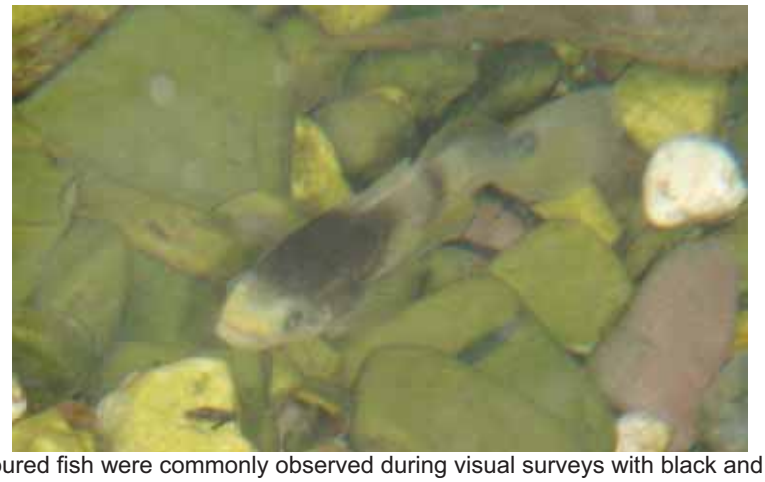

Figure 8. Discoloured fish were commonly observed during visual surveys with black and pale yellow pigmentation replacing the usual complex, mottled appearance.

Figure 9. Inspection of diseased fish in an advanced stage reveals large black tumours commonly on the lower jaw, caudal peduncle, tail, flanks and face.

Figure 10. Dead fish from Nepouie Spring.

Water Quality

Water quality parameters are presented in Table 2. Water quality parameters for Weetootla Spring and Nepouie Spring are at the source of the spring and over 500 m downstream where water temperatures had returned to ambient temperatures. Mawson Plateau measurements were for the waterhole at the top and bottom of the reach that was surveyed. All other springs were measured only at their source pool. Water temperatures in springs varied greatly ranging between 13°C and 27°C. Salinity varied slightly but was relatively fresh and certainly tolerable to fish across the survey area. Nitrates ranged greatly between 3508 and 99999 mg/l. Turbidity was extremely low at all sites with the exception of the bottom of Mawson Plateau. Dissolved oxygen was very high at all sites with many sites supersaturated (hyperoxic) (Table2).

Table 2. Water quality measurements from each of the sites surveyed. The pH sensor was malfunctioning so pH values are not presented here.

	Temperature	Conductivity	Total Dissolved Solids	Salinity	Nitrate	Turbidity	Dissolved Oxygen Saturation	Dissolved Oxygen
	°C	mS/cm	g/L	ppt	mg/L	NTU	%	mg/L
Mudlapena Spring	13.01	2.752	1.789	1.44	12123	0	80	8.35
Moro Gorge	15.16	2.671	1.736	1.39	17252	0	115.8	11.54
Weetootla Spring Head	24.77	1.506	0.978	0.75	6105	0	48.6	4.01
Weetootla Spring Tail	14.89	1.542	1.002	0.78	5890	0	77.7	7.82
Nepouie Spring Head	27.18	2.39	1.554	1.22	3508	0	91.7	7.23
Nepouie Spring Tail	17.81	3.401	2.211	1.79	7006	0.2	84.7	7.96
Paralana Spring Head	44.1	2.14	1.391	1.06	3826	0	121.8	7.29
Stubbs Waterhole	17.39	0.529	0.344	0.26	68675	5	109.2	10.45
Nooldoonooldoona Waterhole	13.68	3.97	2.581	2.12	37245	0	81.1	8.31
Mawson Plateau Top	16.61	0.639	0.416	0.31	75873	4.3	91.3	8.88
Mawson Plateau Bottom	13.81	0.295	0.192	0.14	99999	36.5	72.9	7.54
Camelyard Spring	16.17	0.004	0.002	0	20945	9.5	40	3.93
Weedy/Reedy Spring	20.15	2.946	1.915	1.54	24983	0	63.2	5.68
Peach Spring	14.4	4.165	2.707	2.23	44775	1.3	177.8	17.92

Discussion

Distribution and Population Status

The study revealed that the current status of *M. clivicola* in the Northern Flinders Ranges remains stable compared to previous assessments (Pierce *et al.* 2001). The overall population estimate of ~4000 individuals made a decade ago is very close to the total estimate from the current surveys. During this survey the distribution of the species was restricted to two individual west flowing tributaries of Lake Frome; Weetootla Spring in Balcanoona creek, and Nepouie Spring in Nepouie Creek.

The extent of the population consisted of the source/native population over a 4 km stretch of intermittent pools at Weetootla Spring, and one translocated population over a 750 m stretch of intermittent pools at Nepouie Spring. Both populations are dependent on spring flows to maintain permanent surface water habitats when the ephemeral creeks are not flowing from localised rainfall events. With the exception of endemic fish within Dalhousie Great Artesian Basin springs, *M. clivicola* probably has the most restricted distribution of any fish species in South Australia (considering they only exist within two individual springs. Additional populations of *M. clivicola* are attributed to the upper Barcoo and Bulloo Rivers in Queensland, although further investigation of genetic homogeneity is required for this species).

With such limited habitat availability for this species, the maintenance of spring flows and the persistence of pool and stream habitats within Balcanoona and Nepouie Creeks are essential for its survival. Regular monitoring and spatial assessment of pool numbers, position and depth is recommended to ensure that disturbances following large floods do not heavily impact on streambed structure and sufficient habitat remains to support substantial populations of fish. Habitat rehabilitation/modification actions may need to be undertaken to improve the number or habitat value of pools under situations where flooding impacts on available habitat, but regular monitoring is required to inform this need. Regular monitoring of fish numbers and population dynamics is also recommended to allow rapid responses to any developing threats or population collapses in these sites and to allow time to consider available management options.

The Weetootla Spring population exists within the Vulkathunha-Gammon Ranges National Park which falls under the protective jurisdiction of the South Australian Department of Environment and Natural Resources (DENR). It is recommended that

DENR becomes further involved in monitoring and protecting these populations and possibly assisting in the development of a detailed recovery and protection plan for the Weetootla Spring population as recommended by the Action Plan for South Australian Fishes (Hammer *et al.* 2010).

The Nepouie Springs population exists on the Wooltana station pastoral lease. It is envisaged that the SAAL NRM Board in collaboration with DENR, and in consultation with Wooltana station, develop a combined recovery and protection plan for this population.

Other populations translocated to the Balcanoona Homestead water tank are no longer present due to the tank being dry. Some fish were translocated to a Turkeys-nest dam near the border of Wooltana Station and the Vulkathunha-Gammon Ranges National park on the road to Arkaroola; (*pers. comm.* Christian Coulthard; Former Ranger Vulkathunha National Park). This dam was bore-fed and maintained by the Department for Transport for wetting down of the dirt road and during road maintenance. However at the time of the assessment the dam was dry and contained no fish (*pers. obs*.).

Surveyed sites around the Northern Flinders Ranges failed to reveal any other populations of *M. clivicola*. Spangled perch were the only other species encountered in the survey and were found only at Mudlapena Spring in the upper Frome Creek.

The results of this survey support the recommendations made in the action plan for South Australian freshwater fish (Hammer *et al*. 2010) that *M. clivicola* be re-classified as “Critically Endangered” under the Fisheries Management Act (2007) (currently classified as “Protected”) and the EPBC Act (1999) (currently classified as “Vulnerable”). We fully support the recommendation that this species’ classification be upgraded.

Locations of other *M. clivicola* populations have been proposed. Marg and Doug Sprigg from Arkaroola Wilderness Sanctuary discussed the possibility that a population of *M. clivicola* exists on Mawson Plateau, over 40 km from the Balcanoona population. This possibility was confirmed by members of the Adnyamathanha community (Christian Coulthard *pers. comm*.) along with suggestions about other potential locations of fish in the Northern Flinders Ranges. Exploration of museum records revealed a record of spangled perch from the Mawson Plateau (Spangled grunter, Mawson Plateau Creek, upper Hamilton Creek,

Gammon Ranges 30 5' 30" S 130o28' E Bryan Pierce and Brett Hall, 5 July 1992. Rock hole; dip net, cast net, rod and line.1 large (180mm) fish and 26 smaller) but no *M. clivicola* records exist.

An interesting outcome from our short survey of Mawson Plateau was the apparent serendipitous discovery of an undescribed species of frog. During our fish survey, we collected aquatic plant samples of *Chara australis*; upon sorting the plant samples back at camp we found frog eggs. The eggs were kept and hatched back in Adelaide and the frog was described as *Crinea sp*. and within the same Arkaroola area there is also another undescribed frog, *Pseudophryne sp*. (Michael Tyler pers comm.). These discoveries emphasises the value of conducting biological surveys in poorly studied and remote areas and the need for future biological surveys in this area.

Within its restricted distribution, populations of *M. clivicola* appear to be relatively stable, as recent recruitment, spawning and the presence of a range of size classes from larval fish (<15mm) to large adult fish (142mm) was observed during the current survey.

Disease

Fish appeared adequately fed with very low incidence of obvious parasitisation and an absence of bacterial or fungal infections. Of significant concern, however, is the very high proportion of fish that displayed advanced levels of discolouration and growths assumed to be symptomatic of melanoma-type skin cancer reported by Pierce (1996). Estimates revealed that up to 20% of adult fish showed obvious signs of the disease which therefore poses a significant threat to the stability of the population and the potential long-term survival of the species. Whilst the initial identification of melanoma in *M. clivicola* led to the hypothesis that the disease was the result of increased ultra-violet radiation passing through the hole in the ozone layer, there are at least two alternative hypotheses that may explain the development of such high levels of cancer in the populations.

1: If existing populations of *M. clivicola* represent 'edge' remnants of a once broad distribution across the Lake Eyre Basin (Pierce 1996), then the current population is likely to be significantly in-bred. If this is the case, reduced genetic variation around key gene loci may have led to an increased sensitivity to cancer in the population. With the Nepouie population stocked from a very small number of seed fish (Pierce *et al.* 2001), further genetic limitations and susceptibility may be increased in this population.

2: Closely related species of Mogurnda (*Mogurnda mogurnda*) have been shown to be highly sensitive to the impacts of uranium (Bywater *et al.* 1991). As large deposits of uranium are to be found throughout the Northern Flinders Ranges it is possible that the warm spring water that feeds both Balcanoona and Nepouie springs may be radioactive and therefore may be directly implicated in the development of cancer in large numbers of individuals. In this case, the species is likely to have been living with higher levels of background radiation for thousands of years, and may not face any risk from this scenario.

Interactions between reduced genetic resistance and increased environmental impacts through groundwater contamination may combine to influence the prevalence of melanoma in this population. The relationships between genetics (particularly around gene loci known to be involved with the development of melanoma) and the radioactivity of spring water should be assessed as a priority for the long term protection of the species. In addition, if genetic homogeneity is contributing to increased melanoma, then research into the role of particular genes in increasing susceptibility may reveal important knowledge that can help us understand and treat the disease both in fish and in humans. It is also recommended that further pathology be conducted to verify the nature of this disease as little information is provided in the report by Pierce (1996).

