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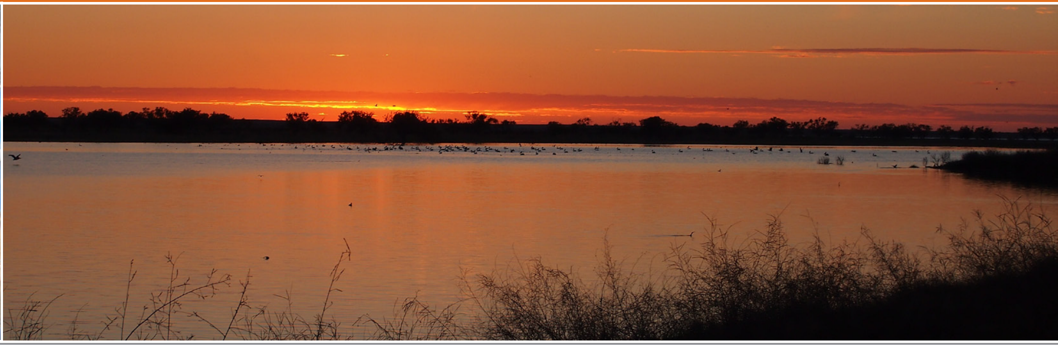

October 2013

South Australian Arid Lands Natural Resources Management Board

Aquatic ecology assessment and analysis of the Cooper Creek, South Australia

David Schmarr, Rupert Mathwin, David Cheshire, Dale McNeil

AQUATIC ECOLOGY ASSESSMENT AND ANALYSIS OF THE COOPER CREEK: LAKE EYRE BASIN, SOUTH AUSTRALIA

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Dale McNeil

October 2013

Report to the South Australian Arid Lands Natural Resources Management Board

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Schmarr, D.W., Mathwin, R., Cheshire, D.L. and McNeil, D.G. (2013). Aquatic ecology assessment and analysis of the Cooper Creek: Lake Eyre Basin, South Australia. Report by the South Australian Research and Development Institute (Aquatic Sciences) to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

Cover images:

L) Cooper Creek catfish
R) Lake Hope sunset autumn 2012

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Acknowledgements

We acknowledge the traditional custodians of the lands at all of the sites surveyed for this project and pay our respects to the elders both past, present and future.

Our authors would like to thank Henry Mancini and the South Australian Arid Lands Natural Resources Management Board (SAALNRMB) for directing the Caring for Our Country Project "Managing the high ecological value aquatic ecosystems of the Cooper Creek catchment (SA)". The project follows on from the previous successful Neales Catchment Critical Refugia Project (McNeil et al 2011).

Our field team Rod Ward, Gabriel Shepherd and Jed MacDonald have made this project both a success and a pleasure. Likewise our collaborators all made this a rewarding and informative project, they were: Justin Costelloe, Graham Tomlinson and Darren Ludeman, (University of Melbourne); Henry Mancini, Perri Carter and Matthew Westover (SAALNRMB); Gresley Wakelin-King and Hyangah (Hana) Lee (Wakelin Associates Pty Ltd); Gini Lee and Brooke Madill (University of Melbourne), Jake Gillen and Julian Reid (Australian National University). Rod Ward and Kate Frahn provided comments on this manuscript and Qifeng Ye provided overall staff and project management

Our journey has seen highs and lows, and our successful completion and safe return often hinged on people we had only just met. Paul Broad and Jason Dunn at Etadunna station assisted us on several occasions with equipment repair and directing us around obstacles. Department of Environment Water and Natural Resources (DEWNR) rangers at Innamincka Andy and Trevor assisted us with accommodation, local knowledge and fish processing. Garry and Paul Overton from Mulka station have helped us greatly with demonstration of their fishery and expert fish knowledge. We look forward to collaborating with Garry and Paul to better understand Lake Hope's unique system. Trevor Whitelaw and SANTOS have repeatedly allowed us access to their flights and facilities and Rod Glover and Beach Energy allowed us access to the Eaglehawk and Beach bridge sites. Phil Gregurke and Pam Farrington have made Mungeranie Hotel an oasis to our team, their warmth and generosity will be sorely missed.

Thanks must also go to the tourists who participated so willingly in our surveys and to the Toyota Landcruiser Club of South Australia for their enthusiastic efforts to preserve the bush.

Executive Summary

This study is part of a collaborative research project investigating the high ecological value aquatic ecosystems of Cooper Creek in South Australia. This report addresses the aquatic ecology assessment and analysis of the catchment.

The project objectives were to: investigate aquatic ecosystem health and function in the Cooper Creek system in South Australia, engage with stakeholders regarding monitoring and awareness throughout the system, identify and highlight threats and impacts to the system and develop management action recommendations. Each of these objectives was successfully addressed.

Fish populations performed seasonally predictable expansions and contractions in abundance with high productivity over summer and low productivity over winter. Abundance of small-bodied fish in autumn samples increased dramatically with consistent recruitment to floodplain habitats occurring. More resilient species were the first to form dominant populations in lower reaches of the catchment followed by resistant species as water quality declined. The importance of deep permanent refugia was highlighted by the role of these environments in supporting diverse and mature populations of adult and juvenile fish and other aquatic fauna.

A key finding of this study is that upper and lower reaches of Cooper Creek represent spatially divergent ecosystems. Whilst flows have connected the entire catchment several times over the past two years, the species assemblages of upper and lower reaches maintained a high degree of spatial integrity. Resilient species occupied and dominated ephemeral sites in the lower catchment, a few resistant species took advantage of declining water quality in the lowest reaches of the catchment and less resilient species maintained populations in the upper catchment. This spatial pattern was repeated in observations of fish disease where fish in the upper catchment had higher incidences of disease than the lower catchment. The conclusion to this finding is that refugia in the upper and lower reaches of Cooper Creek should be managed in at least three management units: permanent upper refugia (e.g. Cullyamurra, Burke's, Tirrawarra), semipermanent main branch and northwest branch refugia (e.g. Narie, Kudriemitchie, Coongie Lake, Cuttapirie Corner), and ephemeral lower Cooper refugia (e.g. Eaglehawk Waterhole, Lake Hope, Lake Killalpaninna and Cuttupirra waterhole).

A gap in knowledge regarding the contribution of recreational fishing to fish mortality in Cooper Creek prompted a pilot study into the feasibility of conducting a large-scale recreational fishing survey. The pilot study was able to elicit two key findings: a) there is great potential for an expanded recreational fishing survey, and b) there is strong evidence that information about recreational fishing regulations is not being adequately communicated.

The project was able to engage stakeholders from a variety of backgrounds. The highly successful interaction with the Department of Environment, Water and Natural Resources (DEWNR) staff, as well as with the Toyota Landcruiser Club of South Australia, has proven the value of ongoing grass-roots and inter-agency monitoring in the Innamincka area of Cooper Creek. This type of monitoring will provide invaluable long-term data that would not be otherwise attainable.

Over the course of the project, SARDI researchers were able to build a strong relationship with Garry and Paul Overton from Lake Hope fishery. Their knowledge of the fishery and ecosystem of Lake Hope enhanced our understanding of the system. Further studies are needed to obtain an accurate understanding of this fishery.

Several threats in the Cooper Creek ecosystem were identified, with varying risks and impacts. Goldfish (*Carassius auratus*) and Gambusia (*Gambusia holbrooki*) had well established populations. Gambusia expanded their distribution during the project and at times were caught in extremely large numbers. Goldfish exhibited a typical boom/bust population cycle, with numbers quick to expand into new areas then crashing equally as fast. Gambusia and goldfish were both present in low abundance at key permanent refugia. Both species do not appear to be having a quantifiable effect on the aquatic health of the system.

The ongoing expansion of gas and petroleum extraction in large parts of the Cooper Creek catchment has brought with it large-scale infrastructure needs, particularly the construction of transport infrastructure. Aquatic monitoring work has highlighted the importance of floodplains for fish and invertebrate recruitment. These areas are being intersected quite regularly with bunds, causeways, and bridges. Inappropriate obstruction or channelling of the movement of water over floodplains may have serious consequences for the utilisation of these areas by aquatic fauna.

Whilst no cane toads (*Bufo marinus*) were observed during this study, the biotic and abiotic factors exist for them to invade the South Australian section of Cooper Creek. It is unclear whether they could form a resident population, but it is likely that they could at least interact with aquatic fauna during summer floods. Published literature indicates that cane toads pose a direct threat to some Cooper Creek species through their toxicity, while the threat they pose to other species is still unclear.

From the above findings several recommendations are proposed:

1. Maintaining natural flow regimes in Cooper Creek should remain a priority. Activities that threaten natural flow regimes should be avoided or thoroughly assessed before implementation.
2. Environmental impacts applying to the South Australian Cooper Creek catchment should be independently considered over at least three spatial management units; the Upper Cooper Main Channel, the Main Branch and Northwest Branch, and the Lower Cooper.
3. Ongoing fish monitoring in the Innamincka area should be conducted using volunteer stakeholders and/or interagency staff and detailed monitoring programs should be tailored to their workload and availability. An important component of this will be tagging of large-bodied fish including yellowbelly (*Macquaria ambigua*), Barcoo grunter (*Scortum barcoo*) and Welch's grunter (*Bidyanus welchi*).
4. An expanded recreational fishing survey should be conducted in the Innamincka Regional Reserve.
5. Interpretive signage with information relating to fish size and bag limits, other aquatic fauna, and protection of aquatic ecosystems should be provided at a greater number of locations and made more prominent.
6. Specific interactions between the Cooper Creek aquatic biota and cane toad eggs and tadpoles need further investigation. Infestation pathways and distribution points have been highlighted by concurrent work carried out by Gresley Wakelin-King (in prep).
7. The impact of activities such as road and bridge building on fish passage and floodplain function warrants further investigation. Detailed modelling of altered floodplain inundation and diversion of flow, as well as on-ground monitoring of fish movement will enable these impacts to be quantified.
8. Future construction of transport infrastructure with potential to impact water regimes should be preceded by greater consultation with SAALNRMB.
9. Research funding through the Fisheries Research and Development Corporation (FRDC) and PIRSA Fisheries and Aquaculture should be sought to collect comprehensive fisheries data for the Lake Hope fishery.
10. Research through the Lake Eyre Basin Rivers Assessment should be ongoing in order to monitor trends in aquatic ecosystem condition and inform adaptive management of key refugia such as Coongie Lakes and Cullyamurra Waterhole.

Introduction

Cooper Creek is one of two major river systems flowing into Lake Eyre in central Australia, the other being the Diamantina. The catchment encompasses a large part of western Queensland with two rivers, the Thompson and Barcoo, meeting near Windorah to become Cooper Creek, which then flows over an extensive floodplain before entering South Australia through the Innamincka dome geological formation. In this area (referred to here as the Upper Cooper Main Channel) the creek comprises of several deep permanent refuge waterholes due to the scouring effect of frequent flows over this high gradient landscape. Downstream of the Innamincka dome the landscape flattens out and the creek branches into two main anabranches. The Northwest Branch receives most flows and directs water into the Coongie Lakes area, the only truly permanent wetland area in arid central Australia. In large floods, water then continues on from Coongie Lakes to rejoin the Main Branch further downstream. After this junction, the creek (referred to here as the Lower Cooper) flows towards Lake Eyre alternating between several large flood plains and channel areas, filling numerous lakes along the way including Perigundie, Hope, Kopperamanna and Killalpaninna. The creek becomes saltier as it flows towards Lake Eyre as it entrains salt from lakes and sediment along the way. Cooper Creek reaches the eastern side of Lake Eyre North approximately once every six years. The entire system is located in a remote and sparsely populated part of the country. Whilst there has been a long history of pastoral use and increasing pressures from mining infrastructure and tourism, the system remains a unique and high ecological value ecosystem due to the absence of major flow regulation.

This fish ecology project stems from the larger Caring for Our Country Project “Managing the high ecological value aquatic ecosystems of the Cooper Creek catchment (SA)”. The project set several broad objectives including: investigating aquatic ecosystem health and function in the Cooper Creek system in South Australia, engaging stakeholders in monitoring and awareness and highlighting threats and impacts to the system with associated management recommendations.

The study will provide SAALNRMB with important baseline data for assessment of water resources to inform decisions and provide recommendations for activities affecting water regimes, environmental water requirements and, in partnership with DEWNR staff, park management decisions. It also builds on knowledge from previous reports and addresses key knowledge gaps identified in recent reports such as the ARIDFLO and Coongie Lakes studies.

More specifically, this component aimed to:

- assess the distribution and habitat use of native and introduced fish species in South Australia's Cooper Creek Catchment.
- examine population dynamics of non-target taxa including turtles, crustaceans, and mussels.
- assess the ecological function and importance of key refuge habitats for aquatic fauna in this reach of Cooper Creek.
- identify key threatening processes affecting the Cooper Creek aquatic biota.
- undertake a pilot study into recreational fishing behaviours within a key refuge location.
- use findings to determine key recommendations aimed at improving management of high ecological value resources within the study area.

This project addresses a major gap in our understanding of the functioning of arid zone waterways and the role of different types of refugia in maintaining the long-term biodiversity of ephemeral arid zone rivers. Key outcomes of the project are an improved understanding of how refugia are used by native and pest fish species and how these findings can have significant applied benefits for managing this and other arid zone rivers.

The project encompasses a period of significantly increased river flows and catchment inundation resulting from exceptionally high rainfall climatic conditions throughout the Basin and especially within the western Queensland catchments of the Upper Cooper Creek. The high levels of inundation resulted in certain objectives of the project becoming more important to the analysis and interpretation of the data through necessity.

Objectives relating to the role of drought and climatic severity in limiting the distribution of fish species, and the role of fish species resistance and resilience to this climatic severity have been impossible to ascertain due to the very low impact of seasonal drought throughout the study period. Instead, the study period provided an opportunity to observe the response of the fish community to large scale patterns of long term (~3 years) hydrological connectivity between in-channel, floodplain, wetland and lake systems. Cooper Creek continues to flow at the time of writing.

This period of high flow enabled the first scientific survey of fish communities in the Lower Cooper catchment to be undertaken. Previous studies such as ARIDFLO (Costelloe *et al.* 2004, Pritchard 2006), Lake Eyre Basin Rivers Assessment (LEBRA) fish trajectory trials (McNeil *et al*. 2008) and DRY/WET (Puckridge 1999) have not surveyed Cooper Creek downstream of the junction of the North-West branch, although opportunistic (and unpublished) collections may have been taken at the Birdsville Track Crossing (Justin Costelloe pers. com.). Therefore this study is extremely significant to obtaining an understanding of the ecological health of the extreme lower Cooper. The focus on the extreme lower end of the system also allows for identification of end of catchment patterns that may be useful in determining flow targets for the management of water resources within the system and in determining the extent of fish species migrations towards Lake Eyre. This can be contrasted to existing data from permanent refugia further upstream where species survived climatically drier periods such as those encountered between 2005 and 2009 (McNeil *et al*. 2008; McNeil and Schmarr 2009). This provides new knowledge regarding the expansion and contraction of the Cooper Creek fish population, building upon existing boom-bust and source-sink models developed upstream in the Queensland reaches of the catchment (Arthington *et al*. 2005; 2010; Balcombe *et al*. 2007; Arthington and Balcombe 2011; Kerezsy *et al*. 2011).

Ichthyological observations, assessed the distribution and habitat use of native and introduced fish species, providing site specific community composition and productivity data through space and time. This assessment of fish assemblage and productivity provides important baseline data to understand the spatial and temporal variety of refugia that enabled species survival through dry periods. Extrapolation of these identified trends enables inference of the biotic interrelation between these sites and the surrounding transient habitats. This highlights the importance of refuge resilience to the maintenance of fish refugia despite temporal variation in waterhole condition.

Models of fish ecosystems are enhanced through supplementing fish observations with a holistic set of aquatic biota observations. Population observations for crustaceans, mussels and turtles, with specific inferences for each taxa and the system as a whole, can be combined with fish data to add to our understanding of complex ecosystem responses to flow and connectivity.

Examining the location and population dynamics of the exotic fishes gambusia (*Gambusia holbrooki*) and goldfish (*Carassius auratus*) enables options for management and control to be informed and considered in context. Other pest threats evaluated were cane toads and feral pigs (*Sus scrofa*), as well as the biotic implications of anthropogenic impacts observed within the study areas.