Spawning and Diet

The survey also showed that *M. clivicola* spawns in late May, which differs from previous observations of late spring and summer (Mackay 1985). Furthermore, spawning was not associated with any immediate flow events as, at the time of the survey, pools were connected by low levels of base flow only. A key factor, however, is likely to be the warm nature of spring-waters both at Weetootla and Nepouie Springs. Both springs surfaced at over 24°C and remained above ~20°C for at least 100 m downstream. A significant number of pools surveyed were, therefore, within the temperature range for which spawning has been observed in aquaria (Allen *et al.* 2002). If spawning in late autumn and winter are important for this species, then Balcanoona and Nepouie Springs are the only two sites in the area that are warm enough all year round to support such events. This factor could contribute to the failure of the species to establish in nearby cool-water springs and streams such as Italowie and Moro Gorge.

There are varying reports as to the degree of parental care of eggs, ranging from no care (Allen *et al.* 2002) to advanced guarding and fanning of eggs (Mackay 1985). Observations in the current study clearly re-enforced that a high degree of parental care is afforded to egg masses, with males observed and filmed fanning eggs on vertical rock surfaces. Egg counts taken from photographs estimate egg masses with between 780 and 920 eggs, well within the range outlined in the literature (Mackay 1985, Allen *et al.* 2002). Male *M. clivicola* also remained in proximity to older nest sites after hatching with larval fish observed schooling in mid-water above them. These large males were observed to chase other fish from the site.

M. clivicola were observed feeding on caddis fly larvae and on tadpoles added to pools. Whilst there were no tadpoles or frogs observed in pools where *M. clivicola* were abundant, masses of tadpoles were present in pools adjacent and between pools with fish. This pattern and the observation that 10 tadpoles were consumed within two minutes of being introduced to fish-inhabited pools, suggest that tadpoles are likely to form a significant part of the diet of *M. clivicola*. Further gut analysis will be required for more detailed assessment of diet, although it is suggested to include dragonfly larvae, frogs, tadpoles and small fish (which would indicate cannibalism) (Hammer *et al*. 2010).

Recommendations

Future work on *M. clivicola* in the Northern Flinders Ranges should include the following areas of research and management:

- **Monitoring:** Population status (recruitment, survival, health) and the spatial extent and value of habitat within Weetootla and Nepouie Springs should be monitored regularly, especially following severe droughts and flooding impacts, both of which could lead to the demise of the species through habitat disturbance. Monitoring should adopt two approaches:

    1. Comprehensive surveys conducted twice a year by a qualified research team provided that involves observation and capture of fish to assess population size, disease prevalence and population parameters such as age, sex ratio and reproductive status. It is estimated that this would require five days work by two researchers for each survey;

    2. Monthly surveys by stakeholders (e.g. DENR Park Rangers, local community members, pastoral lease holders) to monitor habitat status

and visual assessment of population size and health. These survey participants would require initial training by qualified personnel, but the ongoing comprehensive surveys would validate their observations. This type of survey would require approximately one day per month to assess both populations. A significant advantage of these regular surveys would be to provide a rapid response to any catastrophic declines in the population.

- **Population Genetic Assessment:** Analysis of genetic structure and taxonomic variables should be targeted to reveal the relationship between *M. clivicola* in the Northern Flinders Ranges and the Bulloo and Barcoo River populations in Queensland. Samples have been collected from Weetootla and Nepouie Springs and preserved in ethanol for genetic analysis.

- **Translocation Potential:** Acceptable sites for translocation must be carefully planned and take into account impacts on the ecology of receiving sites as well as the compatibility of those habitats for supporting *M. clivicola*. Accurate genetic information will also inform on the potential for mixing seed stock from various population sources to form a genetically heterogenic population in translocation sites.

- **Cancer Research:** Further study to confirm the pathology and explore the reasons for the high incidence of melanoma in *M. clivicola* is highly recommended. This should include investigations into genetic structure, with a focus on melanoma related gene loci and possible consequences of in-breeding. An assessment of water should be made to establish the possibility of radioactivity in Weetootla and Nepouie Springs. Samples have been collected from Weetootla and Nepouie Springs and preserved in ethanol and formalin for genetic and pathological analysis.

- **Exploratory surveys:** Further surveys are required in the Northern Flinders Ranges to rule out other refugia for this species, specifically the aforementioned site on Mawson Plateau, and other smaller springs within the region that were not surveyed in our recent trip.

- **Pest Fish Exclusion:** The introduction of any fish species into Weetootla or Nepouie Springs would have disastrous consequences for *M. clivicola*. The construction of fish barriers downstream of known populations has been

recommended and the funding, design and construction of these barriers should be immediately considered with the aim of preventing the upstream movement of even small-bodied fish (i.e. Gambusia, spangled perch) into the reach. Pest fish eradication programs elsewhere in the Region (e.g. Western/Northern Flinders Ranges, Cooper Creek catchment) may also prevent the spread of pest species into the area during large floods.

- **Management and protection plan:** Development of a comprehensive management and protection plan to outline a long-term program of protection, restoration and amelioration of threats to *M. clivicola* populations and to engage departments and agencies responsible for the protection of this critically endangered fish species.

- **Cultural significance:** Investigation into the cultural significance of *M. clivicola* to the local Adnyamathanha people including a proposal to include, as a common name, the local name *Wirti Udla Varri* (= Weetootla Fish).

- **Reference information:** distributed to community and landholders as an onsite identification support tool to distinguish between Mogurnda and other local fish. Reference information to include size, colour, population estimates and 'return' option.

SECTION 2: VEGETATION SURVEYS

Author: Melissa White. S.A. Department for Water.

The aquatic ecology team in the Department for Water have been undertaking rapid vegetation assessments of springs, waterholes and rock-holes in the SAAL Board NRM region since 2008 (White and Scholz, 2008; Scholz and Deane 2010; White and Scholz, 2010). Specifically, this report adds to previous information collected at springs in the Flinders Ranges (White and Scholz. 2008).

Methods

Conceptual understanding of springs in the Flinders Ranges

The previous report on springs in the Flinders Ranges undertook a review of current knowledge on springs to formulate a background and conceptual understanding of spring function across the landscape and also to test the rapid vegetation assessment (White and Scholz, 2008). This report will only provide a summary of the 2008 review.

Typically, springs in the Flinders Ranges are located in ephemeral streambeds. These streams may flow episodically (after heavy rainfall events) or seasonally. Spring discharge occurs after the stream flow subsides. The springs will continue to flow in response to the groundwater being recharged from the rain event. Permanent flowing springs have a reliable source of groundwater that is able to withstand dry seasons and droughts. The groundwater source for these permanent springs is probably supplied through larger regional processes/groundwater aquifers, rather than local sources.

The current conceptual understanding of springs in the Flinders Ranges developed through this project work with the SAAL NRM Board has described four distinct hydrogeological processes that can be distinguished that determine springs hydrological function in the Flinders Ranges. These four processes are summarised as:

- Fractured Rock: water follows rock fractures, which may lead to the surface. These fracture features flow after rainfall events.
- Groundwater Discharge: where groundwater from a deeper aquifer is expressed at the surface; these are usually permanent features.

- Sub-surface Flow: whereby a stream disappears underground and is expressed at the surface; these may also be permanent features.
- Fault-line: when groundwater travels along a fault line and intersects a streambed and water is expressed at the surface

On each of the report cards for each site in the field assessment section, one of the above conceptual descriptions have been given to each site. The information presented in this report on conceptual understanding of the hydrogeological processes of springs will need to be updated as more information and understanding on springs is collected in the Flinders Ranges.

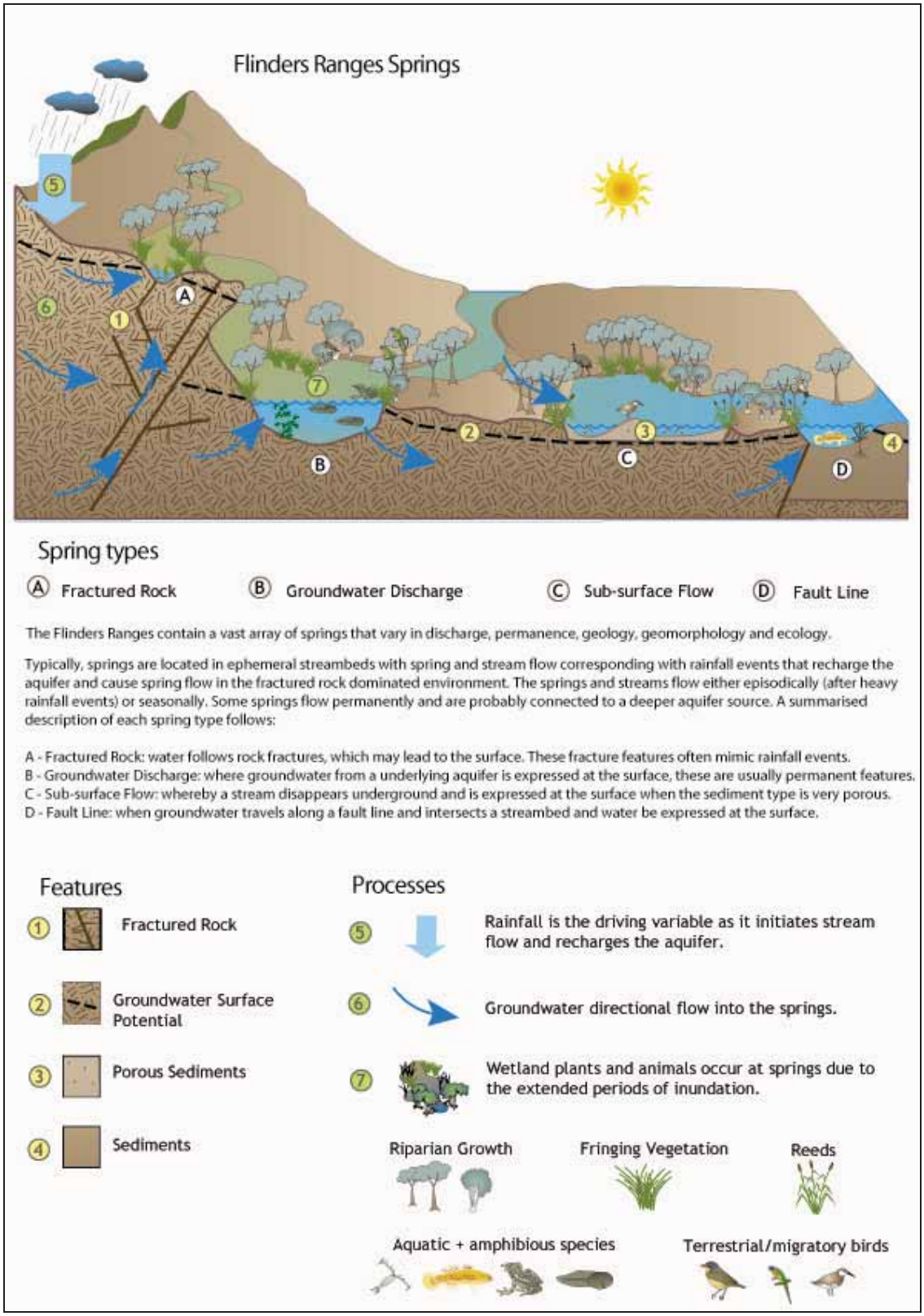

Figure 11. Conceptual diagram of the process and function of spring aquatic ecosystems within the Flinders Ranges.