Permanent waterholes and floodplain habitats are the key ecological drivers of the system. This aquatic ecosystem study provides the SAALNRMB with an improved understanding of these habitats on which to base future management decisions for the preservation of the high value aquatic refugia within South Australia’s Cooper Creek.

Methods

Site Selection

Sites were initially chosen to cover a broad geographic spread and encompass the range of waterhole typologies developed for the Neales River in McNeil *et al.* (2011). This included large permanent waterholes (Ark refuges), periodically significant but ephemeral waterholes (Disco waterholes), Polo Club refuges (environmentally harsh habitats such as saline or hypersaline waterholes), springs, bores and stepping stone habitats that may contain fish during infrequent periods of inundation.

Site selection criteria included:

- Good spatial distribution along South Australia’s stretch of the Cooper Creek,
- Representing a gradient of identified disturbance (where possible) with sites ranging from pristine to extremely degraded,
- Adequately represents the range of habitat types present in the catchment,
- Use of socially significant and high conservation value sites,
- Permanent, as well as temporary waterholes,
- Legacy sites where historic data is available,
- Preplanned contingency sites to allow for informed refocussing where access was not possible.

Fixed long-term sites were to be assessed twice yearly in spring (end of dry season) and autumn (following the wet season). Sampling at the end of the dry season provides maximal detail on refugia and potentially limiting thresholds (i.e. climatic tolerance and water quality). End of wet season sampling provides an assessment of connectivity, fish movement and recolonisation (Humphries *et al.* 2007). Sampling twice a year following this method allows the assessment of catchment scale range expansions and contractions and demonstrates the impact of climatic extremes on the ecology of fishes. Understanding these extremes under natural variability allows assessment of river health trajectories and provides river health indicators.

Due to the exceptionally wet climatic period with high rainfall and inundation patterns, site selection became more opportunistic with the principals of site selection upheld where possible. Furthermore, the large degree of inundation led to the opportunity for sampling rarely inundated habitats such as floodplains, wetlands and off-channel lakes in the lower catchment. The resulting collection of sites were therefore accessible under flooded conditions and was dominated by off-channel lakes, wetlands and waterholes in reasonably confined sections of the catchment. Waterholes that lay within large floodplains were impossible to access throughout 2010/11. Priority monitoring sites identified at the onset of the survey include Cullyamurra (key Ark refuge) and Cuttupirra (end of catchment indicator) waterholes, the Coongie Lake system (Ramsar wetlands), Lakes Hope (commercial fishery site) and Killalpaninna (site of historical and tourism importance).

Priority sites have been sampled on each occasion to ascertain variability through time, although access has limited sampling of some priority sites during some assessment periods. Cullyamurra was inaccessible in autumn 2011 and the Coongie Lakes system was first accessible during spring 2011.

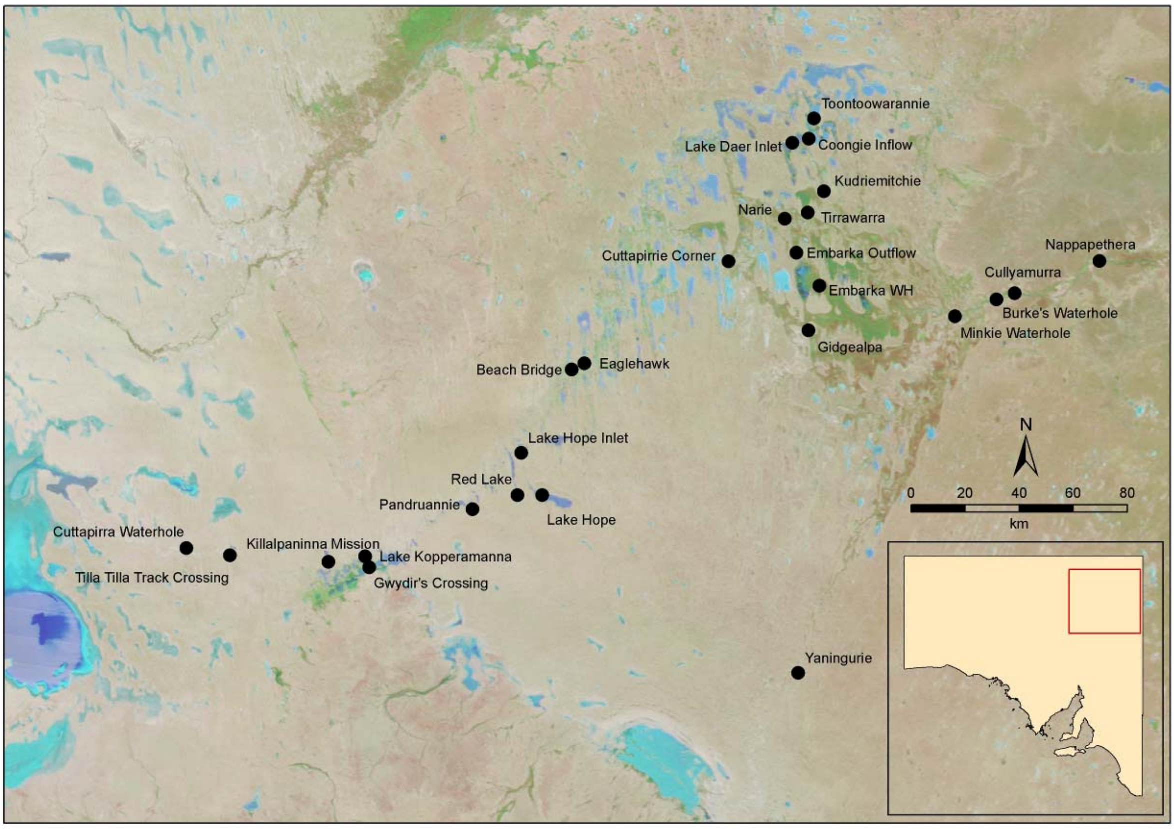

Figure 1. All sample sites in Cooper Creek and Strzelecki Creek.

Water Quality & Habitat

At each site, substrate type, in-stream structure, rate of flow and connectivity to the main channel were assessed and recorded. Percent cover of aquatic, emergent and riparian macrophytes was estimated and the dominant species for each category identified (Sainty and Jacobs 2003). A point of maximum depth was identified within each site where water quality was recorded.

Water quality parameters - dissolved oxygen, water temperature, pH and salinity - were analysed on site using a YSI 6920 multiparameter water quality sonde. Measurements were taken at the water's surface and then at 50 cm depth intervals concluding at the riverbed. These data are used to create a vertical profile of water quality revealing mixing trends (e.g. stratification) within the water column.

Fish Sampling Protocols

Each site was sampled using a standard set of fyke nets which varied between sampling rounds (Table 1). In spring of 2010, the sampling protocol matched that of work previously carried out in the Neales River (McNeil *et al.* 2011). Over the course of this project, this protocol was further expanded and refined to maintain consistency with fish survey methodologies for the Lake Eyre Basin Rivers Assessment (McNeil and Cockayne 2010).

The dimensions and characteristics of the various net types used were:

- Small fyke: meshed single-winged design (3 m wing, 4 mm mesh, 3 m funnel, 0.6 m high) – these nets are effective at sampling small bodied fishes in shallow water microhabitats.
- Long fyke: meshed single wing design (5 m wing, 6 mm mesh, 4 m funnel, 0.6 m high) – these nets are effective in targeting small bodied fishes over long sections of shallow bank.
- Double-wing small fyke: meshed double wing design (2 x 5 m wing, 4 mm mesh, 3 m funnels, 0.6 m high) – these nets are effective at sampling smaller bodied fishes in shallow water habitats.
- Double-wing large fyke: meshed double-wing design (2 x 10 m wing, 12 mm mesh, 5 m funnels, 1.2 m high) – these nets are effective in targeting large bodied fishes and can be set in deeper waters.
- Seine net (ad-hoc): 3 m x 1.2 m drop, 2 mm mesh, in built collection bag, leaded rope bottom) – seine drags are effective at targeting very small fish and benthic species, but require bare substrates free of snags to be effective.

Table 1 Sampling protocols varied between seasons as analysis allowed refining of the methodology.

	Small Fyke	Long Fyke	Double-wing Small Fyke	Double-wing Large Fyke
Spring 2010	4	2	4	
Autumn 2011	4	2	4	2
Spring 2011	6			2
Autumn 2012	6			2

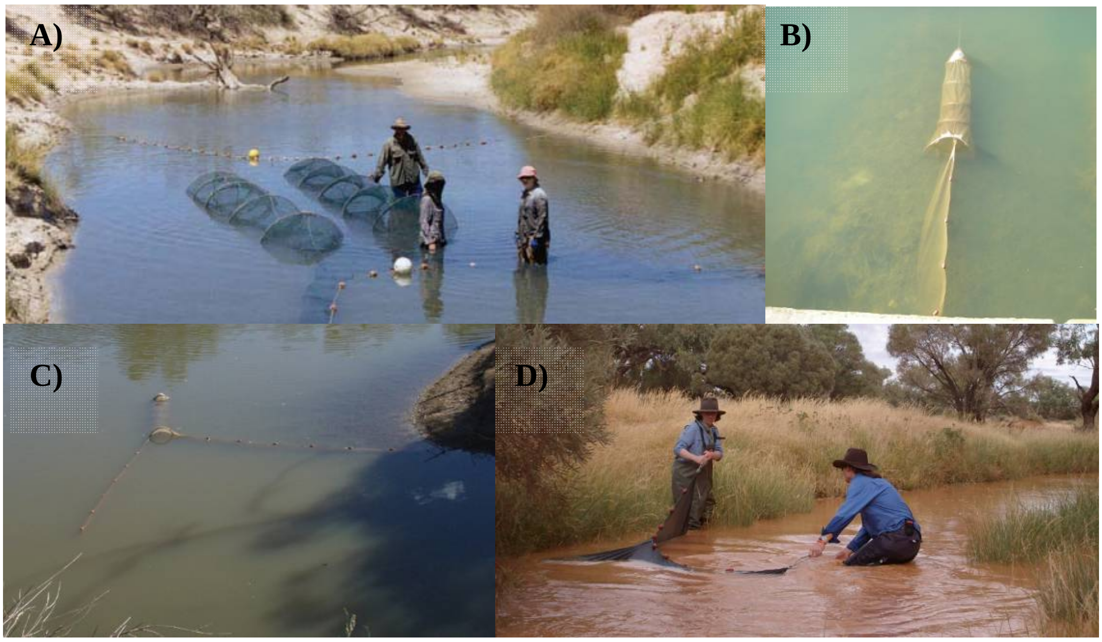

Figure 2. Examples of netting types used for the fish community monitoring. A) double-wing large fykes, B) small fykes, C) double wing small fyke and D) seine netting.

All nets were set within 250 m of an access point (usually the site of GPS waypoint), with each net type deployed to sample a subsection of the waterhole. Small fykes were set in shallow locations targeting distinct microhabitats within the waterhole (e.g. complex snags or dense stands of submerged vegetation). Long fykes allowed longer sections of bank to be sampled. Double-wing small fykes allowed directional catches to be targeted and were often used to intercept movement into or out of an anabranch or channel. Double-wing large fykes were deployed paired and in opposition (Figure 2A) in deeper water, typically targeting larger bodied fishes. Additional ad-hoc sampling was carried out using seine nets, box style bait traps and nocturnal spotlighting to enhance the surety of presence/absence data.

Fyke nets were anchored using heavy gauge chain clipped to the cod and wing ends. Wing tips were tied off on natural structures or, if unavailable, onto stakes. Two polystyrene buoys were placed in each net's cod end to force a pocket of net above the water's surface. This created a space where bycatch (birds, water rats and turtles) could take refuge until the net was processed.

Fykes were set overnight and always set before dusk and collected after dawn, ensuring that each site was set for a minimum of 14 hours. This time period allowed capture during crepuscular activity and allowed adequate deployment for effective sampling.

The following outlines the fish processing procedures adapted from McNeil and Cockayne (2010):

- All fish were identified using well-known keys (Wager & Unmack 2000; Allen *et al.* 2002; J. Pritchard unpublished data).
- The lengths of the first 100 individuals of each species were measured (total length in mm). To eliminate within net selection bias, when the 100th measure was taken, this species' measurements continued until the completion of that net. For the invasive species *Gambusia holbrooki* only the first 50 individuals were counted.
- Measured fish were visually inspected for signs of disease (e.g. lesions or scoliosis) and spawning condition, and returned to the water at the point of capture. Voucher specimens were kept for any fishes where identification was uncertain.
- Fish that were not measured were counted.

For the Cooper Creek short neck turtle (*Emydura sp.*) maximum carapace length (MCL) was recorded and turtles released immediately at the site. Records were also kept of other bycatch which included; water rats (*Chrysogaster hydromus*), yabbies (*Cherax destructor*) shrimp (*Macrobrachium*, *Paratya* and *Caradina* spp.), and freshwater crabs (*Austrothelphusa transversa*).

All large bodied angling species over ~20 cm in total length (TL) including yellowbelly (*Macquaria ambigua*), Welch's grunter (*Bidyanus welchii*) and Barcoo grunter (*Scortum barcoo*), were tagged using individually numbered plastic T-bar tags (65 mm length) implanted on the dorso-lateral surface at less than 45º from the body surface to minimise protrusion. Each tag was implanted approximately 5 mm below the dorsal fin base just below the 2nd and 3rd or the 3rd and 4th dorsal spines. Tag numbers were recorded along with the fish length and any other data recorded for sex, disease, etc. These details were logged with external provider Suntag (http://info-fish.net/suntag/).

Data Analysis

To standardise catches within the project to a catch per unit effort (CPUE), the total catch data for each net from every SARDI Lake Eyre Basin sampling event since December 2007 was compiled noting set and pull times for each event. This dataset was reviewed and events with missing data points such as unrecorded set or pulled times were eliminated along with infrequently used gear types and sampling occasions in which only one gear type was used. This process created a dataset tailored to compare the efficiency of gear types and effort ratios.

Total catch per hour was calculated for each net and a $\log^{10}$ transformation was applied to normalise the data. From this, average catch for each net type was calculated. Using small fyke nets as the base unit produced a gear effort score for each net type. In this way a small fyke set for one hour produced one unit of effort.

Total catch for each sampling event was divided by the total gear effort (sum of all gear effort at the site) and divided by the number of hours that nets were set to produce a CPUE value for each site.

PC-ORD software was used to run multivariate comparison of all sampling events. Sites were divided into geographic reaches to identify clustering patterns. Sample sites were analysed along a geographic gradient comparing water quality, fish community and flow parameters. Visualisation was carried out using a canonical comparison analysis (CCA) plot.

Netting Efficacy Study

During autumn 2012, SARDI researchers collaborated with the Toyota Landcruiser Club of South Australia and SAALNRMB staff to undertake a netting efficacy study at Cullyamurra Waterhole (Figure 3). This nested study aimed to verify the accuracy of the current sampling methodology and determine which factors would influence the final results. A standard set of nets were repeatedly set in the same locations over six consecutive days creating five replicate samples. These data were analysed using a Repeat Measures ANOVA (SPSS statistical software package) to determine if variability existed within the above sampling techniques.

Figure 3. Members of the Toyota Landcruiser Club of SA and SAALNRMB assisting SARDI with fish sampling at Cullyamurra waterhole (Photos Perri Carter).

Recreational Fishing Survey

A 10 question pilot survey was developed with the aim of assessing key aspects of recreational fishing activities in the Innamincka Regional Reserve. Over three days in April 2012, SAALNRMB staff members approached tourist groups in the reserve and used a short interview process to complete surveys. The guide to interviewers and survey form are attached in Appendix 1.

Results

Results for hydrology, water quality, biotic sampling and the recreational fishing survey are considered in the 'whole of catchment' analysis presented below. More detailed data summaries are presented on a site by site basis in the "Site Assessment Sheets" provided in Appendix 2.

Hydrology

The Cooper Creek is a highly variable river system with flow fluctuating unevenly through long dry periods of 'bust' and into high volume floods that drive productivity 'booms' (Kingsford *et al*. 1999). The Cooper Creek Critical Refugia Project occurred within a boom period for the creek following the autumn 2010 floods (Figure 4).

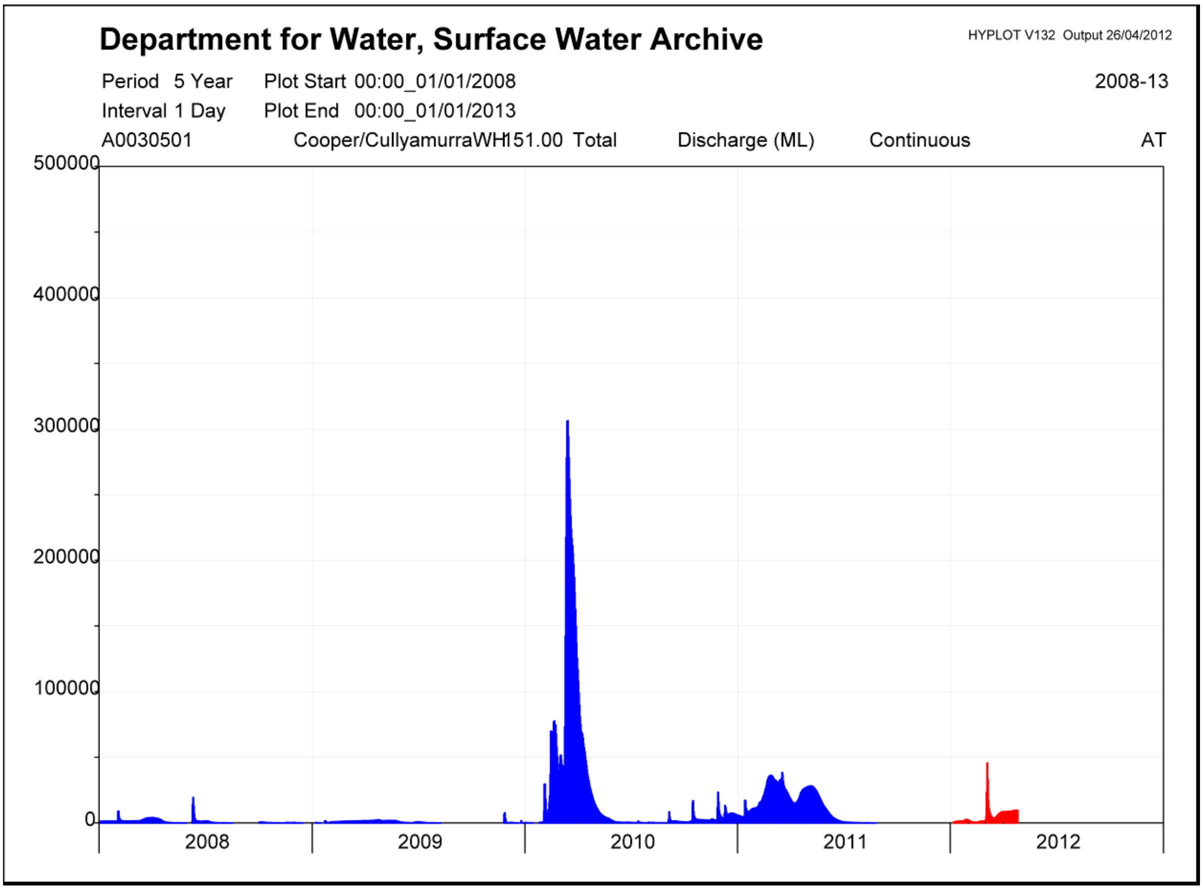

Figure 4. Hydrograph (ML/day) at Cullyamurra waterhole on Cooper Creek 2008-2012.

This timing has allowed the study to observe ephemeral waterholes in periods of high flow and into early decline. Examples of this may be observed in Gwydir's Crossing and Yaningurie Waterhole (Table 2). At these sites salinity and turbidity began low (spring 2010) as regular flushing flows maintained high water quality. As these fresh inputs tapered off, depth decreased and the aquatic microalgal component increased resulting in higher turbidities and higher surface oxygen levels. Without fresh inputs, loss through evaporation and seepage caused *in situ* salinity to increase.

Table 2. Water quality parameters in Gwydir's Crossing and Yaningurie Waterhole between Spring 2010 and Autumn 2012.

Season	Year	Maximum Dissolved Oxygen (mg/L)	Minimum Dissolved Oxygen (mg/L)	Temperature (^{o}C)	Salinity (ppt)	pH	Turbidity (NTU)	Maximum Depth (cm)
Gwydir's Crossing								
Spring	2010	8.7	8.26	25.6	0.33	10.15	39.48	200
Autumn	2011	8.42	7.61	22.04	0.73	10.04	386.83	130
Spring	2011	17.41	14.42	27.56	0.42	10.86	0.5	200
Autumn	2012	25.15	24.16	19.77	2.45	10.53	108.95	50
Yaningurie Waterhole								
Spring	2010	4.93	4.51	24.59	0.65	9.16	9	190
Autumn	2011	6.58	5.81	22.71	0.62	9.29	22.14	260
Autumn	2012	11.65	8.56	15.31	8.36	9.25	60.6	100

Larger, more enduring waterholes like Cullyamurra and Lake Hope did not undergo notable unidirectional decline during the period observed (Table 3). Water quality parameters were complex and variable with increases and declines in turbidity and dissolved oxygen suggestive of dynamic variability in microalgal communities. Despite intrinsic variability in water quality, these larger waterbodies display marked resilience with values varying dynamically but remaining within a spectrum of values that is habitable to fishes. Lake Hope lies further downstream than Cullyamurra Waterhole. Salinity values at Lake Hope were higher than those observed upstream reflecting an accumulation of salts in influent waters. Further concentration can be observed in elevated autumn 2012 salinity readings attributable to *in situ* evaporation.

Table 3. Water quality parameters at Cullyamurra Waterhole and Lake Hope between Spring 2010 and Autumn 2012.

Season	Year	Maximum Dissolved Oxygen (mg/L)	Minimum Dissolved Oxygen (mg/L)	Temperature (°C)	Salinity (ppt)	pH	Turbidity (NTU)	Maximum Depth (cm)
Cullyamurra Waterhole								
Spring	2010	5.98	3.67	28.08	0.09	7.71	160.11	510
Autumn	2011	8.99	8.36	14.77	0.1	8.87	62.56	730
Spring	2011	7.31	6.22	25.31	0.19	9.44	9.08	450
Autumn	2012	7.23	6.53	22.28	0.08	7.76	35.32	650
Lake Hope								
Spring	2010	8.28	8.12	24.61	0.48	9.25	66.93	420
Autumn	2011	11.22	10.54	14.01	0.71	9.73	13.68	530
Spring	2011	11.03	10.79	25.85	0.91	9.92	4.73	150
Autumn	2012	9.94	9.81	17.95	1.33	9.78	12.2	150

Catch per Unit Effort

Using five years of catch data within the Lake Eyre Basin, a stochastically robust approach to catch per unit effort (CPUE) was enabled. A gear effort score was calculated for each gear type used in the study based upon the average catches for each net type over the five year period (Table 4). The average catch for a small fyke was fixed as one unit of netting effort, while all other net types were adjusted by their relative factor. CPUE was calculated by dividing the total catch by the total netting effort and the number of hours set.

Table 4. Effort factors for each gear type employed in the present study.

Gear Type	Effort factor
Small Fyke	1
Long Fyke	0.41
Double Winged Small Fyke	2.28
Double Winged Large Fyke	2.02
Bait Trap	0.33

Cullyamurra Netting Efficacy Study

No specific effect of net type ($F(1,6)=2.827$, $p=0.144$) or species ($F(4,6)=3.782$, $p=0.072$) was found, however, sample day was a significant factor in differences between CPUE on successive days during the netting efficacy study $F(1,6)=144.2$, $p<0.01$. However, after removing the non-significant factors (net type and species) from the model and adding soak time as a covariate, the effect of day was not significant $F(4,179)=1.541$, $p=0.192$. This result indicates that differences between sites can be attributed to catch size and species presence or absence rather than stochastic effects due to the day sampled. By adjusting catch totals to reflect time set and gear specific differences, catches at different locations and times are directly comparable.

Fish Monitoring

Sampling over four seasons identified 15 species of fish with 13 native and two exotic species captured. A total of 140,851 fish were caught at 28 sites, which equates to an average CPUE of 0.78 fish/net/hour. This was broken down into average CPUE of 0.21, 1.92, 0.44 and 0.54 fish/net/hour for each successive season. These values are comparable, apart from autumn 2011 (CPUE 1.92). Here elevation is suggestive of a boom in response to sustained, high antecedent flow combined with high summer temperatures driving primary productivity. Catch rates may have also been elevated due to high rates of migrant captures with nets often set in flow conditions.

In spring 2010, the system was dominated by large catches of spangled perch (*Leiopotherapon unicolor*), bony herring (*Nematalosa erebi*), silver tandan (*Porochilus argenteus*), Hyrtl's tandan (*Neosilurus hyrtlii*), and yellowbelly (*Macquaria ambigua*) recruits. These catches were spatially divided by the upper reaches where tandans dominated and lower reaches where bony herring dominated (Figure 5).

In autumn 2011, the fish assemblage changed dramatically to one dominated by extreme catches of gambusia and glassfish (*Ambassis mulleri*) upstream, bony herring, spangled perch and rainbowfish (*Melanotaenia splendida*) downstream, and the emergence of Lake Eyre hardyhead (*Craterocephalus eyresii*) at the most downstream site at Cuttupirra waterhole (Figure 6).

In spring 2011, the assemblage changed again to one dominated by carp gudgeon (*Hypseleotris* spp.) and bony herring throughout, while goldfish numbers peaked in the lower reaches and Lake Eyre hardyhead expanded its range (Figure 7).

In Autumn 2012, glassfish and Gambusia increased in number, but not as prolifically as in autumn 2011 (Figure 8). At the furthest upstream sites the species assemblage became more evenly distributed with large numbers of most species observed at each site. Yaningurie Waterhole on Strzelecki Creek became anoxic and the fish assemblage declined with only a few gambusia remaining.

Native species

Australian smelt (*Retropinna semoni*)

Australian smelt were observed from the upper reaches at Minkie Waterhole to the lowest site at Cuttupirra Waterhole. There was no pattern to their distribution but abundance was always low. Most were larger fish and were frequently in spawning condition. This species appears to be distributed throughout the study range but in very low abundance. Smelt were only captured on nine occasions, totaling 34 fish.

Barcoo grunter (*Scortum barcoo*)

The distribution of Barcoo grunter was patchy within and between seasons. Over the course of the study they were identified from Cullyamurra to Cuttupirra Waterhole, but never in large numbers. The suggestion by ARIDFLO (Costelloe *et al.* 2004, Pritchard 2006) that hybrids exist between Barcoo and Welch's grunter remains unclear.

Bony herring (*Nematolosa erebi*)

Bony herring is an early migrant into novel habitats. At the commencement of the study this species had moved with floodwaters to occupy every site. While they dominated early successional communities their numbers reduced through time. This dynamic is most likely a reflection of a poor capacity for interspecific competition, or of failing microalgal production.

Carp gudgeon (*Hypseleotris spp.*)

This species expanded from only two records in autumn 2010 at the upper (Minkie Waterhole) and lower (Cuttupirra Waterhole) reaches of the study area to become one of the ubiquitous fish in the following seasons. This species was observed increasing in numbers on several occasions and at several sites. It is hypothesised that this species relies on the fecundity of a few successful migrants to seed distribution patterns in ephemeral systems. In this way it appears to be a mid-late successional species.

Cooper Creek catfish (*Neosiluroides cooperensis*)

In total only four individuals of this species were caught throughout all sites and seasons. This species was caught in the upper and mid Cooper Creek with the furthest downstream individual located at Cuttapirie Corner. There are reports of Cooper Catfish catches further downstream at Lake Walpayapeninna during autumn 2012 (Garry Overton pers. comm).

Desert glassfish (*Ambassis mulleri*)

During the first sampling round in autumn 2010 the desert glassfish had a patchy distribution and was found as far downstream as Lake Hope. Over the course of the study this species displayed high breeding success at several sites and in several seasons. At the completion of sampling this species was represented at all but three sites examined. These sites (Yaningurie Waterhole, Lake Kopperamanna and Cuttupirra Waterhole) were downstream sites where water quality had declined. Like the carp gudgeon, the desert glassfish appears to be a late-mid successional species that is intolerant of declining water quality.

Desert rainbowfish (*Melanotaenia splendida tatei*)

The desert rainbowfish was a ubiquitous fish in this study. It was found throughout the study range from the furthest upstream (Nappapethera Waterhole) to the furthest downstream site (Cuttupirra Waterhole) and was the only native species to persist in the highly degraded Yaningurie site during autumn 2012. The highest numbers of this species were observed in autumn 2011.

Golden perch (*Macquaria ambigua*)

Golden perch appears to be the top fish predator in the system. Its distribution spanned the length of Cooper Creek in South Australia, although it was not observed at Cuttupirra Waterhole on the final sampling round. Abundances were highest in the first two rounds of sampling and declined during the last two rounds. It was observed using recently established flow to enter Lake Daer during autumn 2012.

Hyrtl's tandan (*Neosilurus hyrtlii*)

This patchily distributed fish was found in only three of the ten sites examined during the first round of sampling (autumn 2010). Hyrtl's tandan does not appear to be a rapid or successful disperser having been located at only one site in the Lower Cooper (Lake Killalpaninna Mission) and on only one occasion. Where populations were observed in the mid Cooper (Ealglehawk Waterhole and Lake Hope), populations were much smaller than those in the permanent upper lakes.

Lake Eyre hardyhead (*Craterocephalus eyresii*)

Lake Eyre hardyhead appear to be specialised to high salinity environments. In autumn 2010, they were located at only a single site, Cuttupirra waterhole, the furthest downstream site in the study and the saltiest site in the study round. Over the course of the study they were found sequentially further upstream having moved to occupy seven sites (of the 19 sampled) during autumn of 2012. The furthest upstream this species was identified was at the Lake Hope inlet.

Silver tandan (*Porochilus argenteus*)

This species was restricted to the upper and mid sections of Cooper Creek on both the main channel and the north-west branch. Initial (autumn 2010) numbers at Cullyamurra and Minkie waterholes were the highest observed with numbers decreasing towards the end of the study.

Spangled perch (*Leiopotherapon unicolor*)

One of the fastest migrants, this species had spread throughout the study range from the commencement of this study. Although spangled perch were frequently seen to dominate early successional communities their numbers declined towards the end of sampling. This was especially noted in downstream sites where water quality had begun to decline (e.g. the Lake Hope sites during autumn 2012).

Welch's grunter (*Bidyanus welchii*)

Welch’s grunter did not appear to penetrate into the extreme lower Cooper (Gwydir’s Crossing and Cuttupirra Waterhole) but were spatially well distributed otherwise. Welch’s grunter was the most variably distributed species, with the proportion of sites that they were found at varying from 70% in autumn 2010 to 38% in spring 2011.

Invasive species

Gambusia (*Gambusia holbrooki*)

Gambusia expanded their range from two out of 10 sites in spring 2010 to 18 out of 21 sites in autumn 2012 (Figure 5-8). They also increased in abundance significantly over both summers, representing a majority of the catch at some sites (Figure 6, 8); although the increase in abundance was much lower after the second summer in autumn 2012. When water quality conditions became anoxic at Yaningurie, gambusia was the only species to survive there (Figure 8).

Goldfish (*Carassius auratus*)

Goldfish showed a pronounced “boom/bust” pattern. Only four goldfish were captured at the start of the study at two sites. Their numbers increased dramatically in autumn 2011 but they were confined to the upper reaches of the Cooper. They expanded into the lower reaches in spring 2011 and then contracted to the upper reaches in autumn 2012 (Figure 6-8). Whilst CPUE for goldfish was much lower than gambusia, their biomass was significantly higher due to their larger body size. This biomass was exploited by piscivorous birds in the upper reaches, to the extent that emesis was observed in pelicans at Cullyamurra (Trevor Whibley pers. comm.).