Prioritisation of springs

A desirable outcome in investing in spring health is improved biodiversity. The first step in prioritising springs is to focus on the appropriate scale for an improved biodiversity outcome. As discussed in the previous Flinders Ranges report (White and Scholz, 2008) the most relevant considerations for biodiversity planning are:

1. In unmodified regions, landscape scale considerations are the most relevant.
2. In partially modified regions, ecosystem scales are more relevant.
3. In heavily modified regions, individual species considerations are more relevant.

In relation to the aquatic ecosystems in the Flinders Ranges region, the biodiversity management considerations this project will focus on are (1) landscape and (2) ecosystem scale.

Within this context, prioritisation for investment was weighted towards those springs that have the greatest contribution as an aquatic ecosystem refuge within the catchment as well as those that have the greatest recoverability potential in relation to management investment and intervention. This means that those springs that are significantly ecologically impaired may have a lower priority for investment due to a low recovery potential. Those that are ecologically intact may also have a lower priority for investment due to their relative security under current environmental conditions and management regimes.

The primary focus of this continued spring prioritisation program is a rapid assessment to guide investment in improved aquatic ecosystem processes and function at the landscape and ecosystem scale. Biodiversity 'conservation' outcomes are a significant issue, but this process requires further investment through site flora and fauna surveys. This biodiversity approach was targeted for this 2010 field assessment with fish surveys being undertaken for the critically endangered Flinders Ranges Mogurnda (*Mogurnda clivicola*) (see Section 1).

The first step in prioritising springs is to map their location across the landscape. Spatial understanding is fundamental to some key prioritisation questions for example:

- How many are there and what is the spatial distribution of springs in catchments?

- What is the landscape setting? Considering position within the catchment, elevation (uplands/lowlands), geomorphic processes and land tenure(pastoral/reserve).
- What ecosystem values need to be considered? For example the potential to support processes like dispersal and provision of drought refuge areas, or the level of and habitat diversity represented.

This next section of the report describes the background behind the prioritisation attributes with the following results sections applying these attributes to each site that was visited in the 2010 survey.

Rapid vegetation assessment

Each spring has an individual assessment sheet which is broken into four sections/pages.

- 1: describes the site information, a map and photos of the spring.
- 2: describes the ecosystem values and threats information.
- 3: describes the condition assessment values.
- 4: summarises the assessment information into site restoration potential and investment priority.

The information presented in each section of the assessment sheet is further described below.

1: Site Information

- Spring hydrogeological process class is described here. By necessity this is a qualitative judgement though this may need to be reviewed as further investigations are undertaken on more springs across the landscape.
- Springs physical dimensions are described at time of visit. This is a highly variable measure, as during drought the spring may be greatly reduced in size. This has not been used to classify the springs at this stage. Prior to the May 2010 field survey, flooding had occurred in many creeks in the Flinders Ranges, including the area visited.
- A species list is provided from the qualitative rapid assessment (see Section 3). Perennial species are the main focus of the surveys to determine any grazing impacts. Seasonal influences on annual species are not used to determine the condition rating of a site. Annual weed species are included to

determine condition rating. Foliage cover of the three most dominant species at each site are highlighted in the species list, this ranking is not categorically based.

2: Ecosystem Values and Threats

- This section comprises two tables, the first table details information about the site which is filled in using a key, an example of the key is provided below (Table 3). The 'key' table describes the various values which can be assigned to an indicator. Currently values are by necessity assigned on a relative scale as more information is needed to correctly assign each attribute a value based on more quantitative criteria. Gaps in the table are purposely used, to allow simple descriptions of an attribute. The attributes and values within the table have been developed to help identify key aquatic refuge and aquatic ecosystems within the landscape.

Table 3. Key to ecosystem values used within the ecological site assessment and evaluation form for each site.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3: Site Condition

- The Aquatic Ecosystems Task Group (AETG) formed the River Health Contact Group (RHCG) in May 2007 to provide advice on river health indicators for the National NRM Monitoring and Evaluation Framework. The RHCG was tasked with developing a nationally agreed methodology for assessing riparian vegetation condition. A major hurdle in developing a common methodology for a vegetation condition theme is that there are many methodologies available across Australia based on varying purposes and outcomes with a high degree of methodology turnover and evolution. Consensus on agreeing to a single vegetation condition assessment

methodology that could achieve everyone's desired outcomes was considered a near impossible task. Progressing this issue the RHCG determined that it was the interpretation of the data for management that was of more significance than the specific methodology used to collect the data. The approach adopted was to design a framework based on the common elements of existing methods that would provide a consistent evaluation of vegetation condition. To be useful as an ongoing NRM tool the framework would need to potentially be able to accommodate data from a range of older methods as well as adapt to emerging methods and future developments. Roberts et al, (2009) developed the draft Riverine (Riparian) Condition protocol for the RHCG. This project has adopted the framework (protocol) to assess the condition of springs, the table summary developed by Roberts et al (2009) which was used for this assessment is presented in Table 4.

Table 4.The method developed by Roberts et al (2009) that was used for this assessment and evaluation.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Current Management, Restoration Potential and Investment Priority

- Section 4 of the assessment sheet summarises the information described in Sections 1-3 and provides recommendations on current management, restoration potential and investment priority of the spring.

- As the inventory is further increased to include more springs, some attribute data may change which potentially could change the investment priority.
- The prioritisation schedule of the springs should be reviewed and updated as additional information becomes available.
- It should also be noted that by nature, vegetation communities in the Rangelands have attributes of resistance (withstand disturbance) and resilience (recover from disturbance) although it must be understood that rehabilitation of Rangeland ecosystems occurs over decades, especially if long dry periods persist.
- Long-term success of these rehabilitation projects in rangeland ecosystems need both financial and land management support.

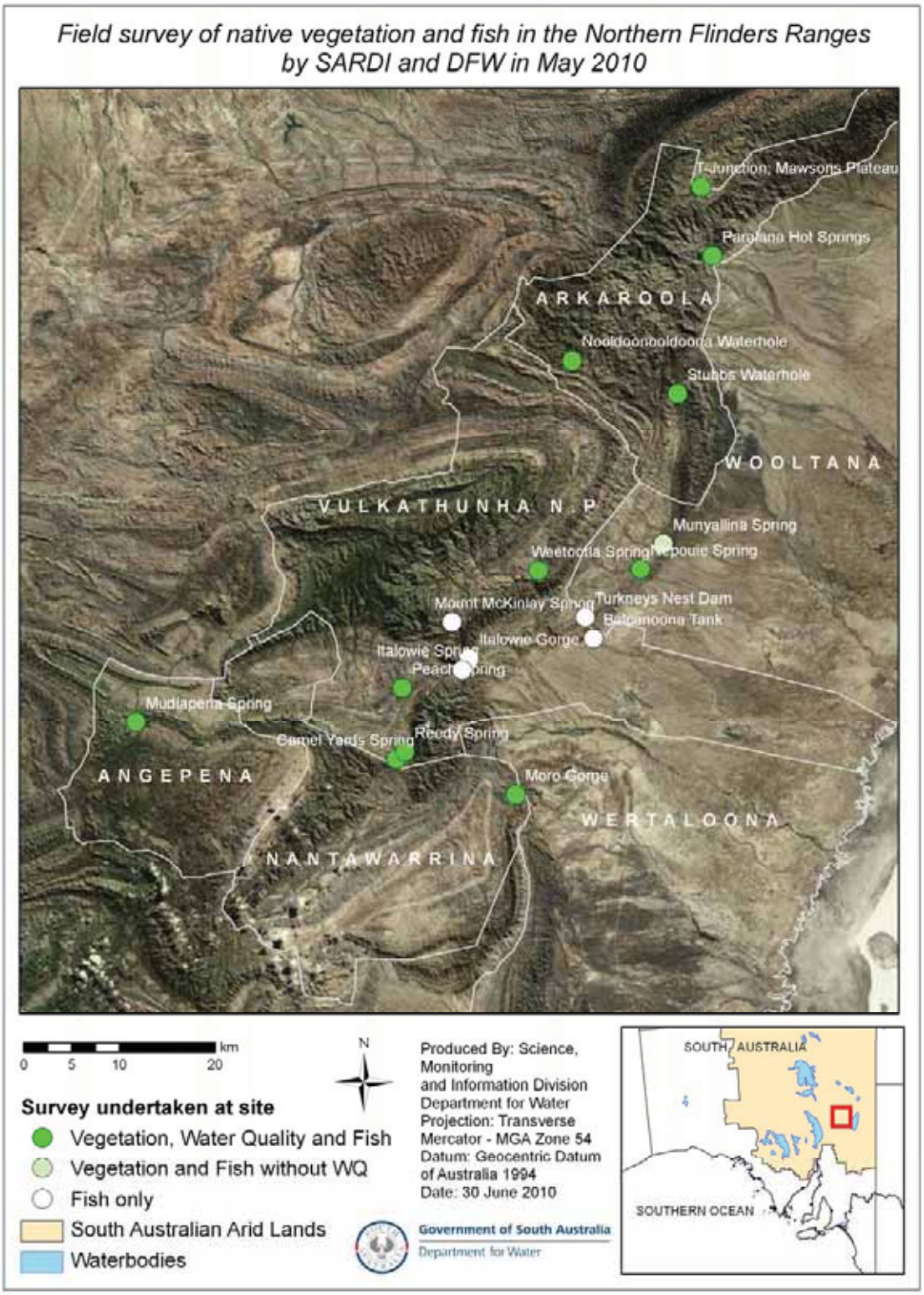

Figure 12. Map showing sites that had a rapid vegetation survey undertaken during the May 2010 survey.

FIELD ASSESSMENTS

Angepena Station

Mudlapena Spring; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E 289791 N 6611911
Date visited: 13th May 2010
Description of feature assessed

- *Type of Aquatic Ecosystem:* Spring
- *Size / Area:* ~200 m long and varied from 1 – 20m wide (field notes)
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 585 m
- *Vegetation association:* Mixed woodland of *Eucalyptus camaldulensis* (river red gum) lining the creek edge with *Callitris glaucophylla* (white cypress pine) on the hillslope.

Table 1.Species list of perennials from a rapid survey (annual weed species have been included).

Strata	Species
Aquatic / Semi-aquatic	**2.*Cyperus gymnocaulos***, *Juncus usitatus*
Understorey (grasses and forbs)	**Anagallis arvensis* (Blue Pimpernel), **Brassica tournefortii* (Mediterranean Turnip), **Centaurea melitensis* (Maltese Cockspur), *Cheilanthes lasiophylla* (Woolly Cloak Fern), *Cymbopogon ambiguous* (Lemon Grass), **Echium plantagineum (*Paterson's Curse), **Melilotus indicus* (Hexham Scent), **Solanum nigrum* (Black-berry Nightshade), Unidentified species # 06
Shrubs (low-shrubs and tall-shrubs)	*Cassinia laevis* (Wild Rosemary), **Nicotiana glauca* (Tree Tobacco)
Trees	**1.*Eucalyptus camaldulensis* (River Red Gum)**, **3.*Callitris glaucophylla* (White Cypress Pine)**

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 13. Photograph of Mudlapena Spring showing a mixed woodland of *Eucalyptus camaldulensis* (River Red Gum) and *Callitris glaucophylla* (White Cypress-pine).