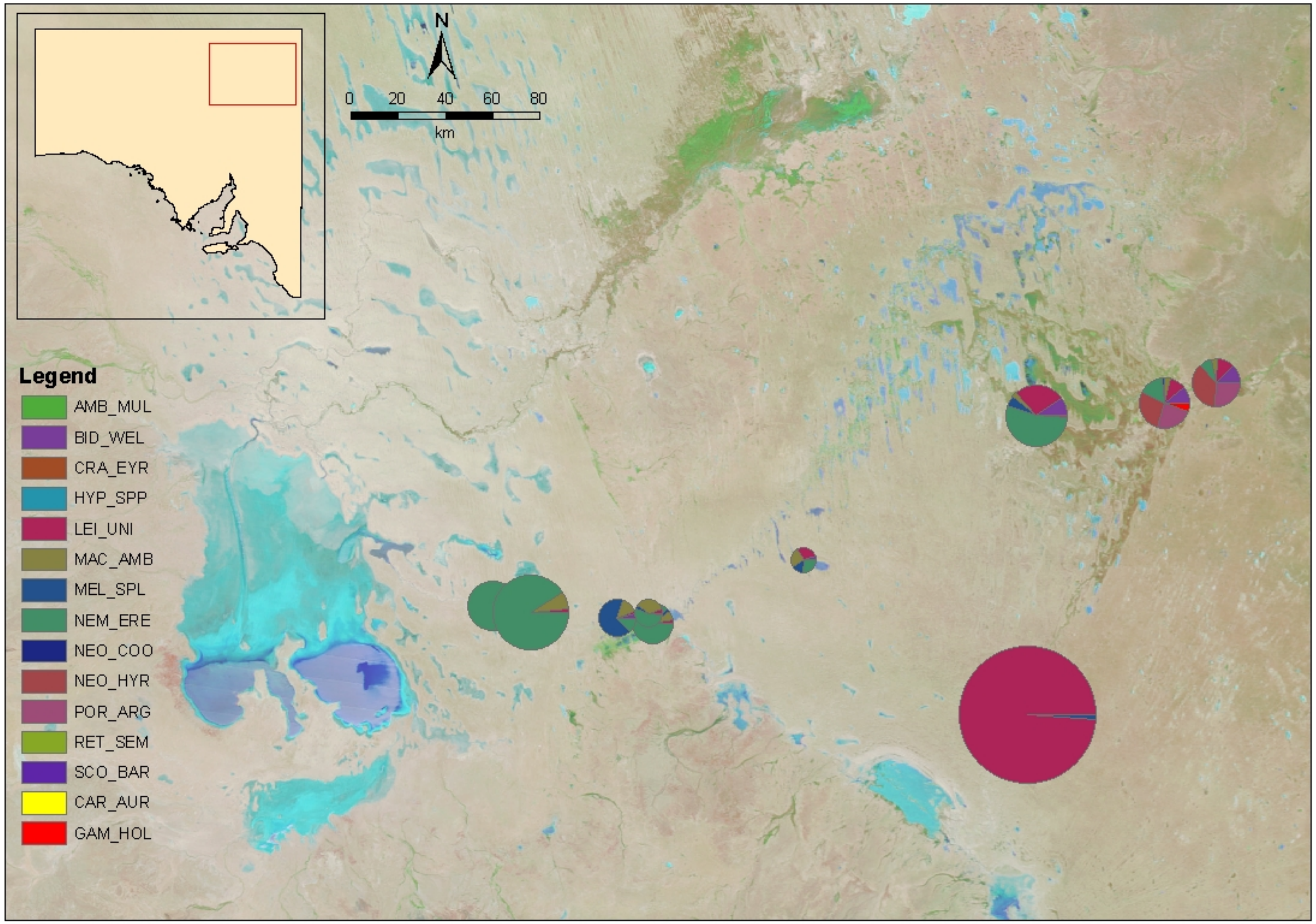

Figure 5. Relative CPUE (log transformed) and distribution of species captured during the spring 2010 Cooper survey. Glassfish (AMB MUL), Welch's grunter (BID WEL), Lake Eyre hardyhead (CRA EYR), carp gudgeon spp. (HYP SPP), spangled perch (LEI UNI), yellowbelly (MAC AMB), desert rainbowfish (MEL SPL), bony herring (NEM ERE), Cooper Creek Catfish (NEO COO), Hyrtl's tandan (NEO HYR), silver tandan (POR ARG), Australian smelt (RET SEM), Barcoo grunter (SCO BAR), goldfish (CAR AUR) and gambusia (GAM HOL).

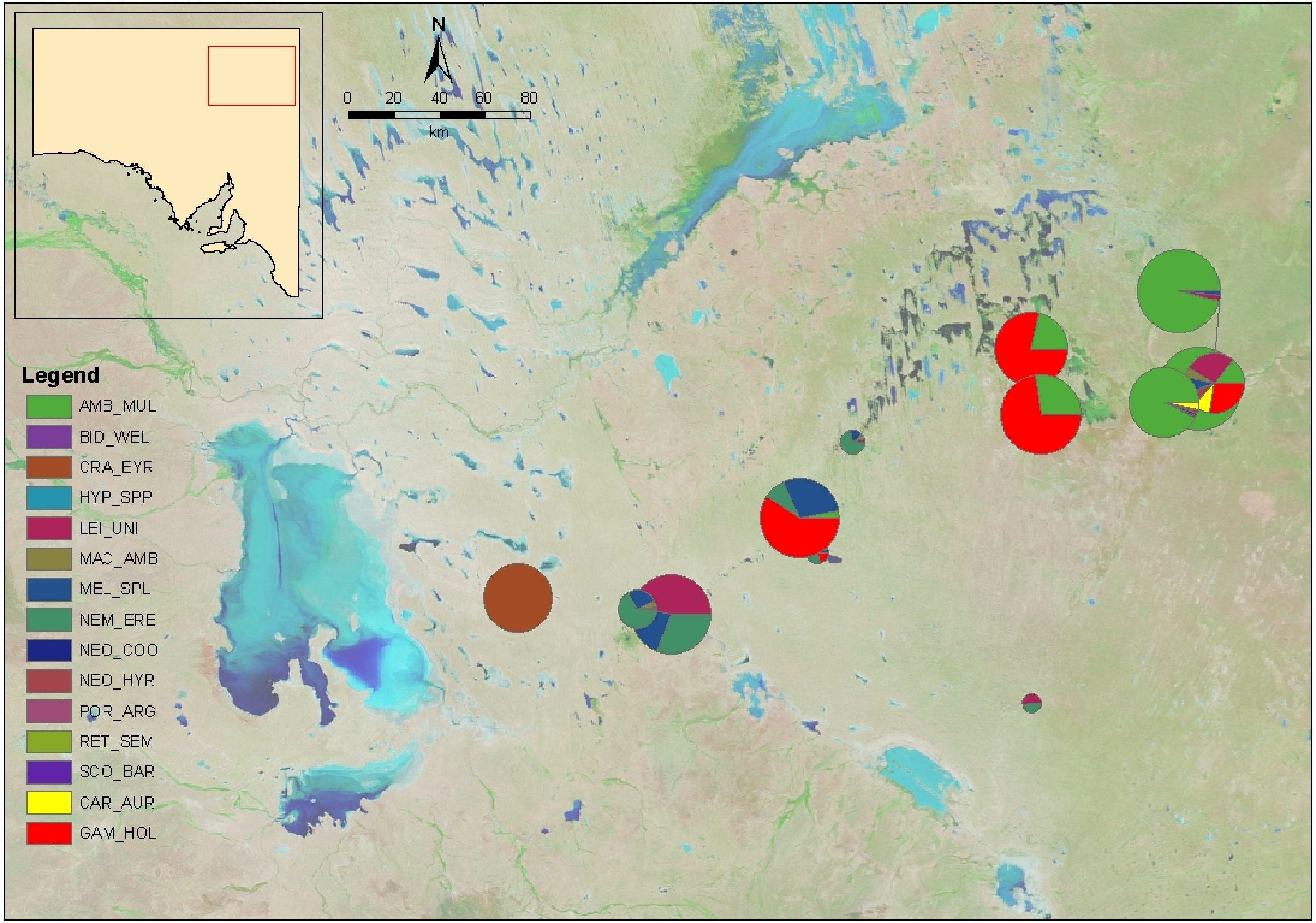

Figure 6. Relative CPUE (log transformed) and distribution of species captured during the autumn 2011 Cooper survey. Species abbreviations in Figure 5 caption.

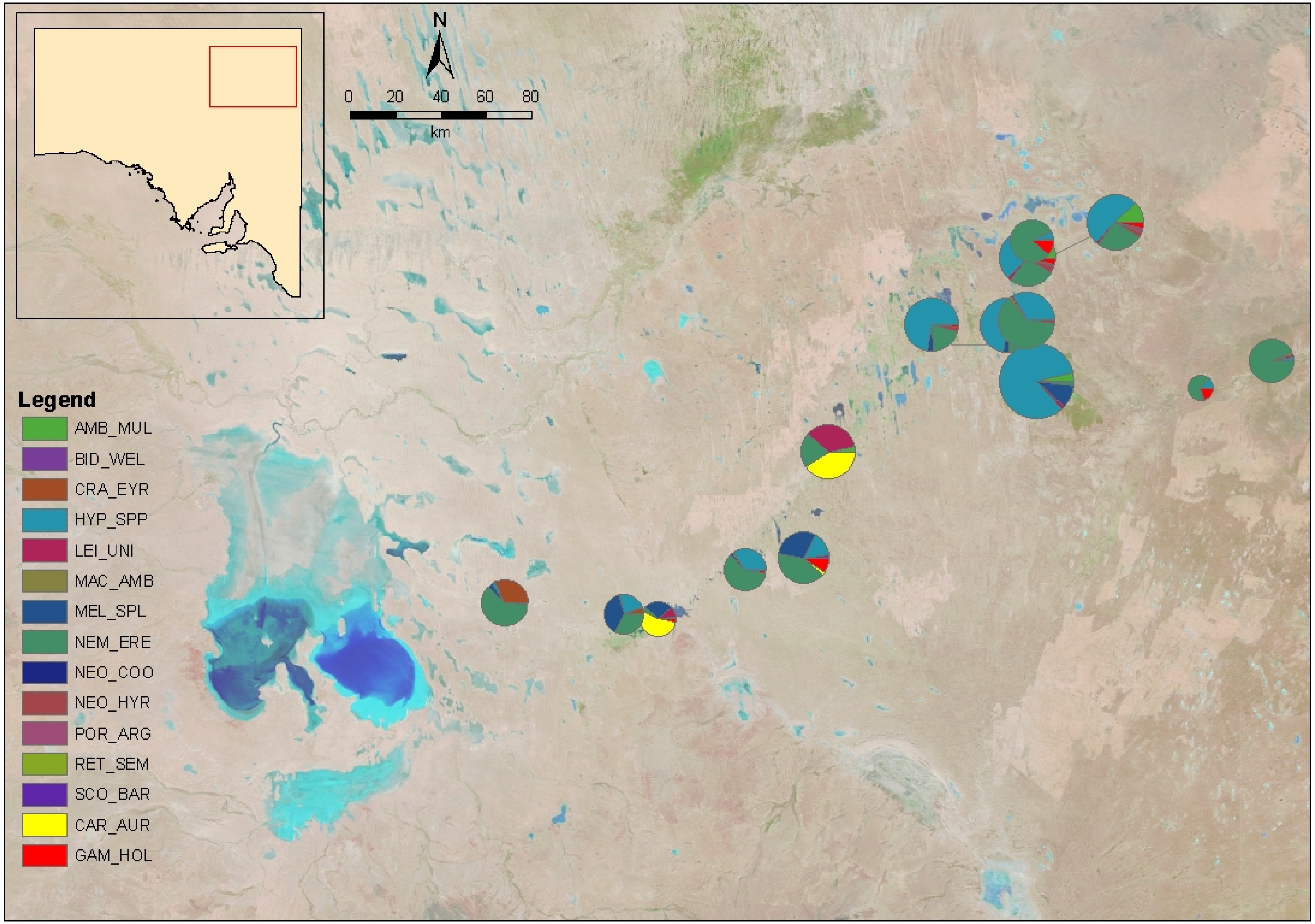

Figure 7. Relative CPUE (log transformed) and distribution of species captured during the spring 2011 Cooper survey. Obscured pie charts are repeated on call-out lines. Species abbreviations in Figure 5 caption.

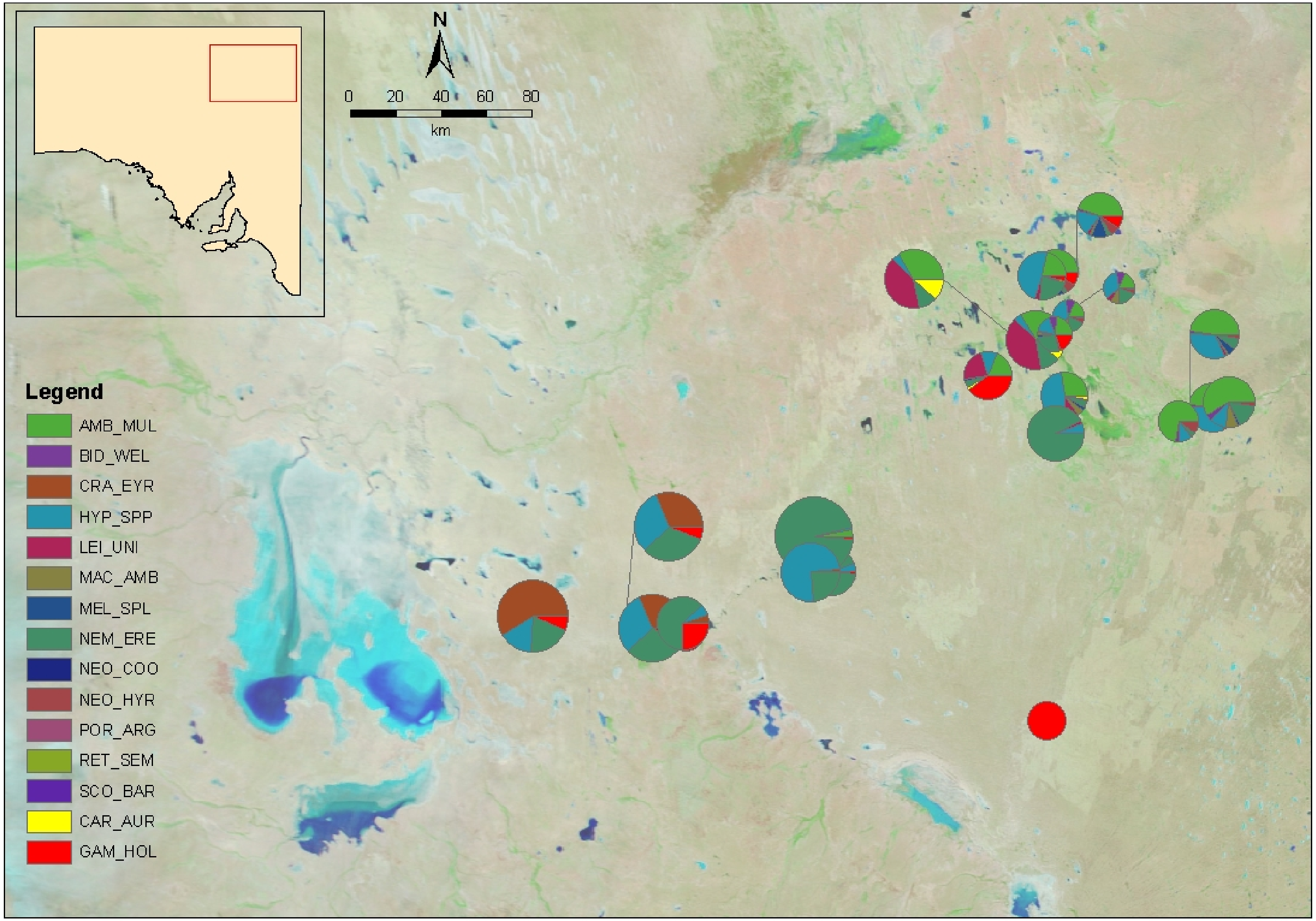

Figure 8. Relative CPUE (log transformed) and distribution of species captured during the autumn 2012 Cooper survey. Obscured pie charts are repeated on call-out lines. Species abbreviations in Figure 5 caption.

Multivariate Statistical Comparison

The multivariate comparison of all sampling events divided sites into six geographic reaches.