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 2 species present Understorey: 9 species present Shrub: 2 species present Canopy: 2 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	HIGH	Shallow pool Deep pool Riffle Cyperus marsh at toe of spring	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	Aboriginal Knowledge
4	**Salinity**	SUB-SALINE	TDS = 1376 mg/L	YSI Multi-parameter
5	**Cultural site**	HIGH (Aboriginal)	*Tjukurrpa*[1]: Akurra (Serpent) resting place.	Tunbridge, 1998
6	**Uniqueness**	MODERATE	Other springs exist within the catchment, but their permanency has not been investigated during this project.	Moderate
7	**Key aquatic refuge**	HIGH	This permanent spring is a refuge for Spangled Perch, which are limited in distribution across the Flinders Ranges.	Quantitative Fish Survey
8	**Weeds**	PRESENT	7 different weed species were recorded, but not considered high threat weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	No presence of exotic animals were observed.	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW	Light grazing of vegetation, no stock on station at present.	Qualitative Survey
12	**Nutrients**	LOW	The absence of algae indicated low nutrients.	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

[1] *Tjukurrpa*: Aboriginal law or *Tjukurrpa* forms part of a rich cultural landscape passed from generation to generation through story and song.

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	River red gums line the bank of the spring and continue along the length of the creek. Connection to the terrestrial vegetation is present at the spring with integration of species on the rocky slope and riparian edge.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no high threat weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This spring resembles a non-modified environment with four strata intact.	Observation
Age Structure	SLIGHTY MODIFIED	Canopy cover of red gums was healthy, only two age classes were present; adult and sub-adult trees.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
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Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

This site recorded two age classes of its dominant species while all other sites during the survey recorded three age classes of its dominant species.

The dominant species at the site was *Eucalyptus camaldulensis* (River Red Gum) with adults and sub-adults recorded at the site, no saplings or seedlings were recorded. Without species recruitment, population replacement of species is limited. A number of factors may be limiting recruitment at the site, but historic and current grazing of seedlings and saplings by both native animals and stock is likely to be the cause.

Restoration Potential:

MODERATE: This site had the most weed species recorded than any other site during the May 2010 field-trip though none of the species are considered significant weeds (Thorp and Wilson, 1998 onwards). The cover of weeds at the site may limit recruitment of native plants from the different strata.

Investment Priority:

MODERATE: Other springs exist within the catchment, though their permanency was not investigated during this project. If further investigations found that this is the only permanent spring and refuge for Spangled Perch, which was caught during the fish sampling, it would support the reasoning of additional investment at this site.

Figure 14. Water quality sampling at Mudlapena Spring in May 2010 (pictured David Schmarr).

Nantawarrina Aboriginal Lands

The SAAL NRM Board in partnership with the Nepabunna Community have assisted in the protection of Moro Gorge through the construction of a boardwalk and viewing platform at the site. This has improved safety and access and managed visitor site impacts. The site has important cultural significance to the Adnyamathanha people.

Figure 15. Moro Gorge (in foreground), Northern Flinders Ranges.

Moro Gorge; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: undisclosed for cultural privacy. A permit is required from the Nepabunna community to allow access to the site as it is located in an Indigenous Protected Area.
Date visited: 14th May 2010
Description of feature assessed

- *Type of Aquatic Ecosystem:* Spring
- *Size / Area:* spring flows in the creek line for ~ 500 m until it disappeared into the creek-bed (taken from field notes not GPS).
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 212 m
- *Vegetation association:* Mixed woodland of *Melaleuca glomerata* (Desert Tea-tree) and *Eucalyptus camaldulensis* (River Red Gum) lining the creek edge.

Table 1.Species list of perennials from a rapid survey (annual weed species have been included).

Strata	Species
Aquatic / Semi-aquatic	*Cyperus gymnocaulos, Juncus usitatus, Typha domingensis,*
Understorey (grasses and forbs)	*Abutilon otocarpum* (Desert Lantern), *Cymbopogon ambiguous* (Lemon Grass), *Dianella sp., Enneapogon sp., *Malvastrum americanum* (Spiked Malvastrum), *Nicotiana velutina*, *Panicum sp.*, *Plectranthus parviflorus* (Cockspur Flower), *Solanum ellipticum* (Potato Bush), *Stipa sp.*, *Wahlenbergia sp., Zygophyllum apiculatum* (Gallweed, Pointed or Common Twinleaf)
Shrubs (low-shrubs and tall-shrubs)	**1&2.*Melaleuca glomerata* (Desert Tea-Tree)**
Trees	**3.*Eucalyptus camaldulensis* (River Red Gum)**,

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 16. Photograph of Moro Gorge showing mixed woodland of *Melaleuca glomerata* (Desert Tea-tree) and *Eucalyptus camaldulensis* (River Red Gum)

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 3 species present Understorey: 12 species present Shrub: 1 species present Canopy: 1 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	HIGH	Deep and Shallow pools Riffle and Waterfalls Rock-holes on instream rock slab (yellow footed rock wallaby and Xerothamnella parvifolia habitat)	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	Aboriginal Knowledge
4	**Salinity**	SUB-SALINE	TDS = 1,335 mg/L	YSI Multi-parameter
5	**Cultural site**	HIGH (Aboriginal)	*Tjukurrpa*[1]: Akurra (Serpent) resting place.	Tunbridge, 1998
6	**Uniqueness**	MODERATE	Other springs exist within the catchment, but their permanency was not investigated during this project.	Moderate
7	**Key aquatic refuge**	MODERATE	Yabbies and tadpoles present within this permanent spring. Further investigation of other springs within the catchment is required.	Qualitative Survey
8	**Weeds**	PRESENT	1 weed species was recorded, but it is not considered a 'significant' weed.	Qualitative Survey
9	**Exotic animals**	PRESENT	Goat and rabbit scats present. One dead goat at the site.	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	MODERATE	Moderate goat and rabbit grazing also occurring on the hill slopes above the spring.	Qualitative Survey
12	**Nutrients**	MODERATE	In non-flowing pools there was a build-up of filamentous algae.	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of Tea-tree and Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This spring resembles a non-modified environment with four strata intact.	Observation
Age Structure	LARGELY UNMODIFIED	Canopy cover of red gums was healthy with all age classes present; adults, sub-adults and seedlings. The dominant shrub species, Desert Tea-tree also had adults, sub-adults and saplings present.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

Nantawarrina was Australia's first Indigenous Protected Area (IPA) to be declared on 26 August 1998. Nantawarrina spreads across 58,000 hectares of rugged terrain between the Flinders Ranges and Gammon Ranges National Parks. Nantawarrina IPA is managed by the Adnyamathanha people of the Nepabunna Aboriginal community. As well as protecting Australian animals, such as the yellow footed rock wallaby, the IPA is of great cultural significance to the people as a birthplace, traditional tribal territory and a place of important mythological sites. The IPA, is restoring the landscape from previous pressures of grazing and protecting its heritage sites.

Restoration Potential:

INTACT: if current land management practices of revegetation, feral animal control and weed control are maintained, the site will continue to improve and stay in good ecological condition.

Investment Priority:

MODERATE: In 2009, *Xerothamnella parvifolia* (Small-leaved Xerothamnella) was found downstream of the gorge on Nantawarrina and Wertaloona Stations. This plant is listed as vulnerable – extinction nationally, and endangered in South Australia. If the plant has the potential to be impacted by goats and rabbits, it is recommended that goat and rabbit control are a priority on Nantawarrina and Wertaloona to ensure the survival of *Xerothamnella parvifolia*.

Figure 17. One of the deep pools at Moro Gorge with the viewing platform still being constructed (right).

Arkaroola Wilderness Sanctuary

The SAAL NRM Board requested that all anecdotal information on where the Flinders Ranges Mogurnda may exist be surveyed. This involved targeting Arkaroola Wilderness Sanctuary and talking to members of the Sprigg Family, owners of the property. Margaret and Douglas Sprigg thought that the Flinders Ranges Mogurnda may have in the past been introduced to Paralana Hot Springs.

The main focus of the field survey was to visit sites where people had reported observing fish, and permanent springs which were more likely to support a fish population if one existed in the area. Sites visited during the field survey were; Paralana Hot Springs, Stubbs Waterhole, Nooldoonooldoona Waterhole and Tee Junction Waterhole (Mawson's Plateau). A rapid vegetation assessment was undertaken at all of these sites along with a fish survey. No fish were found during this survey at Arkaroola Wilderness Sanctuary.

Figure 18. One of the numerous pools downstream of Tee Junction Waterhole on Mawson Plateau, *Xanthorrhoea quadrangulata* (Yacca) is present along the bank edge.

Mawson Plateau; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: Tee Junction waterhole E348764 N6667924
Date visited: 20th May 2010
Description of feature assessed

- *Aquatic Ecosystem Type:* Creek with numerous pools
- *Size / Area:* The Mawson Plateau is a 71 km² granite batholith (an exposed area of igneous rock mostly >100 km²). We walked ~ 6 km along the creek downstream from Tee Junction Waterhole. Pools of water persisted over a large distance beyond the area surveyed.
- *Conceptual understanding:* The creeks are fed from precipitation with some of the deeper holes known to retain water during droughts (D. Sprigg pers. comm.).
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* Escarpment height of 600 - 750m
- *Vegetation association: Eucalyptus camaldulensis* (River Red Gum) woodland lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weed species have been included).

Strata	Species
Aquatic / Semi-aquatic	*Chara australis, Cyperus alterniflorus* (Umbrella Sedge), *Cyperus gymnocaulos, Limosella curdieana* (Large Mudwort), Unidentified species # 08
Understorey (grasses and forbs)	**Anagallis arvensis* (Blue Pimpernel), *Bulbine bulbosa* (Native Leek), *Calandrinia ptychosperma* (Creeping Parakeelya), *Centipeda thespidioides* (Desert Sneezeweed), *Cheilanthes lasiophylla* (Woolly Cloak Fern), *Cheilanthes sieberi spp. sieberi* (Narrow Rock-fern), **Citrullus colocynthis* (Paddy Melon), *Cymbopogon ambiguus* (Lemon Grass), *Isotoma petraea* (Rock Isotome), *Marsilea sp., Nicotiana velutina, Plectranthus parviflorus* (Cockspur Flower), *Pleurosorus rutifolius* (Blanket Fern), **Solanum nigrum* (Black-berry Nightshade), *Solanum petrophilum* (Rock Nightshade), *Triodia irritans* (Spinifex), *Wahlenbergia sp.,* Unidentified species # 06, 07, 09 & 10
Shrubs (low-shrubs and tall-shrubs)	*Cassinia laevis* (Wild Rosemary), *Dodonaea viscosa ssp. angustissima* (Narrow-leaved Hopbush), *Senna sp.*, *Xanthorrhoea quadrangulata* (Yacca)
Trees	*Callitris glaucophylla* (White Cypress Pine)**1 & 2.*Eucalyptus camaldulensis* (River Red Gum)**,

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 19. Downstream of Tee Junction Waterhole on Mawson Plateau

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 5 species present Understorey: 20 species present Shrub: 4 species present Canopy: 2 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	HIGH	Shallow pool Deep pool Rock-holes on granite slab in-stream Waterfall Chain of ponds Runs	Qualitative Survey
3	**Hydrological value**	MODERATE - HIGH	Seasonal pools exist. Due to recent rains, we surveyed all pools with no distinction. Some pools may exist during dry periods.	Anecdotal
4	**Salinity**	FRESH	TDS = 200 mg/L	YSI Multi-parameter
5	**Cultural site**	MODERATE - HIGH	Wilderness Sanctuary	
6	**Uniqueness**	MODERATE - HIGH	Some pools are known to hold water on the Mawson Plateau during droughts	Anecdotal
7	**Key aquatic refuge**	MODERATE	Tadpoles and frogs present in numerous pools. Some pools may exist during drought periods as refuge.	Qualitative Survey
8	**Weeds**	PRESENT	3 weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed.	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW	Has been a non-grazed sanctuary since 1967.	Qualitative Survey
12	**Nutrients**	LOW	Scattered occurrence of algae in pools.	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of River Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This creek-line resembles a non-modified environment with four strata intact.	Observation
Age Structure	LARGELY UNMODIFIED	Canopy cover of red gums was healthy with all age classes present; adults, sub-adults and seedlings.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal, continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

The property is managed as a Wilderness sanctuary, with only limited tourists visiting the Mawson Plateau. The owners undertake goat management on the plateau, with a recent shoot in 2009.

Restoration Potential:

INTACT: if continued land management practices are maintained, the site will continue to stay in good ecological condition.

Investment Priority:

MODERATE: Based upon the restoration potential ranking of intact, it is recommended that goat control is maintained. The site is also a unique feature within the Northern Flinders Ranges with an undescribed species of frog, *Crinea sp.* inhabiting the area; it therefore is recommended that this area requires future investment to understand how the ecosystem acts as a drought refuge.

Figure 20. Granite Plateau Creek on the Mawson Plateau at Arkaroola Wilderness Sanctuary

Nooldoonooldoona Waterhole; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E335291 N6649762
Date visited: 19th May 2010
Description of feature assessed

- *Aquatic Ecosystem Type:* it is thought to be a spring fed 'waterhole'
- *Size / Area:* The depth of the large pool was 4.5 m and with annual evaporation rates up to 2.0 m, this waterhole may also be semi-permanent without any groundwater input.
- *Conceptual understanding:* The creeks are fed from precipitation with some of the deeper holes known to retain water during droughts due to groundwater discharge.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* ~ 400 m
- *Vegetation association:* Mixed woodland of *Eucalyptus camaldulensis* (River Red Gum) and *Melaleuca glomerata (Desert Tea-tree)* lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	None observed
Understorey (grasses and forbs)	*Abutilon sp., *Anagallis arvensis* (Blue Pimpernel) , *Asphodelus fistulosus* (Onion Weed), **Brassica tournefortii* (Wild Turnip), *Chenopodium melanocarpum* (Black Crumbweed), **Citrullus colocynthis* (Paddy Melon), *Cymbopogon ambiguus* (Lemon Grass), *Datura leichhardtii* (Native Thornapple), *Dianella revoluta sp., *Echium plantagineum* , **Malvastrum americanum* (Spiked Malvastrum), *Nicotiana velutina, Plectranthus parviflorus* (Cockspur Flower), *Solanum sp.*, ?*Trigonella suavissima* (Cooper Clover)?, *Zygophyllum apiculatum* (Gallweed, Pointed or Common Twinleaf, Non-ID 03, Non-ID 04, Non-ID 12
Shrubs (low-shrubs and tall-shrubs)	*Acacia tetragonophylla* (Dead Finish), *Melaleuca glomerata* (Desert Tea-tree), *Xanthorrhoea quadrangulata* (Yacca)
Trees	*Callitris glaucophylla* (White Cypress Pine)**1 & 2.*Eucalyptus camaldulensis* (River Red Gum)**, *Hakea ednieana* (Flinders Ranges Hakea), Non-ID 11

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 21. The large pool at Nooldoonooldoona Waterhole at Arkaroola Wilderness Sanctuary.

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	MEDIUM - HIGH	Aquatic: 0 species present Understorey: 19 species present Shrub: 3 species present Canopy: 4 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	HIGH	Shallow pool Deep pool Riffle	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	Anecdotal
4	**Salinity**	SUB-SALINE	TDS = 1,985 mg/L	YSI Multi-parameter
5	**Cultural site**		Unknown	
6	**Uniqueness**	LOW	Upstream of Stubbs WH (also surveyed) and thought to have some permanency	Desktop GIS
7	**Key aquatic refuge**	LOW - MODERATE	No aquatic fauna were observed, and there is more than one spring type in the area.	Anecdotal
8	**Weeds**	PRESENT	6 weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW	Has been a non-grazed sanctuary since 1967.	Qualitative Survey
12	**Nutrients**	LOW		Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of River Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	SLIGHTLY MODIFIED	No aquatic or semi-aquatic plant species were observed at the site, indicating that where the permanent water occurs it is unsuitable habitat for vegetation to establish eg. in-stream gravel bed.	Observation
Age Structure	LARGELY UNMODIFIED	Canopy cover of red gums was healthy with all age classes present; adults, sub-adults and saplings.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

The property is managed as a wilderness sanctuary. The site is a noted tourist destination although no tourist impact was observed at the site. The sanctuary also has signage at the site requesting that tourists do not swim in the waterhole to protect the aquatic ecosystem.

Restoration Potential:

INTACT: Current tourist management of the site is low impact and should be maintained.

Investment Priority:

LOW: current management is maintaining the site in good condition.

Figure 22. Smaller seasonal pools at Nooldoonooldoona Waterhole at Arkaroola Wilderness Sanctuary.

Paralana Hot Springs; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E349932 N6660782
Date visited: 19th May 2010
Description of feature assessed

- *Feature type:* Spring
- *Size / Area:* intermittent pools and sedge marsh over ~ 1km.
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence. Water temperature at discharge point is hot at 44 ºC, which indicates that the water source is from a deeper groundwater aquifer than other springs in the area.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 197 m.
- *Vegetation association:* Mixed woodland of *Eucalyptus camaldulensis* (River Red Gum) and *Melaleuca glomerata (Desert Tea-tree)* lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	**3.*Cyperus gymnocaulos***, *Juncus usitatus, Typha domingensis*
Understorey (grasses and forbs)	*Abutilon sp., *Anagallis arvensis* (Blue Pimpernel), *Boerhavia dominii* (Tarvine), *Euphorbia australis* (Hairy Caustic Weed), **Malvastrum americanum* (Spiked Malvastrum), *Nicotiana velutina*
Shrubs (low-shrubs and tall-shrubs)	*Acacia tetragonophylla* (Dead Finish), **2.*Melaleuca glomerata* (Desert Tea-tree)**, *Sida Sp.*
Trees	**1.*Eucalyptus camaldulensis* (River Red Gum)**, *Myoporum platycarpum* (Sugarwood), Unidentified # 11

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 23. The discharge point of Paralana Hot Springs looking downstream, Arkaroola Wilderness Sanctuary.

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 3 species present Understorey: 6 species present Shrub: 3 species present Canopy: 3 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	HIGH	Shallow pool Riffle Marsh	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	Local knowledge
4	**Salinity**	SUB-SALINE	TDS = 1,070 mg/L	YSI Multi-parameter
5	**Cultural site**	HIGH (Aboriginal)	*Tjukurrpa*[1]: Vadaardlanha (story of how the hot spring was created).	Signage at site
6	**Uniqueness**	HIGH	Only spring in stream reach, and only 'hot-spring' in area.	Qualitative Desktop GIS
7	**Key aquatic refuge**	MODERATE - HIGH	A permanent spring with aquatic fauna (invertebrates and tadpoles) and is the only hot-spring in the area.	Qualitative Survey
8	**Weeds**	PRESENT	2 weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW	Has been a non-grazed sanctuary since 1967.	Qualitative Survey
12	**Nutrients**	MODERATE	Algal benthic scum at discharge and downstream	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good crown density and cover of River Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This spring resembles a non-modified environment with four strata intact.	Observation
Age Structure	LARGELY UNMODIFIED	Canopy cover of red gums was healthy with all age classes present; adults, sub-adults and saplings.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and deposited debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

The property is managed as a wilderness sanctuary. The site is a noted tourist destination although no tourist impact was observed at the site. The sanctuary also has signage at the site requesting that tourists do not swim in the waterhole to protect the aquatic ecosystem.

Restoration Potential:

INTACT: Current tourist management of the site is low impact and should be maintained.

Investment Priority:

LOW: current management is maintaining the site in good condition.

Figure 24. Panorama of Paralana Hot Springs creekline, Arkaroola Wilderness Sanctuary.

Figure 25. The *Tjukurrpa*, story of Paralana Hot Springs creation.

Stubbs Waterhole; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E346301 N6646353
Date visited: 19th May 2010
Description of feature assessed

- *Aquatic Ecosystem Type:* it is thought to be a spring fed 'waterhole'
- *Size / Area:* A large pool > 50 m long.
- *Conceptual understanding:* The creeks are fed from precipitation with some of the deeper holes known to retain water during droughts due to groundwater being fed into these pools.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 200 m.
- *Vegetation association:* Mixed riparian woodland of *Eucalyptus camaldulensis* (River Red Gum) and *Melaleuca glomerata* (Desert Tea-tree) lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	None observed
Understorey (grasses and forbs)	*Boerhavia dominii* (Tarvine), **Citrullus colocynthis* (Paddy Melon), *Convolvulus remotus* (Australian Bindweed), *Cymbopogon ambiguus* (Lemon Grass), *Datura leichhardtii* (Native Thornapple), **Echium plantagineum* (Salvation Jane), *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush), *Euphorbia australis* (Hairy Caustic Weed), *Euphorbia drummondii* (Caustic Weed), **Malvastrum americanum* (Spiked Malvastrum), *Ptilotus exaltatus var. exaltatus* (Showy Foxtail), *Ptilotus obovatus var. obovatus* (Silver Mulla Mulla), **Solanum nigrum* (Black-berry Nightshade), *Trichodesma zeylanicum* (Cattlebush), Non-ID 01, Non-ID 02, Non-ID 03, Non-ID 04, Non-ID 05
Shrubs (low-shrubs and tall-shrubs)	**3.*Melaleuca dissitiflora* (Green Tea-tree)**, **2.*Melaleuca glomerata* (Desert Tea-tree)**, *Senna sp.* (sapling), *Sida petrophila* (Rock Sida), *Solanum sturtianum* (Thargomindah Nightshade)
Trees	**1.*Eucalyptus camaldulensis* (River Red Gum)**,

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 26. *Melaleuca* riparian woodland lining the creek at Stubbs Waterhole, Arkaroola Wilderness Sanctuary

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	MEDIUM - HIGH	Aquatic: 0 species present Groundcover: 15 species present Shrub: 4 species present Canopy: 3 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	HIGH	Shallow pool Deep pool Riffle	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	
4	**Salinity**	FRESH	TDS = 264 mg/L	YSI Multi-parameter
5	**Cultural site**		Unknown	
6	**Uniqueness**	LOW	Downstream of Nooldoonooldoona Waterhole	Qualitative Desktop GIS
7	**Key aquatic refuge**	MODERATE	Aquatic fauna (yabbies) were observed, and there is more than one spring type in the area.	Qualitative Survey
8	**Weeds**	PRESENT	Four weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW		Qualitative Survey
12	**Nutrients**	LOW		Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of River Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	SLIGHTLY MODIFIED	No aquatic or semi-aquatic plant species were observed at the site, indicating that where the permanent water occurs it is unsuitable habitat for vegetation to establish eg. steep banks.	Observation
Age Structure	LARGELY UNMODIFIED	Canopy cover of red gums was healthy with all age classes present; adults, sub-adults and saplings.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

The property is managed as a wilderness sanctuary. The site is a noted tourist destination although no tourist impact was observed at the site. The sanctuary also has signage at the site requesting that tourists do not swim in the waterhole to protect the aquatic ecosystem.