- 1 **Upper Cooper** consisted of all sites above the split between the North West Branch and Main Channel.
- 2 **Northwest Branch** was all sites on the North West Branch.
- 3 **Main Channel** was all sites on the main channel between the splitting and rejoining of the North West Branch.
- 4 **Mid Cooper** was all sites between the rejoining of the North West Branch and where the Cooper Creek crosses the Birdsville Track.
- 5 **Lower Cooper** was all sites downstream of the Birdsville Track.
- 6 **Strzelecki Creek** was a single site (Yaningurie) on the Strzelecki Creek.

The CCA plot (Figure 9) shows sites and reaches occur in a gradient from left to right with higher salinity, pH and dissolved oxygen associated with lower sites. Fish are spread across the plot in line with their strongest association. In this way species that prefer lower salinity and lower algal loads appear nested in the upper reaches (e.g. silver tandan and Hyrtl's tandan). Conversely species that are associated with higher salinity (Lake Eyre hardyhead), higher algal loads (bony herring) and the more resilient species (spangled perch and rainbowfish) are most strongly associated with the lower reaches of the river. Sites from the Upper, Northwest and Main Channel reaches are mostly clustered on the left of the plot, while Mid, Lower and Strzelecki Creek reaches are clustered on the right. These patterns show strong and significantly divergent assemblages between the upper and lower Cooper Creek in South Australia.

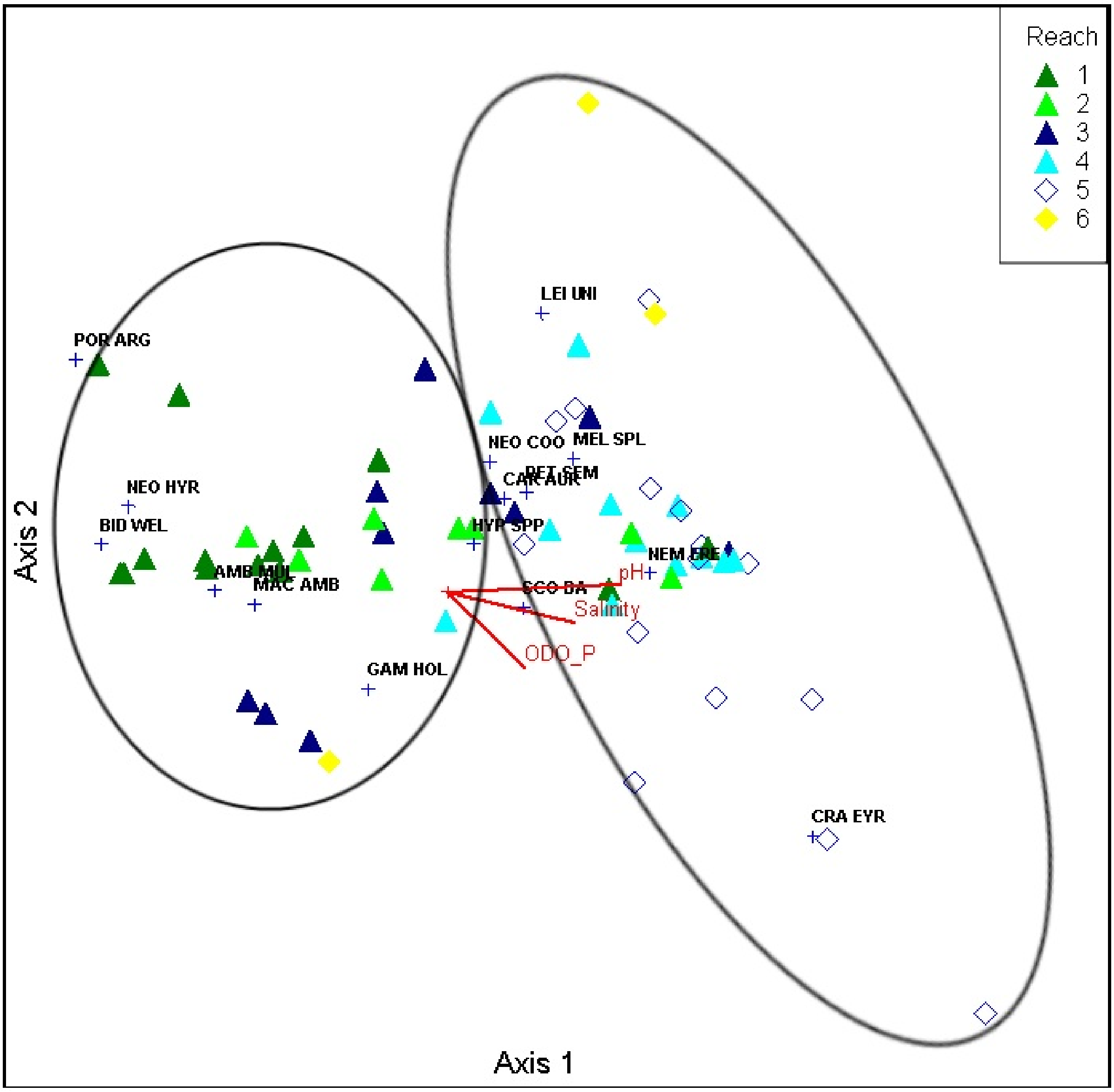

Figure 9. Multivariate CCA ordination of species assemblages at all sites sampled in Cooper Creek between spring 2010 and autumn 2012. Ellipses are indicative only.

Length Frequency

Species with consistent catches throughout Cooper Creek and across the sampling period were selected for length frequency comparison. These species provided the best data for comparison due to their ubiquitous presence throughout the study. The species chosen were bony herring, yellowbelly, spangled perch and Hyrtl's tandan.

Bony herring were captured in high numbers throughout the catchment in each sampling season (Figure 10). They had a broad size structure at each season and displayed continuous recruitment throughout the catchment.

Yellowbelly began the period with large size classes in the upper reaches of the catchment and two modes of recruits in the lower reaches (Figure 11). These two modes grew over the following two years with the larger mode attaining legal fishing size by autumn 2012 and the smaller mode 20-40 mm off legal size. The size frequency graphs also highlight the presence of new recruits in reaches that were the receiving floodwaters. In other words, juvenile yellowbelly recruited to wherever the floodwaters reached. By autumn 2012, there was a large complex population of yellowbelly distributed throughout the Cooper.

Spangled perch followed a similar trend to yellowbelly, beginning with a large mature population in the upper reach in spring 2010, recruiting to reaches in the mid to lower reaches, and eventually forming a complex population structure by 2012 with a broad size range and multiple size modes (Figure 12).

Hyrtl's tandan began the sampling period with large mature fish only inhabiting the upper reach of the river (Figure 13). In each successive season, this group of fish displayed modal progression, growing 40-50 mm over the two year period. In each autumn sample, Hyrtl's tandan recruits were captured at sites downstream from the upper Cooper, indicating the importance of these floodplain areas as a nursery for juvenile fish.

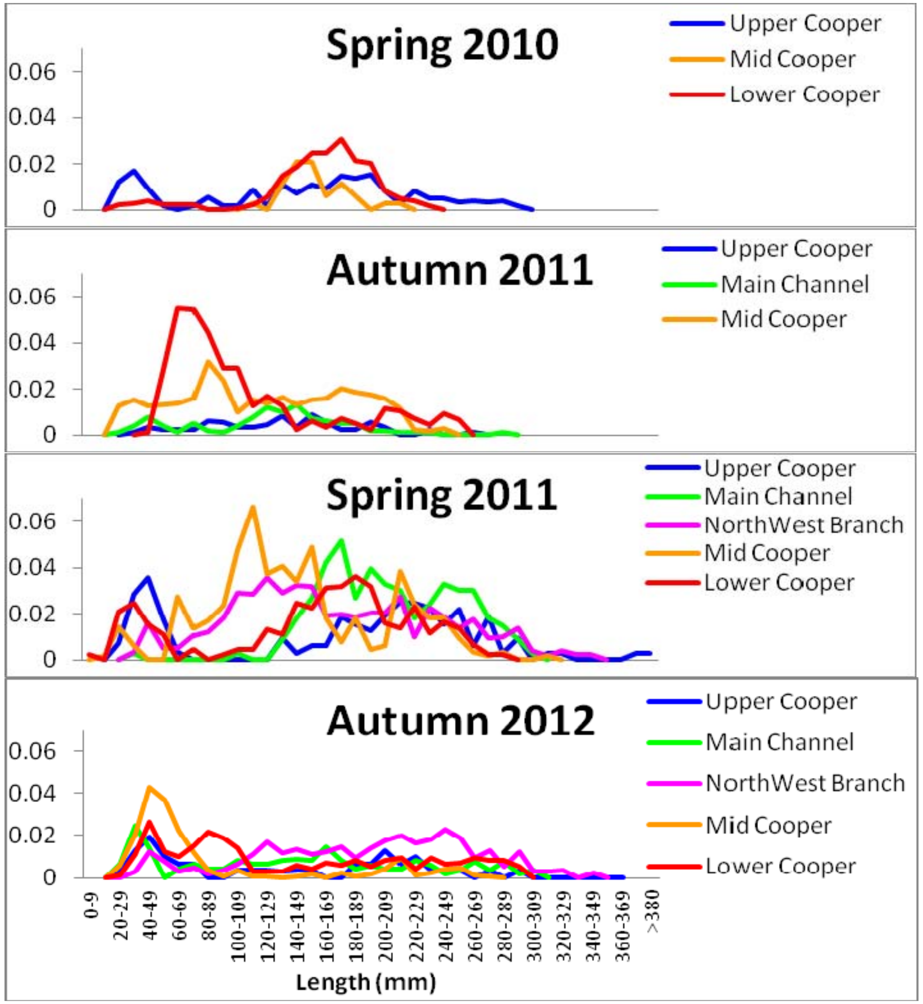

Figure 10. Length frequency distributions of bony herring by CPUE, within South Australian reaches of the Cooper Creek from summer 2010 through autumn 2012.

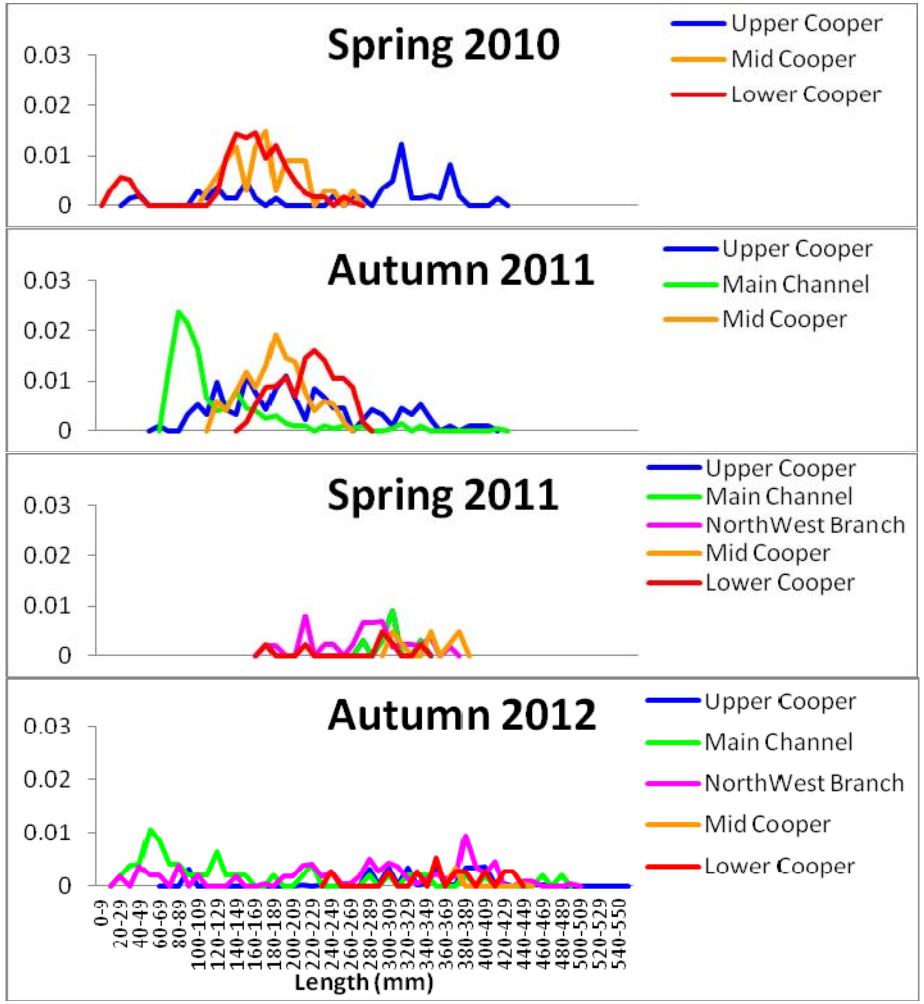

Figure 11. Length frequency distributions of yellowbelly by CPUE, within South Australian reaches of the Cooper Creek from summer 2010 through autumn 2012.

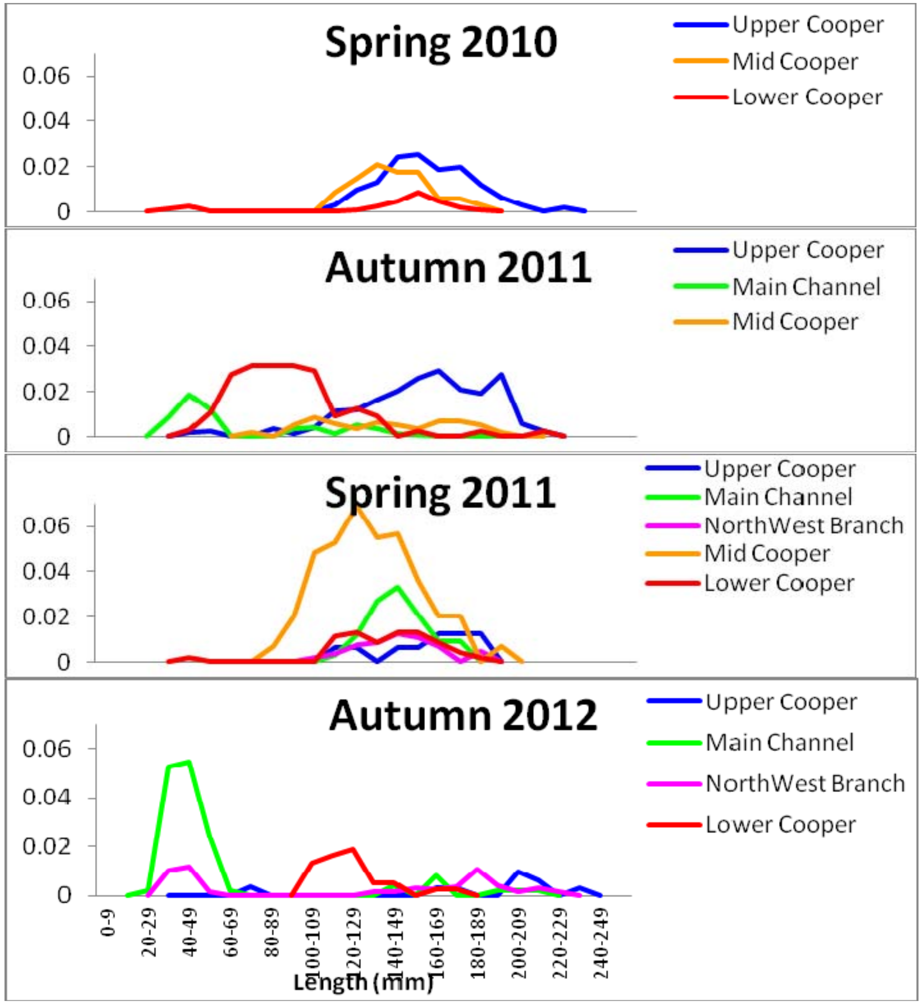

Figure 12. Length frequency distributions of spangled perch by CPUE, within South Australian reaches of the Cooper Creek from summer 2010 through autumn 2012.