Restoration Potential:

INTACT: Current tourist management of the site is low impact and should be maintained.

Investment Priority:

LOW: as current management is maintaining the site in good condition.

Figure 27. A section of Stubbs Waterhole with the car parking area in the immediate foreground, and showing *Eucalyptus camaldulensis* (River Red Gum) woodland lining the creek.

Wooltana Station

Information sourced from SA Museum records indicates that the Flinders Ranges Mogurnda is known to occur at Nepouie Spring. The nearby Munyallina spring was also surveyed.

Figure 28. Fish biologists Dale McNeil and David Schmarr from SARDI photographing and observing a male Flinders Ranges Mogurnda protecting and fanning its eggs at Nepouie Spring, May 2010.

Munyallina Spring; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing:
Date visited: 21st May 2010
Description of feature assessed

- *Feature type:* Spring
- *Size / Area:* the main pools existed over an ~500 m stretch of the creek-line.
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 135 m.
- *Vegetation association: Eucalyptus camaldulensis* (River Red Gum) and *Melaleuca glomerata* (Desert Tea-tree) mixed riparian woodland within and lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	*Cyperus gymnocaulos.*
Understorey (grasses and forbs)	*Abutilon sp.*, **Anagallis arvensis* (Blue Pimpernel) , **Brassica tournefortii* (Wild Turnip), **Citrullus colocynthis* (Paddy Melon) , *Chenopodium melanocarpum* (Black Crumbweed), *Convolvulus remotus* (Australian Bindweed), *Datura leichhardtii* (Native Thornapple), *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush), **Malvastrum americanum* (Spiked Malvastrum), *Nicotiana velutina*, *Senecio magnificus* (Showy Groundsel), *Solanum ellipticum* (Potato Bush), *Trichodesma zeylanicum* (Cattlebush), *Zygophyllum apiculatum* (Gallweed, Pointed or Common Twinleaf), Non-ID 01 , Non-ID 03
Shrubs (low-shrubs and tall-shrubs)	**3.*Melaleuca glomerata* (Desert Tea-Tree),** Acacia sp. *Acacia tetragonophylla* (Dead Finish), *Acacia victoriae* (Elegant Wattle, Prickly Wattle), *Sida sp.*
Trees	**1 & 2.*Eucalyptus camaldulensis* (River Red Gum)**,

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 29. A section of Munyallina Spring showing *Eucalyptus camaldulensis* (River Red Gum) woodland and recent debris from flooding within the creek

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 1 species present Understorey: 16 species present Shrub: 5 species present Canopy: 1 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	MODERATE	Shallow pool Riffle	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent ? though it doesn't seem to be a large enough spring to be permanent.	Anecdotal
4	**Salinity**		Not tested	
5	**Cultural site**		Unknown	
6	**Uniqueness**	MODERATE	It is the only spring within the stream reach, but more springs occur within the catchment	Qualitative GIS Desktop
7	**Key aquatic refuge**	MODERATE	Aquatic fauna present (tadpoles), other springs within the catchment and permanency is unverified.	Qualitative Survey
8	**Weeds**	PRESENT	4 weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed.	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW		Qualitative Survey
12	**Nutrients**	LOW	Only a green algal tinge in pools (on the rocks)	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of River Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This spring resembles a non-modified environment with four strata intact.	Observation
Age Structure	LARGELY UNMODIFIED	Canopy cover of red gums was healthy with all age classes present; adults, sub-adults and saplings. The shrub layer consisting of *Melaleuca glomerata e* was healthy with all age classes present; adults, sub-adults and saplings present.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

Stock grazing evident. The site is located along a public track that criss-crosses the spring at various points along the creek-line. However, the site remains un-impacted and in good condition.

Restoration Potential:

INTACT: Continuation of current management to ensure that the road does not cause erosion and hence potential impact to the spring.

Investment Priority:

LOW: Current management is maintaining the site in good condition.

Figure 30. A section of Munyallina Spring on Wooltana Station

Nepouie Spring; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E342432 N6627937
Date visited: 18th May 2010
Description of feature assessed

- *Feature type:* Spring
- *Size / Area:* Intermittent pools flowed over ~750 m of creek line.
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence. Water temperature at discharge point is warm 27 ºC, which indicates that the water source is from a deeper groundwater aquifer than other springs in the area.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 142 m.
- *Vegetation association: Eucalyptus camaldulensis* (River Red Gum) woodland lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	*Cyperus gymnocaulos, Typha domingensis*
Understorey (grasses and forbs)	*Abutilon otocarpum* (Desert Lantern), *Boerhavia dominii* (Tarvine), **Chenopodium album* (Fat-hen), *Cymbopogon ambiguous* (Lemon Grass), *Datura leichhardtii* (Native Thornapple), *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush), **Malvastrum americanum* (Spiked Malvastrum), *Nicotiana velutina*, *Ptilotus obovatus var. obovatus* (Silver Mulla Mulla), *Solanum quadriloculatum* (Tomato Bush), *Solanum sp. Tetragonia tetragonioides* (New Zealand Spinach, Native Spinach), Non-ID 03 , Non-ID 04 , Non-ID 13
Shrubs (low-shrubs and tall-shrubs)	**3.*Melaleuca glomerata* (Desert Tea-Tree),** *Acacia victoriae* (Elegant Wattle, Prickly Wattle), *Senna sp., Sida petrophila* (Rock Sida), Non-ID 05, Non-ID 14
Trees	**1 & 2.*Eucalyptus camaldulensis* (River Red Gum)**, *Capparis mitchellii* (Iga, Native Orange)

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 31. A d/s section with a *Cyperus gymnocaulos* marsh within the creek (left) and u/s section showing *Eucalyptus camaldulensis* (River Red Gum) lining the creek (right) of Nepouie Spring

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 2 species present Understorey: 15 species present Shrub: 6 species present Canopy: 2 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	HIGH	Shallow pool Deep pool Riffle Marsh	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	Supports fish population
4	**Salinity**	SUB-SALINE	TDS = 1,200 mg/L	YSI Multi-parameter
5	**Cultural site**		Unknown	
6	**Uniqueness**	MODERATE	It is the only spring within the stream reach, but more springs occur within the catchment	Qualitative GIS Desktop
7	**Key aquatic refuge**	HIGH	Endangered fish species present *Mogurnda clivicola,* and only 'warm' permanent spring within the catchment.	Quantitative Survey
8	**Weeds**	PRESENT	2 weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed.	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW		Qualitative Survey
12	**Nutrients**	MODERATE	At discharge point at the top of the spring, the pools of water had high abundance of algae.	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of River Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This spring resembles a non-modified environment with four strata intact.	Observation
Age Structure	LARGELY UNMODIFIED	Canopy cover of red gums was healthy with all age classes present; adults, sub-adults and saplings. The shrub layer consisting of *Melaleuca glomerata* and *Acacia sp*. and *Acacia victoriae* was healthy with all age classes present; adults, sub-adults and saplings present. Saplings of *Capparis mitchelli* (iga, Native Orange) were observed, which is a rare find according to the Traditional Owners of the area, who haven't observed juvenile trees of this species in the wild.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Management Recommendations

Current Management:

Open water point with evidence of stock grazing. The site is located near a track and remains un-impacted and in good condition.

Restoration Potential:

INTACT: Continuation of current management to ensure condition of the site is maintained.

Investment Priority:

HIGH: Being the second and only non-National Park site that had saplings of *Capparis mitchelli*, Iga / Native Orange tree. This tree is of high local cultural significance to the Adnyamathanha people. A mapping project is recommended to be undertaken as a next step with the community to gain a better understanding of their current distribution and recruitment along creek-lines and springs and to preserve the only population of the critically endangered fish, *Mogurnda clivicola* outside of a National Park.

Figure 32. A cluster of four *Capparis mitchelli*, Iga tree saplings at Nepouie Spring, a culturally important species to the Adnyamathanha people

Vulkathunha – Gammon Ranges National Park

The critically endangered native fish, the Flinders Ranges Mogurnda is known to occur at Weetootla Spring within Vulkathunha, Gammon Ranges National Park. Seven other sites within the national park were also surveyed for fish either based on anecdotal information or permanency of spring as they are more likely to support a fish population (Figure 33). See section 1 in this report regarding the results from the fish survey. Four of these seven sites had a rapid vegetation assessment undertaken; Camel Yards Spring, Peach Spring, Reedy Spring and Weetootla Spring.

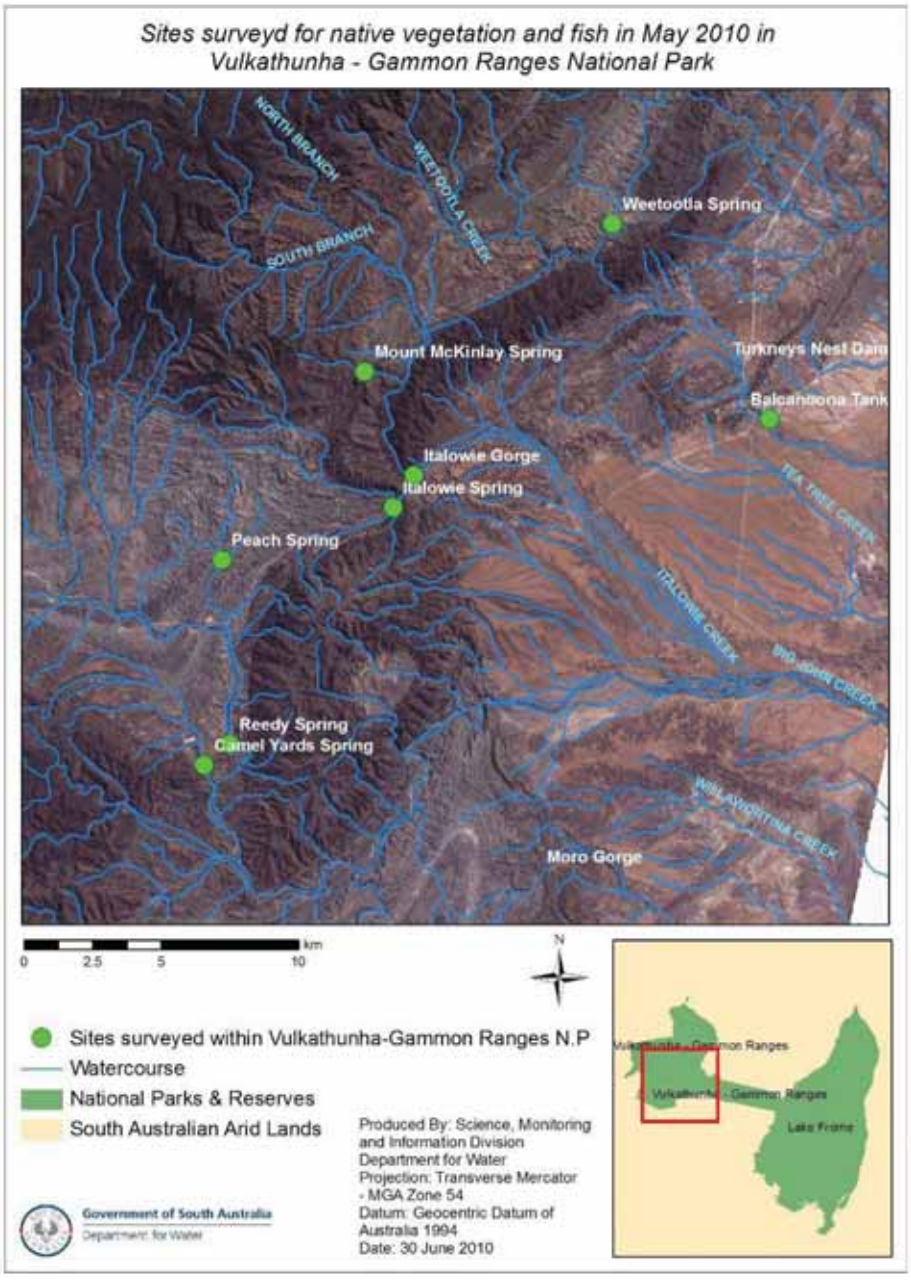

Figure 33. Map of sites surveyed for native vegetation and fish in Vulkathunha National Park

Camel Yards Spring; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E316930 N6608013
Date visited: 21st May 2010
Description of feature assessed

- *Feature type:* Spring
- *Size / Area:* Intermittent pools flowed over ~500 m of creek line.
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 310 m.
- *Vegetation association: Melaleuca glomerata* (Desert Tea-tree) woodland lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	*Cyperus gymnocaulos, Juncus usitatus,*
Understorey (grasses and forbs)	*Abutilon leucopetalum* (Desert Chinese-lantern), **Carrichtera annua* (Ward's Weed), *Cymbopogon ambiguus* (Lemon Grass), *Datura leichhardtii* (Native Thornapple), *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush), *Euphorbia australis* (Hairy Caustic Weed), **Malvastrum americanum* (Spiked Malvastrum), *Ptilotus exaltatus var. exaltatus* (Showy Foxtail), *Ptilotus obovatus var. obovatus* (Silver Mulla Mulla), *Sida sp., *Solanum nigrum* (Black-berry Nightshade), *Solanum quadriloculatum* (Tomato Bush), **Sonchus oleraceus* (Common Sowthistle), *Wahlenbergia sp.*, *Zygophyllum sp.* Non-ID 03
Shrubs (low-shrubs and tall-shrubs)	**1&2.*Melaleuca glomerata* (Desert Tea-Tree),** *Acacia tetragonophylla* (Dead Finish), *Acacia victoriae* (Elegant Wattle, Prickly Wattle),
Trees	**3.*Eucalyptus camaldulensis* (River Red Gum)**, *Myoporum platycarpum* (Sugarwood)

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 34. A section of Camel Yards Spring showing *Eucalyptus camaldulensis* (River Red Gum) *Melaleuca glomerata* (Desert Tea-tree) lining pools within the creek.

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 2 species present Groundcover: 16 species present Shrub: 3 species present Canopy: 2 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	MODERATE	Shallow pool Riffle	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	Anecdotal
4	**Salinity**	FRESH	TDS = 2 mg/L	YSI Multi-parameter
5	**Cultural site**		Unknown	
6	**Uniqueness**	MODERATE	Numerous springs exist within the Mount McKinlay catchment	
7	**Key aquatic refuge**	MODERATE	Aquatic fauna present (tadpoles) and numerous springs within the catchment.	
8	**Weeds**	PRESENT	Four weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed.	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW	This site is in a National Park. It has low grazing by kangaroos.	Qualitative Survey
12	**Nutrients**	LOW	Low density of algae observed.	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of Desert tea-tree. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This spring resembles a non-modified environment with four strata intact.	Observation
Age Structure	LARGELY UNMODIFIED	The shrub layer consisting of *Melaleuca glomerata* was healthy with all age classes present; adults, sub-adults and saplings present.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

The site is managed as a National Park.

Restoration Potential:

INTACT: Due to the site being assessed as largely unmodified and no other impacts were recorded for the site, the current management regime of the site should be continued.

Investment Priority:

LOW: current management of the site should be continued.

Figure 35. A section of Camel Yards Spring showing a riffle zone with *Melaleuca glomerata* (Desert Tea-tree) lining the pool.

Peach Spring; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E317574 N 6615505
Date visited: 16th May 2010
Description of feature assessed

- *Feature type:* Spring
- *Size / Area:* Intermittent pools flowed over ~250 m of creek line.
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* ~ 400 m.
- *Vegetation association:* Mixed *Eucalyptus camaldulensis* (River Red Gum) and *Melaleuca glomerata* (Desert Tea-tree) woodland lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	
Understorey (grasses and forbs)	*Abutilon leucopetalum* (Desert Chinese-lantern), **Carrichtera annua* (Ward's Weed), *Datura leichhardtii* (Native Thornapple), *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush), *Euphorbia australis* (Hairy Caustic Weed), ***3.*Malva parviflora* (Small-flowered Mallow)**, **Malvastrum americanum* (Spiked Malvastrum), *Salsola kali* (Buckbush), *Sida sp., Zygophyllum sp.*
Shrubs (low-shrubs and tall-shrubs)	**1.*Melaleuca glomerata* (Desert Tea-Tree),**
Trees	***2.Eucalyptus camaldulensis* (River Red Gum)**,

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 36. A section of Peach Spring showing *Eucalyptus camaldulensis* (River Red Gum) *Melaleuca glomerata* Desert Tea-tree) lining the creek with *Salsola kali* (Buckbush) in the foreground.

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	MODERATE - HIGH	Aquatic:0 species present Groundcover: 10 species present Shrub: 1 species present Canopy: 1 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	MODERATE - HIGH	Shallow pool Riffle	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	Aboriginal Knowledge
4	**Salinity**	SUB-SALINE	TDS = 2,082 mg/L	YSI Multi-parameter
5	**Cultural site**		Unknown	
6	**Uniqueness**	MODERATE	Numerous springs exist within the Mount McKinlay catchment	Qualitative GIS Desktop
7	**Key aquatic refuge**	LOW-MODERATE	No aquatic fauna observed and numerous springs within the catchment.	
8	**Weeds**	PRESENT	Three weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed.	Qualitative Survey
10	**Water abstraction**	Historical	Pipe from springs to old stockyards	
11	**Grazing pressure**	Historically HIGH	This site is in a National Park though is located next to old stockyards, with high density of *Salsola Kali* and **Malva parviflora*	Qualitative Survey
12	**Nutrients**	HIGH	High density of algae observed.	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	SLIGHTLY MODIFIED	Good health and cover of Desert tea-tree though the connection of the riparian zone with the terrestrial zone has been impacted by severe historical grazing (stockyards at site). Cover of understorey in the terrestrial zone is reduced.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present. Both Wards Weed and Small-flowered Mallow dominate within the riparian zone and adjacent.	Observation
Structural Integrity	MODERATELY MODIFIED	There are no aquatic species present (sedges) which supports that severe historical grazing has impacted the site.	Observation
Age Structure	LARGELY UNMODIFIED	The shrub layer consisting of *Melaleuca glomerata* was healthy with all age classes present; adults, sub-adults and saplings present.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

This site is currently managed within the National Park.

Restoration Potential:

LOW: The site has historically been severely grazed by stock due to it being a site with yards and water supply. Approximately 200 m from the stock yards, the understorey is less impacted. Degraded rangeland ecosystems may take decades to recover from severe grazing, this site being one of those.

Investment Priority:

LOW: Due to the low recovery potential, weed impact and modified condition of the site, this area would not be a high priority for investment to restore ecological function.

Figure 37. Historical stock yards at Peach Spring showing severely impacted understorey from historical grazing.

Reedy (Weedy) Spring; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E317853 N 6608769
Date visited: 21st May 2010
Description of feature assessed

- *Feature type:* Spring
- *Size / Area:* Intermittent pools flowed over ~500 m of creek line.
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 300 m.
- *Vegetation association: Eucalyptus camaldulensis* (River Red Gum) woodland.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	**3.*Cyperus gymnocaulos***,
Understorey (grasses and forbs)	*Arabidella glaucescens, *Asphodelus fistulosus* (Onion Weed), **Carrichtera annua* (Ward's Weed), *Datura leichhardtii* (Native Thornapple), *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush), **Malvastrum americanum* (Spiked Malvastrum), *Wahlenbergia sp.*
Shrubs (low-shrubs and tall-shrubs)	**2.*Melaleuca glomerata* (Desert Tea-Tree),**
Trees	**1.*Eucalyptus camaldulensis* (River Red Gum)**, *Myoporum platycarpum* (Sugarwood)

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 38. A riffle section of Reedy Spring showing large mature *Eucalyptus camaldulensis* (River Red Gum) within the creek.

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 1 species present Groundcover: 7 species present Shrub: 1 species present Canopy: 2 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	MODERATE	Shallow pool Riffle	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent?	Anecdotal
4	**Salinity**	SUB-SALINE	TDS = 1,473 mg/L	YSI Multi-parameter
5	**Cultural site**		Unknown	
6	**Uniqueness**	MODERATE	Numerous springs exist within the Mount McKinlay catchment	Qualitative GIS Desktop
7	**Key aquatic refuge**	LOW - MODERATE	No aquatic fauna observed and numerous springs within the catchment.	
8	**Weeds**	PRESENT	Three weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed.	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW	This site is in a National Park. It has low grazing by kangaroos.	Qualitative Survey
12	**Nutrients**	LOW	Low density of algae observed.	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of River Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This spring resembles a non-modified environment with four strata intact.	Observation
Age Structure	LARGELY UNMODIFIED	The shrub layer consisting of *Melaleuca glomerata* was healthy with all age classes present; adults, sub-adults, saplings and seedlings present.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary and Management Recommendations

Current Management:

The site is managed as a National Park.

Restoration Potential:

INTACT: The site being assessed as largely unmodified with no other impacts recorded. The current management regime of the site should be continued.

Investment Priority:

LOW: current management of the site should be continued.

Figure 39. Photograph of a section of Reedy Spring showing *Eucalyptus camaldulensis* (River Red Gum) and *Cyperus gymnocaulos* lining pools within the creek.