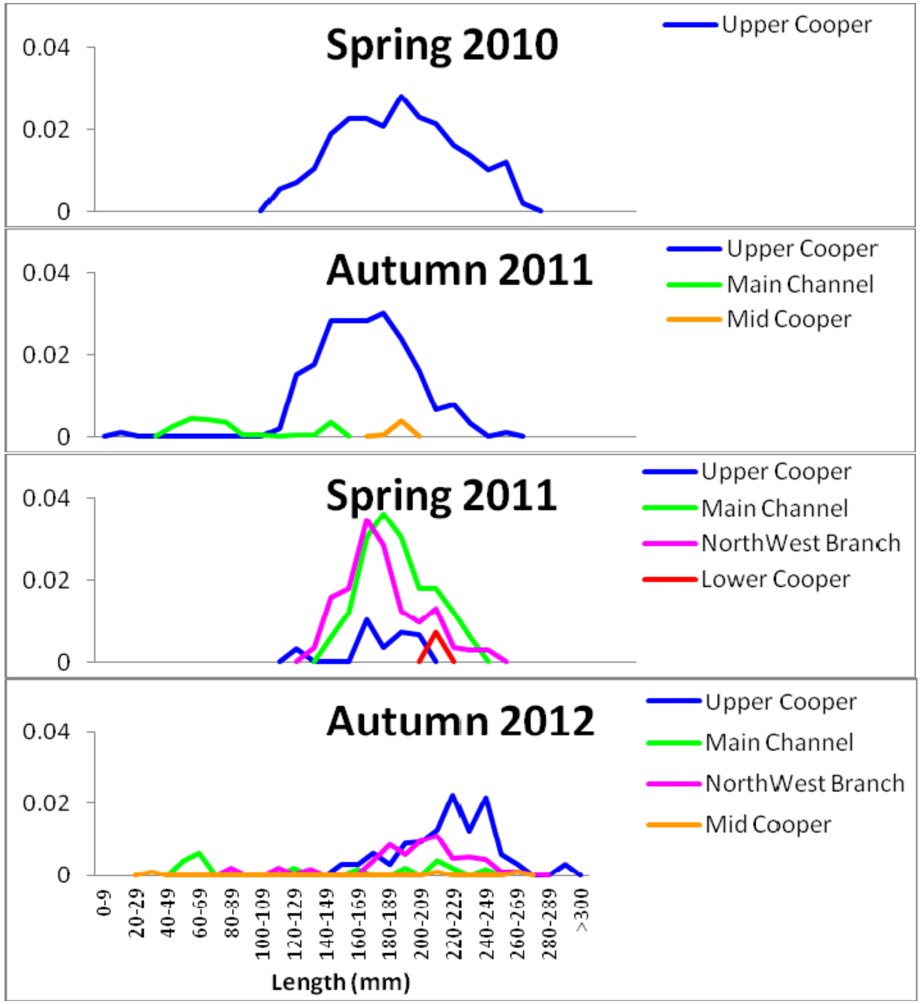

Figure 13. Length frequency distributions of Hyrtl's tandan by CPUE, within South Australian reaches of the Cooper Creek from summer 2010 through autumn 2012.

Disease Results

Disease was observed in eight species of fish and varied greatly by season with 92% of disease observed in autumn (60% in 2011, 32% in 2012) (Figure 14). When disease was observed, rates were generally low with 2.2% the highest overall rate observed at Cullyamurra Waterhole in autumn 2011. Spatial patterns were noted with disease most commonly observed in the Upper Cooper and Northwest Branch and almost absent in the Lower Cooper.

A 2-tailed Pearson correlation was run on disease prevalence, pH and salinity. Decreasing pH corresponded significantly with increases in disease rates r=-0.407, P=0.001 and salinity was proportional to pH r=0.273, P=0.035.

Fish in Spawning Condition

Spawning activity was observed in nine fish species throughout this study (indicated by the presence of milt or eggs during palpation). These included six small bodied fish; glassfish, hardyhead, carp gudgeon, rainbowfish, smelt and gambusia and three large bodied fish; spangled perch, yellowbelly and bony herring. Almost all spawning individuals were identified during spring 2011 (86%) with the second largest spawning component identified in the following autumn (Figure 15).

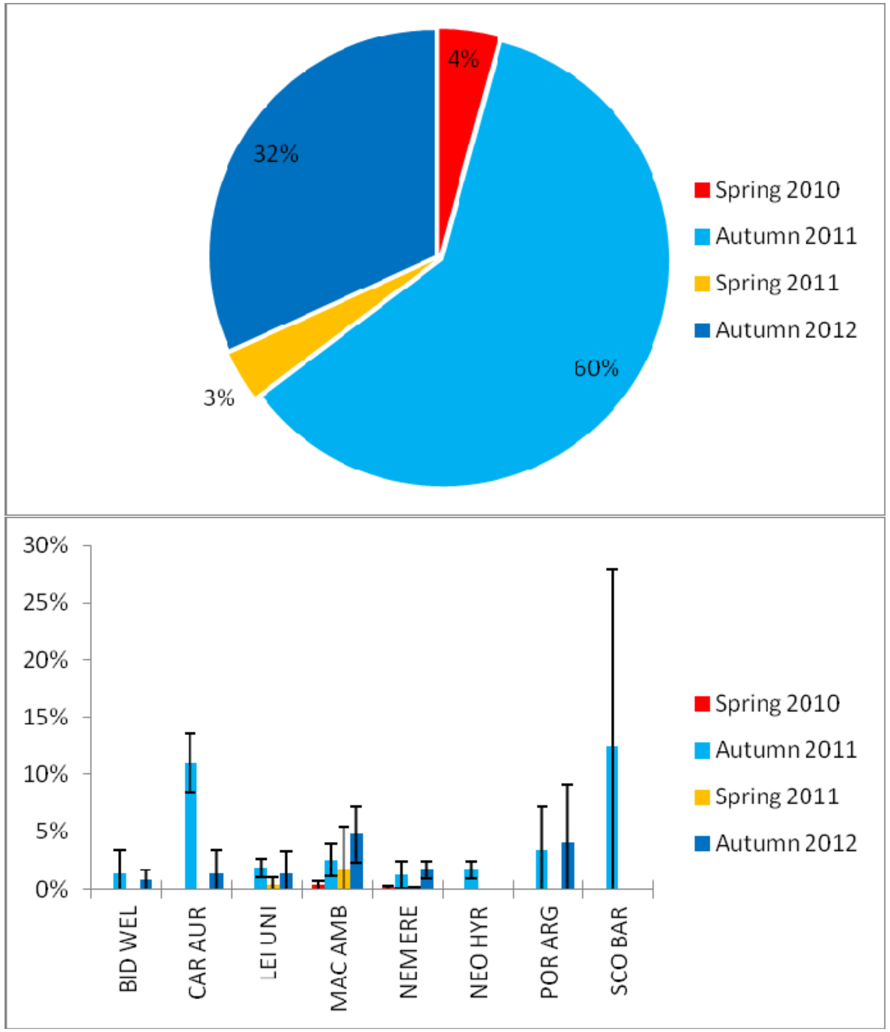

Figure 14. Prevalence of diseased fish within the South Australian Cooper Creek catchment from spring 2010 through autumn 2012.

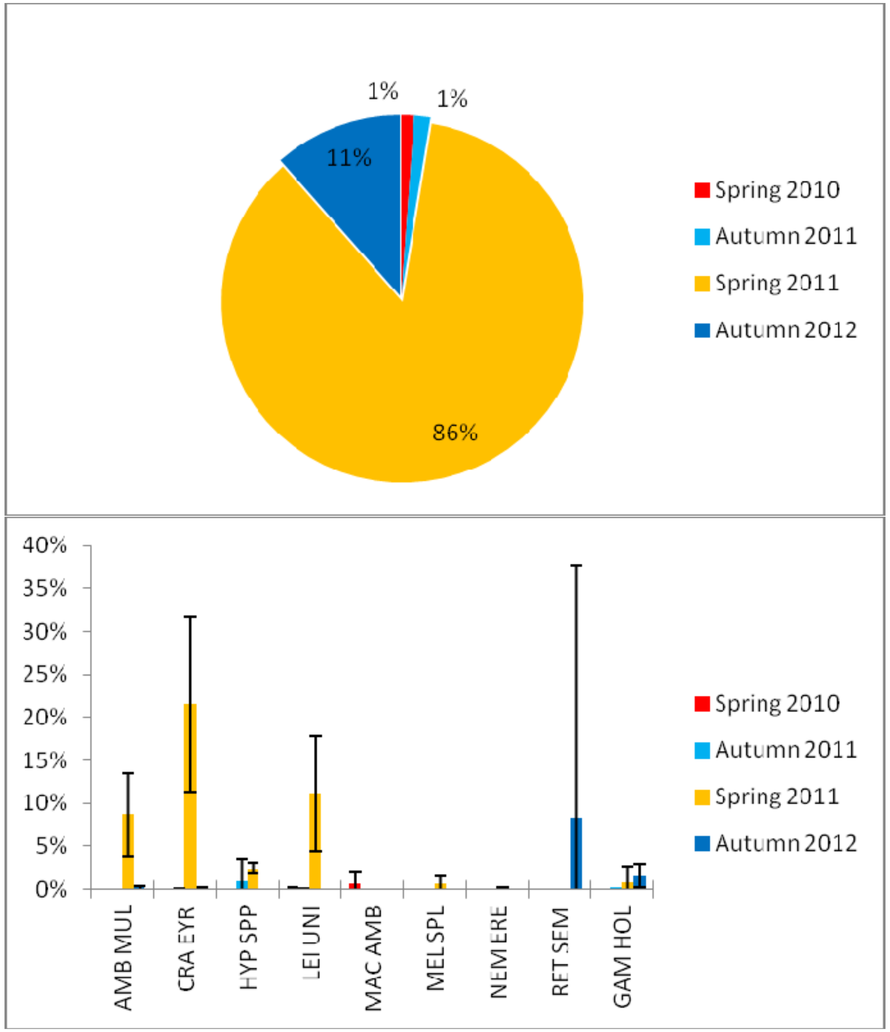

Figure 15. Prevalence of fish spawning activity within the South Australian Cooper Creek catchment from spring 2010 through autumn 2012.

Cryptic Fish Species

Two species provided confounding results throughout the sampling period. Smelt and Cooper Creek Catfish were only captured infrequently.

Only four Cooper Creek Catfish were captured during the study. Conversely, the Lake Eyre Basin Rivers Assessment (LEBRA) sampling in Queensland, captured large numbers of these fish at one location, indicating that capture rate is unrelated to gear type. These fish were all captured in highly turbid water in Main branch waterholes. Small numbers of this species have been captured recently in the Lake Hope fishery at Red Lake (Lake Walpayapeninna) (Garry and Paul Overton pers. comm.).

Smelt were captured on nine occasions across the range sampled, totaling 34 fish. Most were larger individuals, often in spawning condition.

Other Taxa

Cooper Creek Turtle (*Emydura sp.*)

Cooper Creek turtles (Figure 16) were caught at 12 sites in the South Australian stretch of the Cooper Creek. Populations existed along both the North West branch and the main channel and extended downstream as far as Lake Toontoowarannie in the Coongie Lakes system (North West Branch) and Cuttapirie Corner on the Main Channel.

Figure 16. Turtles from Cooper Creek ranging from 42 mm to 370 mm. (Right photo P Carter)

Maximum carapace lengths (MCL) were compiled from all turtle measurements and separated by sampling round. Length frequencies were normalised to percentage of total catch (per round) and used to construct a length frequency distribution (Figure 17). Turtle measuring protocols were implemented in autumn 2011 hence there are no figures from spring 2010 sampling.

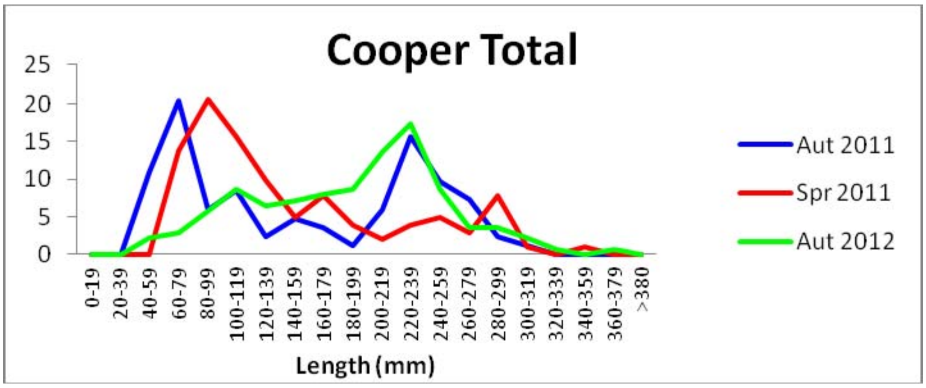

Figure 17. Length frequency of Cooper Creek turtles from all sites in autumn and spring 2011 and autumn 2012.

Throughout the sampling period, dominant length distributions are bimodal. Turtles between 40 and 59 mm MCL were the smallest size class identified and appeared only during autumn sampling. By spring 2011, the autumn 2011 juvenile cohort (mode 60-79 mm) had shifted (mode 80-99 mm) consistent with an average growth of around 20 mm.

The dominant adult mode at both autumn 2011 and 2012 was 220 to 239 mm MCL. This value was consistent with growth between the two rounds. This growth was less than was observed in the juvenile cohort consistent with age related decrease in growth rates.

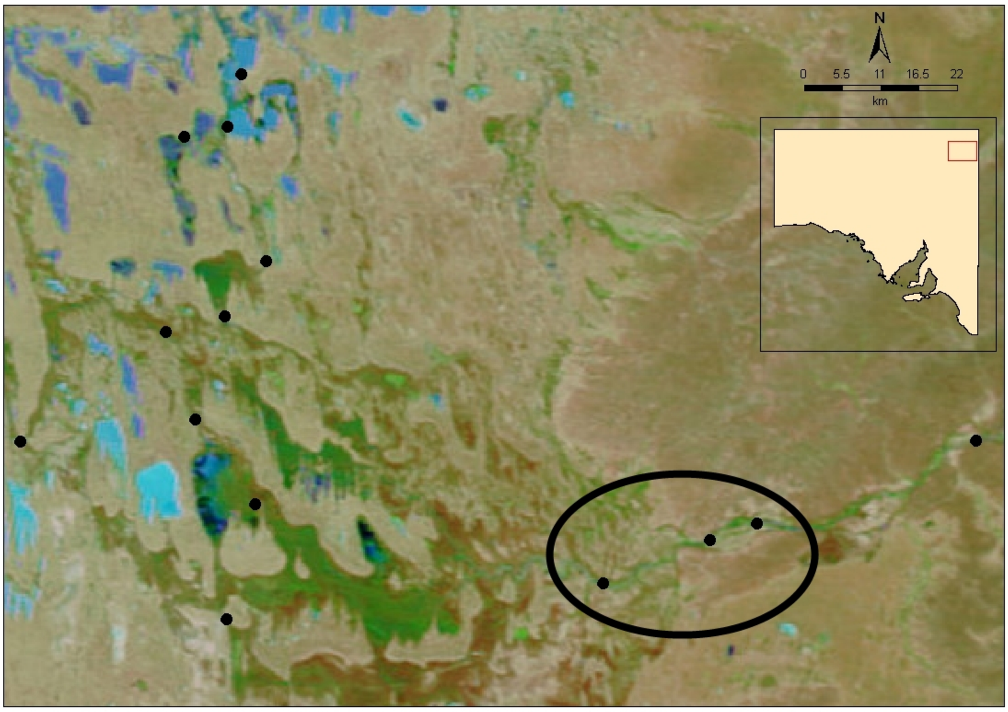

Figure 18. The upper reach of Cooper Creek in South Australia showing the main branch, northwest branch and Coongie Lakes. Ellipse indicates the location of Cullyamurra, Burke's and Minkie waterholes.

Length frequencies were generated for autumn 2011 and 2012 sampling rounds for three waterholes sampled in the Innamincka area (Figure 19). Cullyamurra waterhole is a permanent refuge whereas Burke's and Minkie waterholes are nearby near-permanent habitats (Figure 18). Autumn 2011 turtle counts in Cullyamurra waterhole were the lowest observed at these sites (n=7). At this time turtles appear to have relocated to the nearby Burke's (n=58) and Minkie (n=19) waterholes. This trend reversed by the autumn 2012 round with higher turtle numbers observed at Cullyamurra waterhole than at any other site in the study (n=126). Turtle numbers in this round had dropped to seven at Burke's waterhole and remained stable at Minkie waterhole (n=21).

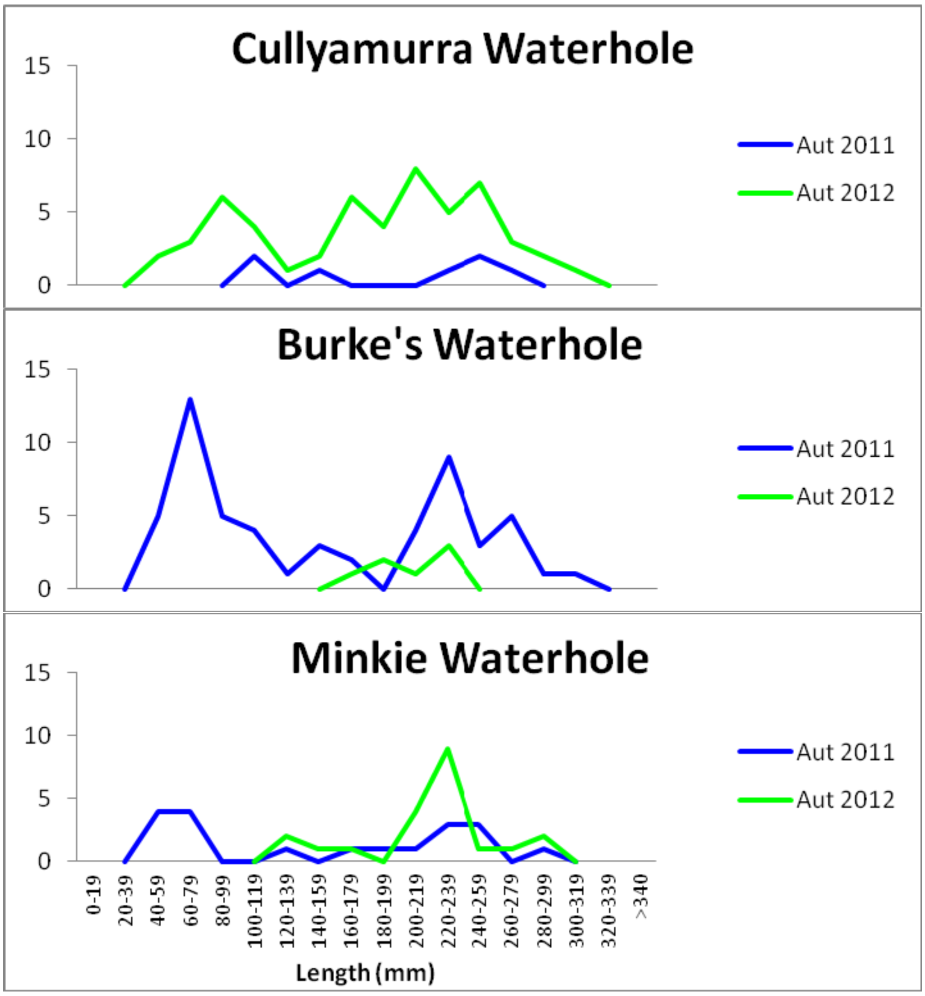

Figure 19. Length frequency of Cooper Creek turtles at Cullyamurra, Burke's and Minkie Waterholes in autumn 2011 and 2012.

Crustaceans

A high degree of variability was observed between the seasonal distribution and abundance of crustaceans (Figure 22). Freshwater shrimps (*Macrobrachium, Paratya* and *Caradina* species) were the most commonly recorded and widely distributed of the macroinvertebrates, with records at every location sampled throughout this study. Yabbies (Figure 20) were recorded across most reaches and were the second most widely distributed macroinvertebrate. The upstream reaches of Cooper Creek had the highest richness of crustacean species, with Cullyamurra Waterhole being the most diverse site.

Figure 20. Large yabbie (*Cherax destructor*) specimen.

Molluscs (*Velesunio spp*)

Freshwater mussels (*Velesunio spp*) were identified in the uppermost sites in the Upper Cooper, and distribution also occurred in both the Main Channel and the North West Branch (Figure 22).

Freshwater Crab (*Austrothelphusa transversa*)

Despite its distribution across the northern half of Australia, the freshwater crab *Austrothelphusa transversa* (formerly *Holthuisana transversa*) (Figure 21) was identified at only a single site in the Cooper Creek, Gidgealpa Waterhole (Figure 22). It is unclear why this site is the only refuge identified for this species whose life history remains unclear.

Figure 21. Freshwater crab (*Austrothelphusa transversa)* captured at Gidgealpa Waterhole.

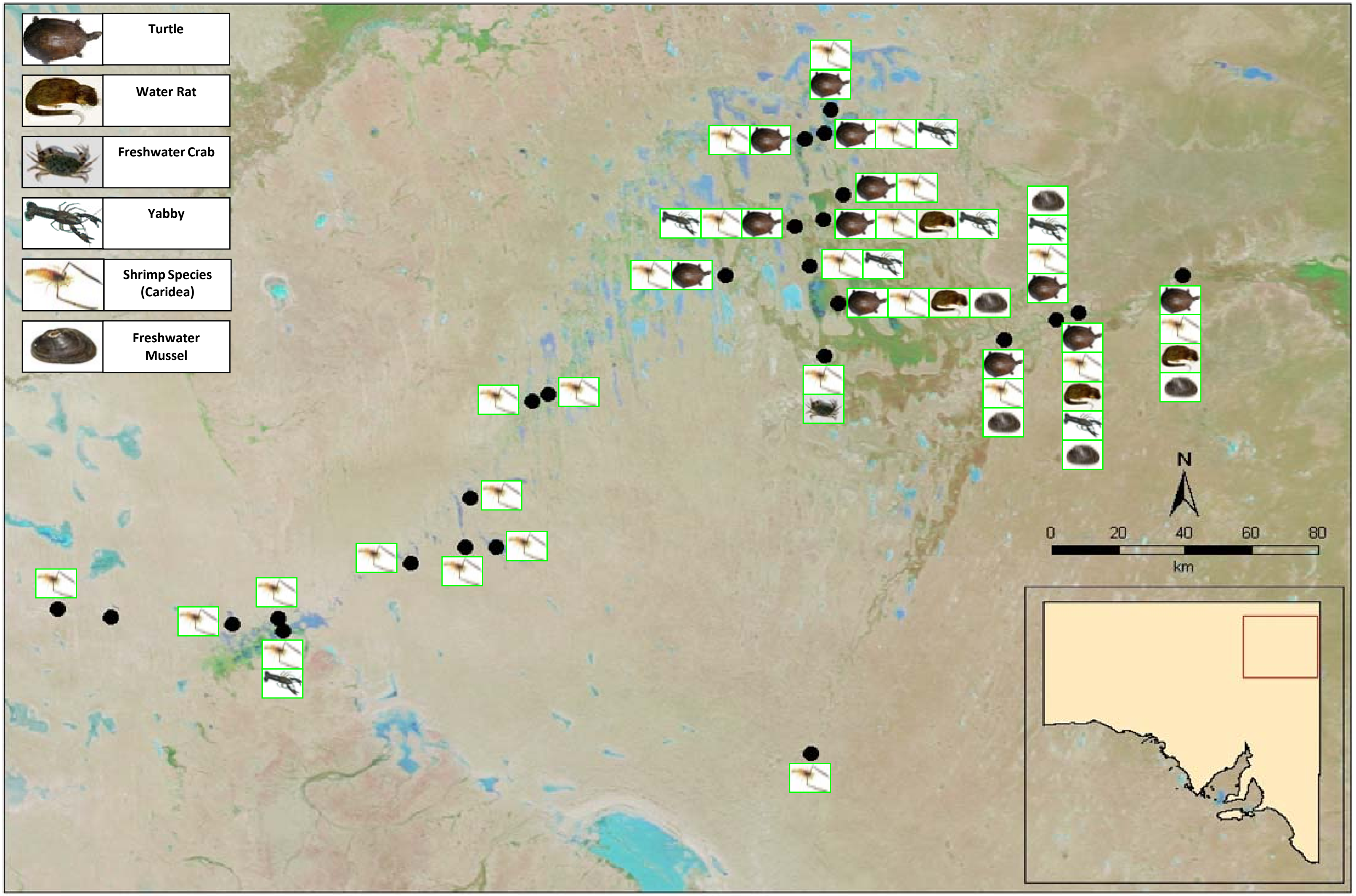

Figure 22. Observed distribution of turtles, water rats, and selected aquatic macroinvertebrates in Cooper Creek between spring 2010 and autumn 2012.

Recreational Fishing Survey

Surveys were carried out by SAALNRMB staff members over three days in, and around, the Innamincka region. Surveys recorded the activities of 42 tourists in 11 groups providing an ideal pilot study for collecting social data in this context.

Tourists were consistently amenable to answering the questionnaire. When approached, no groups refused to participate (Question 1) and all seemed to enjoy the experience of being consulted. Groups ranged in size from two to eight people (average 4.2) and stayed between one and five nights (average 2.6 nights). Five of the 11 groups (representing twenty individuals) intended to fish during their stay in the Innamincka Regional Reserve, with two days the average time spent fishing. This included one group who did not normally fish but had chosen to do so for the first time at Cullyamurra Waterhole. Two of the groups surveyed were return fishers, having visited and fished the site twice previously.

Of the 20 tourists planning to fish in the reserve, only one group of two fishers were aware of bag and size limits. A second group of two fishers had recently learned of limits from information signage near the toilet block in the reserve. Fishers targeted yellowbelly, grunters, catfishes and yabbies.

Of the five fishing groups encountered, four stated they would be happy to be contacted at a later date to further discuss fishing at the site. These groups freely provided phone numbers and contact details. Ten of the 11 groups approached responded positively to the idea of a recreational fishing survey located at the toilet block. All stated they would gladly complete a survey of this kind although one group stipulated that a pen or pencil would have to be present when they encountered the survey.

DISCUSSION

Cooper Creek Critical Refugia

Native fish species

Over the course of this two year sampling program, fish populations underwent considerable change in response to successive wet seasons. Total fish abundance expanded and contracted seasonally with high abundance over summer and low abundance over winter. There were some dramatic increases in abundance of small-bodied fish such as glassfish in autumn samples. Most fish species consistently utilised floodplain habitats for recruitment. More resilient species were the first to form dominant populations in lower reaches of the catchment followed by resistant species as water quality declined. The importance of deep permanent refugia was highlighted by their role in supporting diverse and mature populations of adult and juvenile fish and other aquatic fauna. In general, native fish species assemblages were in good condition. Population dynamics in the upper reaches were consistent with previous fish studies in Cooper Creek (Costelloe *et al.* 2004).

Spatially Divergent Refugia

Previous studies in Cooper Creek have been geographically limited to the upper reaches (Arthington *et al.* 2005), often restricted by state borders or concentrated on the Coongie Lakes area (Costelloe *et al.* 2004). While this study was restricted to the South Australian section of Cooper Creek, it represents a rare example of comprehensive monitoring along the entire length of this section from the Queensland border to Lake Eyre.

A key finding of this study is that upper and lower reaches of Cooper Creek appear to be spatially divergent. Whilst flows connected the entire catchment several times over the past two years, the species assemblages maintained a high degree of spatial integrity. Resilient species such as bony herring, spangled perch and rainbowfish occupied and dominated ephemeral sites in the Lower Cooper. Resistant species such as Lake Eyre hardyhead took advantage of declining water quality in the lowest reaches of the Lower Cooper. All species maintained populations in the permanent or near-permanent waterholes of the upper catchment, but it was the less resilient species such as Hyrtl's tandan, silver tandan, Welch's grunter, glassfish and yellowbelly that dominated the Upper Cooper Main Branch, and Northwest Branch.

Length frequency data showed how important floodplain inundation was for recruitment. Waterholes and floodplain habitats on the main and Northwest branch contributed most to recruitment. Large permanent waterholes in the Upper Cooper Main Branch including Cullyamurra, Burke's and Minkie also had recruitment, albeit to a lesser extent, however they also had larger numbers of mature adult fish. It is likely that for many species the large permanent waterholes at the upper end of Cooper Creek in South Australia are acting as spawning sources and the floodplains downstream as recruitment sinks. It is vital that the integrity of floodplain ecosystems is maintained for these recruits to move back upstream during prolonged or successive flows to replenish permanent refugia.

This spatial divergence was repeated in observations of fish disease where fish in the upper catchment had higher incidences of disease than the lower catchment. Differences in disease rates were associated with the water quality parameters pH and salinity. These two factors are directly influenced by floodplain processes whereby floodwaters become acidic due to floodplain soils and nutrient loads.

This has important ramifications for management of Cooper Creek in South Australia. When considering threats, impacts and management actions in Cooper Creek, refugia in the upper and lower reaches may need to be managed in at least three management units: permanent refugia in the Upper Cooper Main Branch, semi-permanent Main Branch and Northwest Branch refugia, and ephemeral Lower Cooper refugia.

Tag Recapture

At the time of reporting there have been two tag recaptures in Cooper Creek. The first was recaptured the day after tag application during the Netting Efficacy Study at Cullyamurra Waterhole. The second recapture was initially tagged in the ephemeral Embarka outflow in June 2011 (TL – 416 mm). In May 2012 this fish was recaptured during commercial fishing activities in Lake Hope. During this 11 month period the fish had travelled 200 km downstream and grown to 467 mm, an increase of 51 mm.

To date SARDI staff have tagged 229 fish in the Cooper Creek with many more tagged further upstream by Queensland's Department of Environment and Resource Management. It is anticipated that many of these tagged fish currently reside in regions frequented by recreational fishers. Future tag returns are anticipated and will provide insights into growth and movement that are almost impossible to gain otherwise. In a recent presentation to the 2012 Australian Society for Fish Biology (ASFB) conference, Jarod Lyon (Arthur Rylah Institute) presented long-term data on tag retention in freshwater fish species. Lyon found that t-bar tags like those used in the present study had much higher tag-loss rates than dart tags. Possible tag-loss rates will be taken into account in future analyses of tag-recapture data. Also, in response to this finding, and in the absence of tag retention data for the Cooper project, SARDI will transition immediately to tagging with dart tags.

In line with the stated objective of engaging stakeholders in fieldwork, there is potential to enhance this aspect of the Cooper project in two ways. Firstly, National Parks rangers could be enlisted to tag fish on a regular basis as part of a fish monitoring program in the Innamincka area. This would require a small investment in equipment and some basic training in capturing, handling and tagging large fish. Secondly, in addition to tagging more fish, there needs to be increased public awareness about tagged fish so that recreational fishers provide tag return data. The data from additional tagging has implications for informing recreational and commercial fishery management in Cooper Creek.

Figure 23. Author holding large tagged yellowbelly (*M. ambigua*).

Fish Disease

Disease observations were most commonly assigned to red-edged open lesions with visible fungal hyphae. This most closely matches the symptoms of epizootic ulcerative syndrome (EUS) or mycotic granulomatosis, a fungal disease caused by the *Aphanomyces invadans* fungus (Lilley *et al*. 2003). This disease is common throughout Australia and Asia and has also been isolated in North America and Egypt. It affects wild and farmed fish in freshwater and estuarine environments. In Australia it affects a broad range of fishes including bony herring, the cyprinid family (including goldfish), and silver perch *Bidyanus bidyanus* (close relative of Welch's grunter) (Carroll 2008).

Disease was most commonly observed in the Upper Cooper Main Branch and Northwest Branch and was less common in the Lower Cooper. Given the statistical relationship between disease and pH, and the relationship between pH and salinity, a conceptual model suggests that along the continuum of the Cooper Creek in South Australia, pH increases (decreasing acidity) and salinity increases. In the upper stretches of South Australia's Cooper Creek, where salinity and pH are lower, an environment is developed which supports the infection of fish, possibly by the fungus *A. invadans*. Whilst the source of higher acidity is not clear, it is likely to be related to interactions between floodwaters, allocthonous nutrients and local geology.

No epidemics or fish kills were observed in this study, though these are known to occur in the Cooper system (Turner 1994; Cockayne *et al.* 2012).

Disease was seen in all large bodied fishes in the system except Cooper catfish. As Cooper catfish were observed in small numbers it is unlikely that the sample size was large enough to determine the presence of disease. In smaller bodied species, it is unclear if identification rates are absent due to the proportionally smaller size of fatal lesions or if small bodied fishes are less susceptible to this pathogen.