Weetootla Spring; Ecological Site Assessment and Evaluation

1 - Site Information

Easting / Northing: E331779 N 6627759
Date visited: 16th May 2010
Description of feature assessed

- *Feature type:* Spring
- *Size / Area:* Intermittent pools flowed over ~4 km of creek line.
- *Conceptual understanding:* Fractured rock spring fed from groundwater discharge, as indicated by its permanence. Water temperature at discharge point is warm (27 ºC), which indicates that the water source is from a deeper groundwater aquifer than other springs in the area.
- *Recent rainfall / inundation events:* Major rain event which caused flooding of creeks in the whole Northern Flinders Ranges area, 34.7 mm over 2 days, 9th-10th April 2010.
- *Elevation:* 320 m.
- *Vegetation association: Eucalyptus camaldulensis* (River Red Gum) woodland lining the creek.

Table 1.Species list of perennials from a rapid survey (annual weeds species have been included).

Strata	Species
Aquatic / Semi-aquatic	*Cyperus gymnocaulos,* **2.*Cyperus sp.***, **3.*Juncus usitatus***, **Rorippa nasturtium-aquaticum* (Watercress), *Typha domingensis*
Understorey (grasses and forbs)	*Abutilon leucopetalum* (Desert Chinese-lantern), **Acetosa vesicaria* (Rosy Dock), *Chenopodium melanocarpum* (Black Crumbweed), *Convolvulus remotus* (Australian Bindweed), *Datura leichhardtii* (Native Thornapple), *Enchylaena tomentosa var. tomentosa* (Ruby Saltbush), **Malvastrum americanum* (Spiked Malvastrum), *Plectranthus parviflorus* (Cockspur Flower), *Ptilotus obovatus var. obovatus* (Silver Mulla Mulla), *Sida petrophila* (Rock Sida), **Solanum nigrum* (Black-berry Nightshade), **Sonchus oleraceus* (Common Sowthistle), *Trichodesma zeylanicum* (Cattlebush), *Zygophyllum sp.,* Non-ID 02, Non-ID 03
Shrubs (low-shrubs and tall-shrubs)	*Melaleuca glomerata* (Desert Tea-Tree), *Acacia victoriae* (Elegant Wattle, Prickly Wattle), *Dodonaea lobulata*, *Pimelea microcephala* (Shrubby Rice-flower), *Eremophila sp.*
Trees	**1.*Eucalyptus camaldulensis* (River Red Gum)**, *Capparis mitchellii* (Iga, Native Orange)_saplings and adults.

*Foliage cover of dominant species are highlighted. * denotes introduced weed species.*

Figure 40. Pools within Weetootla Spring ranging from marshes to bare open pools.

2 – Ecosystem Values and Threats

Table 2. Ecosystem value and threat (see Table 3 for 'value' description).

	Indicator	Value	Description	Confidence
1	**Plant diversity** (see species list in Section 1)	HIGH	Aquatic: 5 species present Groundcover: 16 species present Shrub: 5 species present Canopy: 2 species present	Qualitative Survey
2	**Habitat diversity** (geomorphic features)	HIGH	Shallow pool Deep pool Riffle Marsh	Qualitative Survey
3	**Hydrological value**	HIGH	Permanent	Aboriginal Knowledge
4	**Salinity**	SUB-SALINE	TDS = 750 mg/L	YSI Multi-parameter
5	**Cultural site**		Unknown	
6	**Uniqueness**	HIGH	Only permanent warm temperature spring in the Balcanoona Catchment	Qualitative GIS Desktop
7	**Key aquatic refuge**	HIGH	Endangered fish species present Mogurnda *clivicola* and only warm permanent spring in catchment.	
8	**Weeds**	PRESENT	Five weed species were recorded, but are not considered 'significant' weeds.	Qualitative Survey
9	**Exotic animals**	ABSENT	None observed.	Qualitative Survey
10	**Water abstraction**	ABSENT		
11	**Grazing pressure**	LOW	This site is in a National Park. It has low grazing by kangaroos.	Qualitative Survey
12	**Nutrients**	MODERATE	Algae was mostly present in pools below a riffle.	Qualitative Survey

Table 3. Key to the ecosystem 'values' listed in Table 2 above.

ECOSYSTEM VALUES							THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
1 sp. for each strata (aquatic)	≥ 3 geomorphic features	Permanent	TDS <500 mg/L (fresh)	National Park, Aboriginal or European heritage	Only 'type' in catchment / rock outcrop	High Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Absent			Low	
1 sp. for each strata (non-aquatic)			TDS 500 – 3,000 mg/L (sub-saline)								
1 strata missing	2 geomorphic features	Seasonal	TDS 3,000 – 20,000 mg/L (Hypo-saline)	Infrastructure at site e.g. pump	>1 type in catchment / rock outcrop	Moderate Value (site within catchment and ecosystem value) for this aquatic ecosystem type.					
2 strata missing			TDS 20,000 – 50,000 mg/L (meso-saline)								
3 strata missing	1 geomorphic features	Episodic	TDS > 50,000 mg/L (hyper-saline)	Stock watering point	>1 type in stream reach	Low Value (site within catchment and ecosystem value) for this aquatic ecosystem type.	Present			High	

3 – Site Condition

Table 4. Vegetation condition (see Key 1 for the description of the indictors and Table 5 for the attributes used to assess vegetation condition).

Indicator	Value	Description	Confidence
Spatial Integrity	LARGELY UNMODIFIED	Good health and cover of River Red Gum. There is connection with the riparian habitat from the creek channel to the terrestrial hill-slope.	Observation
Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with few weeds and no 'significant' weeds present.	Observation
Structural Integrity	LARGELY UNMODIFIED	This spring resembles a non-modified environment with four strata intact.	Observation
Age Structure	LARGELY UNMODIFIED	Canopy cover of red gums was healthy with all age classes present; adults, sub-adults and seedlings. The shrub layer consisting of *Melaleuca glomerata* was healthy with all age classes present; adults, sub-adults and saplings present. Saplings of *Capparis mitchelli* (Iga, Native Orange) were observed, which is a rare find according to the Traditional Owners of the area, who haven't observed juvenile trees of this species in the wild.	Observation
Debris	LARGELY UNMODIFIED	Recent flooding of creek in April, stripped and dumped debris in creek line and spring.	Observation

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 5 for assessment criteria).

Spatial Integrity: Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness: Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).

Structural Integrity: Number of strata and/or life forms. Cover for each stratum.

Age Structure: Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris: Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	Slightly Modified	Moderately Modified	Substantially Modified	Severely Modified
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (e.g. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

4 – Summary Management Recommendations

Current Management:

The site is currently managed within the Vulkathunha-Gammon Ranges National Park. The spring is sited along one of the walking tracks within the park and is 1 km from the nearest vehicle track.

Restoration Potential:

INTACT: Continuation of current management to ensure condition of the site is maintained.

Investment Priority:

HIGH: This was the only National Park site that had saplings of *Capparis mitchelli*, Iga / Native Orange tree. This tree is of high local cultural significance to the Adnyamathanha people. A mapping project is recommended to be undertaken as a next step with the community to gain a better understanding of their current distribution and recruitment along creek-lines and springs and to preserve the only population of the critically endangered fish, *Mogurnda clivicola* within the National Park.

Figure 41. Braided channel within Balcanoona Creek, with most of these pools having the Flinders Ranges Mogurnda present.

DISCUSSION

Overall, most sites were assessed in good condition as largely unmodified. A summary of the 12 springs visited and prioritised for this project are listed in Table 5. Three key prioritisation attributes have been taken from the individual site score-cards to summarise the important assets that the NRM Board can use to direct on-ground works.

Investment Priority:

- Prioritisation for investment was weighted towards those springs that have the greatest contribution as an aquatic ecosystem refuge within the catchment as well as those that have the greatest recoverability potential in relation to management investment and intervention. This means that those springs that are significantly ecologically impaired may have a lower priority for investment due to a low recovery potential. Those that are ecologically intact may also have a lower priority for additional investment due to their relative security under current environmental conditions and management regimes.

Restoration Potential:

- Rangeland attributes of resistance (withstand disturbance) and resilience (recover from disturbance) was used to determine its restoration potential. A heavily disturbed site will have a low score, with a less disturbed or recovering site having a higher score. Those sites that are under good management and show resistance to disturbance are rated as intact.

Key Aquatic Refuge:

- Flexibility was needed in determining what a key aquatic refuge is for each type of aquatic ecosystem. To simplify and allow transferability between different aquatic ecosystems, attributes from the ecosystem value scores were synthesised to give an indication of the importance of the site as a key aquatic refuge.

The two springs that had a high investment priority rating both had populations of the critically endangered fish species, *Mogurnda clivicola*, and also saplings of *Capparis mitchelli*, an important tree species to the local Adnyamathanha People. Five saplings were found during this trip; one at Weetootla Spring and four at Nepouie Spring. It is recommended that a mapping project is undertaken, as a next step with

the community, to gain a better understanding of the current distribution and recruitment rate of *Capparis mitchelli* within the Northern Flinders Ranges area. The high investment priority rating of these two sites both recommend further investment into understanding the ecological function of these springs and their importance in the landscape. Current management should be maintained but monitored to ensure future disturbance does not impact the springs.

The three sites with a moderate investment priority rating were also highlighted as sites with unique features (see each site card for details in the previous section). Again, current management should be maintained but monitored to ensure future disturbance does not impact the springs. Those sites with a low investment priority would only need future management if required for a specific purpose.

Table 5. Summary of rapid vegetation condition assessments at sites visited in the Northern Flinders Ranges in May 2010.

Property	Site	Investment Priority	Restoration Potential	Key Aquatic Refuge
Vulkathunha NP	Weetootla Spring	HIGH	INTACT	HIGH
Wooltana Station	Nepouie Spring	HIGH	INTACT	HIGH
Arkaroola Sanctuary	Mawson Plateau, Tee Junction	MODERATE	INTACT	HIGH
Nantawarrina IPA	Moro Gorge	MODERATE	INTACT	MODERATE
Angepena Station	Mudlapena Spring	MODERATE	MODERATE	HIGH
Arkaroola Sanctuary	Paralana Hot Springs	LOW	INTACT	MODERATE – HIGH
Wooltana Station	Munyallina Spring	LOW	INTACT	MODERATE
Vulkathunha NP	Camel Yards Spring	LOW	INTACT	MODERATE
Arkaroola Sanctuary	Stubbs Waterhole	LOW	INTACT	MODERATE
Vulkathunha National Park	Weedy/Reedy Spring	LOW	INTACT	LOW - MODERATE
Arkaroola Sanctuary	Nooldoonooldoona Waterhole	LOW	INTACT	LOW - MODERATE
Vulkathunha National Park	Peach Spring	LOW	LOW	LOW - MODERATE

Overall, the rapid assessment approach that this project has used in conjunction with a qualitative evaluation provides the SAAL NRM region with a cost effective indication of the functional condition of the springs to base management decisions upon. If the decision is made to further invest in management at a site, a more quantitative assessment methodology can be undertaken for one or each subindex category to provide a baseline for monitoring vegetation ecosystem change.

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