Specific disease rates were variable. Spangled perch and yellowbelly displayed low baseline lesion rates for protracted periods potentially indicating; a higher susceptibility to lesion development, lesser ability to heal lesions once they appear or a greater capacity to survive once infected. Most species displayed no lesions during spring with disease returning during autumn; another indication that disease rates relate to seasonal floodwaters. Given that flows in this system are largely unimpacted by diversion and extraction, the flow regime would be considered natural and the associated disease impacts are likely part of that natural regime.

Other Taxa

Cooper Creek turtles (*Emydura sp.*)

Classification of the Cooper Creek turtle as a distinct species (*Emydura macquarii emmotti)* (Cann *et al*. 2003) is contentious. Strict adherence to the biological species concept (Mayr 1969) requires discrete reproductive units, however this species is known to interbreed with the Murray River turtle *Emydura macquarii macquarii* where their ranges crossover in the

Bulloo River (Georges and Thomson 2010). This lack of genetic isolation is further supported by allozyme electrophoresis which shows sufficient similarity to consider Cooper Creek, Murray River, Coastal New South Wales and Fraser Island short-neck turtles to be the same species (Georges and Adams 1996). Despite overall genetic similarities Cooper Creek populations display phenotypic specialisation reflecting adaption to the unpredictable conditions. These include a larger overall body size, delayed maturity and indeterminate growth rates (White 2002).

Cooper turtles are expected to breed between September and January (Judge 2001). Eggs may be laid twice a year in clutches of 10-30 eggs (White 2002) with Cooper turtle eggs the largest of all Australian Emydurans (Cann 1998). Juveniles hatch at around 30 mm. The smallest turtle observed in this study was during April of 2011. This 42 mm juvenile still retained its egg-beak, indicating a hatching event a short time earlier.

Population expansions into high productivity novel habitats to breed and grow followed by retractions to the more permanent refugia matches patterns observed in long-necked turtles in Jervis Bay (Kennett and Georges 1990). There are some notable variations from the Jervis Bay model. The Cooper system is less amenable to overland travel and to reduce the chance of stranding in dry habitats Cooper turtles appear to utilise stream habitats to move proactively towards refugia. This was observed in Cullyamurra waterhole in autumn 2012 where a previously depauperate population had been bolstered by returning individuals despite continuing flood pulses in the system. It is anticipated that return journeys will be staggered as individuals attempt to maximise their time in high productivity environments without becoming stranded. Demonstrating this, turtle populations continue to inhabit the less permanent waterholes as far downstream as Cuttapirie Corner Waterhole despite the increasing risk of stranding. Similar decisions in fishes are facultative, having genetic (Snyder 1991) and environmental (Wysujack *et al*. 2009) influences and it is anticipated that this is consistent in Cooper Creek turtles. Migrational theory also suggests a sex bias with females more likely to leave their resident waters (Jonsson and Jonsson 1993; McDowall *et al*. 1994). The current study is unable to address this factor, as turtles were not sexed, however this could be incorporated into future work on this species.

While Cooper Creek turtles do not constitute a conservation population unit, they have slow generation times and have been shown to suffer from illegal fishing activities (White 2002) (Figure 24). However, with longevity of up to 80 years (White 2002), the presence of large complex populations of turtles in multiple waterholes in the upper reaches of Cooper Creek is a good indication of long-term waterhole health.

Figure 24. Dead Cooper turtles in illegal fish net found at Nappapethera.

Crustaceans

Crustacean species showed no distinct patterns in spatial distribution and appear to be influenced primarily by the immediate availability of habitat and resources. This appears unrelated to permanence or distance from the nearest permanent source population. The relatively short life cycles and their ‘boom and bust’ population dynamics allow for wide distribution and rapid colonisation of novel environments.

The distribution of yabbies was less consistent than that of the other crustacean species. They were commonly encountered throughout the upper reaches of the river, becoming less common towards the mid reaches. An anomaly was the apparently isolated population of yabbies at Gwydir’s Crossing. This was recorded on multiple sampling occasions, despite the observation that Gwydir’s Crossing is one of the least permanent waterholes in the study. This suggests that despite their apparent reliance on ambulation they are strong migrants and are capable of rapidly moving long distances. This is consistent with observations upstream where yabbies have been observed walking over the Innamincka Causeway in high densities (Darren Wilson pers. comm.). This occurred during a flow event sufficient to cover the causeway with several inches of water.

Mussels (*Velesunio spp*)

Recent work suggests that the freshwater mussels of the *Velesunio* genus in the Cooper Creek form a population consisting of four distinct, cryptic species (Baker *et al*. 2003). The genetic work required to separate these species is beyond the scope of this study and they will instead be considered as a genus. Mussels were only located in the uppermost sites in the studies in deep, permanent waterholes (Embarka and Nappapepethera Waterholes and Coongie Lake). This genus can live up to 60 years (Walker *et al*. 2001) and, being a poor disperser, typically remains within the same waterhole for its entire adult life. In this way it is clear that for observable mussel populations to be present, a waterbody requires near permanence. In this way the presence of live adult mussels in arid waterholes may be considered an indicator of persistance (to around 60 years).

Dispersal in this genus is tied to the spat phase which is an obligate parasite of fishes (Watters 1992). While this allows the mussel to harness the mobility of fish, dispersal between habitats is inferred to be limited based on genetic observations (Hughes *et al*. 2004). The current study observes that fishes are freely able to move between habitats during flood periods supporting the alternate hypothesis from Hughes *et al.* (2004) that mussels do not spawn during flood periods. Future work could use established molluscan sex staging techniques (Haag and Leann Staton 2003) to examine this hypothesis and aging to determine the duration of persistence in the waterhole.

Freshwater Crab (*Austrothelphusa transversa*)

With only a single specimen observed, this species remains an enigma. The presence of a population at the comparatively isolated Gidgealpa Waterhole begs questions of dispersal, connectance and persistence which are beyond the scope of this study.

Threats and Impacts

Invasive Species

Gambusia

Native to northern Mexico and south eastern North America, gambusia were recommended by the World Health Organisation as an effective biological control agent for mosquito control up until 1982. Originally introduced into Australia in 1925 they were quickly spread by the Australian Army, local councils and health authorities to cover most of Australia's landmass and a diverse range of habitats. Gambusia are now recognised as one of the world's 100 worst invasive species (Lowe *et al*. 2007). This is primarily due to their aggressive nature (Macdonald *et al*. 2012) and high reproductive capacity (Milton and Arthington 1983). They are also robust, displaying remarkable environmental tolerances in both the lab (Chervinski 1983) and the field (McKinsey and Chapman 1998).

In the wild, gambusia exert a strong influence on many areas of ecosystem function. Impacted groups include macro- and microinvertebrates (Margaritora *et al*. 2001; Cardona 2006), native frogs (Komak and Crossland 2000; Pyke and White 2000) and they have been implicated in trophic cascades (Ho *et al*. 2011). For native fishes, gambusia represent a risk for larvae (Ivantsoff and Aarn 1999) and affect adult fish through direct aggression (Macdonald *et al*. 2012) and habitat exclusion (Arthington *et al*. 1983).

It is suggested that strong flow patterns disrupt gambusia populations (Costelloe *et al*. 2010; Chapman *et al*. 2012). This survey commenced on the tail of the 2010 flood event which had probably already dispersed gambusia populations through Cooper Creek. As gambusia are generally poor swimmers (Ward *et al*. 2003) it is anticipated that dispersal will be almost exclusively downstream. Despite being resistant to abiotic parameters and possessing high fecundity, populations appear to have been dispersed and diluted sufficiently to remove gambusia as a dominant fish in the system in the flows preceding this study. Intraspecific competition would have also been a significant factor in suppressing gambusia during this period as numbers of native fishes keyed to flood-driven reproduction boomed.

Numbers of gambusia in the system remained low until autumn 2012 when numbers in the lower Cooper increased. This 2 year lag period was probably protracted by secondary flood pulses in early and mid 2011. The return of gambusia, notably in the lower Cooper, corresponds to drying in the system. This matches the suggestion that drying concentrates gambusia numbers, increasing their aggression (Macdonald *et al*. 2012) and favouring their reproduction (Costelloe *et al*. 2010; Chapman *et al*. 2012). The potentially catastrophic effect of favouring gambusia proliferation is ultimately ameliorated by extensive drying in the lower system. As refugia dry out, mass mortalities of gambusia occur removing densely populated gambusia sources from the system.

This cycle of preferential downstream flushing of gambusia during floods and desiccation *in situ* during droughts is a natural protection from their domination in Cooper Creek. This pattern is dependent on natural variability in flow and is an artefact of an unregulated river system in a boom bust environment. As anthropogenic influences in the Cooper Creek and it's upper tributaries increases so too does the likelihood of interference with natural flow regimes through water extraction and river regulation.

Goldfish

Originally from eastern Asia goldfish are one of the most widespread translocated fishes today, having spread throughout North America, New Zealand, Australia and Europe (Lorenzoni *et al*. 2007). They are a hardy species and can be acclimated to temperatures of up to 41^{o}C (Fry and Hart 1948) and held in salinities of 6 ppt without acute physiological changes (Luz *et al*. 2008). Within native ecosystems goldfish act as ecosystem engineers increasing turbidity (Richardson and Whoriskey 1992) and altering macrophyte composition (Richardson *et al*. 1995). They also alter ecosystem function by reducing macroinvertebrate numbers (Richardson and Whoriskey 1992) as well as exerting a competitive effect on native fishes. This interspecific effect is density dependant with higher densities of goldfish resulting in bolder feeding behaviours (Magurran and Pitcher 1983). Due to its integration into the Australian pet trade, this species has also been identified as a vector for exotic diseases and has been identified as the source of several zoonotic diseases present in Australia today (Wilson 2005) and is likely to act as a reservoir for disease in the system.

Goldfish were recorded throughout the Cooper Creek between Nappapethera Waterhole (uppermost sampling site) and Gwydirs Crossing, in abundances ranging from very few individuals to several hundred fish. No goldfish have been observed in the lower Cooper downstream of Gwydirs Crossing. Despite their apparent hardiness towards abiotic extremes, they were rarely observed to dominate sites. Goldfish densities followed the boom-bust pattern common to fishes within this catchment. It appears that goldfish boom during periods of floodplain inundation taking advantage of novel habitats and warm, high productivity waters. While goldfish were not as abundant as the other invasive species in Cooper Creek (gambusia), at times their biomass was significantly higher. It is anticipated that goldfish will exert the most pressure on native ecosystems during this initial boom and in the period of floodwater recession when numbers are at their highest. High densities were not observed to persist at any sites during the study and it appears that population crashes follow booms within the system. This has been observed by DEWNR rangers at Cullyamurra Waterhole (Trevor Whibley, pers. comm.).

Despite their alien status in Cooper Creek, the impacts of goldfish appear moderated by the intrinsically variable nature of the system. While this remains an unregulated river system goldfish are unlikely to become a key disturbing process. Further control measures are not warranted at the current time.

Cane toads (*Bufo marinus*)

Cane toads were not observed at any sites in this study, however they remain a threat to this system. Their ability to disperse rapidly (Phillips *et al*. 2006) and tolerate high salinities (Liggins and Grigg 1985), coupled with their toxicity at almost all life stages, have made cane toads one of the International Union for Conservation of Nature (IUCN) 100 world's worst invasive species (Lowe *et al*. 2007). A detailed examination of the pathways for cane toad invasion was carried out in the geomorphological component of this study (Wakelin-King in prep). This section gives a brief summary of specific interactions with aquatic biota.

Impacts of cane toads are complex, species specific and will vary under a range of circumstances. Due to the preferentially terrestrial life history of adult toads, competitive and antagonistic relationships between fishes and adult toads are likely to be few and indirect. To date most research has focussed on interactions between native fauna and early toxic life stages of the cane toad (egg, tadpole and froglet). This has included laboratory experiments on northern analogues of several Cooper Creek fish species. In this study rainbowfish (*Melanotaenia australis* and *Melanotaenia splendida inornata*), glassfish (*Ambassis macleayi*) and Hyrtl's tandan suffered high rates of mortality after ingesting eggs with lower rates of mortality associated with tadpole ingestion (Greenlees and Shine 2011). This effect is somewhat muted by the temporally limited period of interaction (especially the presence of eggs). The capacity for prey refusal has also been demonstrated in predatory fishes that ingest sub-lethal doses of tadpole toxin (Crossland 2001).

Reports of cane toad driven fish mortality events in the field are rare and, when reported, direct causality difficult to establish. In the Northern Territory one spangled perch fish kill was attributed to ingestion of tadpoles following a cane toad breeding event (Grace and Sawyer 2008), however, no empirical evidence was collected to verify this.

Competitive and predatory interactions are far more likely in anurans than in fishes due to the greater crossover in shared life history traits. Observations of cane toad impacts on anurans have associated toad tadpoles and eggs with mass mortalities in native tadpoles (Crossland *et al*. 2008b). The extent of this impact is highly variable with subtle changes e.g. precise timing of reproduction (Crossland *et al*. 2008a) having a large impact on the extent of the interaction. As with most taxa, anurans can develop learned avoidance behaviours following non-lethal interactions (Greenlees *et al*. 2010) and the extent of interaction will be species specific.

Invertebrate sensitivities are more inconsistent following the higher variability within the taxa. While giant water bugs (Belostomatids) are susceptible to the toxin, other macroinvertebrate predators e.g. such as dytiscid beetles (*Hydaticus vittatus*) and redclaw (*Cherax* *quadricarinatus*) appear unaffected (Crossland 1998). Competitive exclusion of mosquitoes (Hagman and Shine 2007) and direct predation on invertebrates is also noted.

Pigs (*Sus scrofa*)

Feral pigs (*Sus scrofa*) were introduced to Australia with colonisation and have now formed sustaining populations across Australia. Their specific impacts have not been widely studied but include rooting and digging which has been shown to induce vegetation changes (Alexiou 1984; Hone 2002). This effect has been observed to be inconsistent (Bowman and McDonough 1991) and probably site-specific (Hone 1988).

Pigs have been known to predate heavily on turtles in Australia (Fordham *et al*. 2006) and have been observed to eat freshwater mussels (*Velesunio* spp) (Figure 25). In areas of traditional harvesting of these species, this places increased pressure on wild populations (Fordham *et al*. 2007). Predation of long lived turtles and mussels from the upper Cooper Creek waterholes is anticipated to be most damaging during periods of drought when pig, mussel and turtle populations are concentrated into increasingly smaller aquatic environments. While it is anticipated that the large permanent refugia (e.g. Cullyamurra Waterhole) would provide sufficient refuge to support turtles and mussels through grazing from pigs, a precautionary approach supports ongoing population control of feral pigs in this area.

Figure 25. Feral pig (*Sus scrofa*) rooting for freshwater mussels in Nappapethera waterhole spring 2011. This pig was shot by an aerial shooting operation shortly after the photo was taken.

Several strategies have been examined as viable options for pig control in Australia including dog hunting (Caley and Ottley 1995), aerial baiting programs (Fleming *et al*. 2000) and coordinated aerial shoots. In areas where pigs are in high densities, such as Cooper Creek, aerial shooting efficiencies can go from 60.4 kills/hr (Choquenot *et al*. 1999) to significantly higher (pers. comm. Darren Wilson).

Anthropogenic Threats

Wherever human activity crosses over with natural resources, potential impacts to natural systems will arise. While harsh conditions and geographic isolation have largely cocooned Cooper Creek from the broadscale alterations that characterise South Australia's coastal rivers, impacts have appeared nonetheless. In general these impacts arise from three main sources; mining, tourism and agriculture (grazing) activities.

Mining

Rich petroleum and natural gas deposits in the State's north have attracted significant operations in the Cooper Basin. While direct, observable impacts to date have been minimal, the greatest assessed impact during this study relates to the presence and design of bridges. Two main mining bridges were identified, the Walkers Crossing and Beach Bridges (Figure 26). The bridges are structurally similar: both are short, single lane bridges spanning 20-30 metres, spanning a stricture in the Cooper Main channel. Each bridge works in concert with a long artificial levy bank to channel flow preferentially through a series of parallel culverts and beneath the bridge itself. Both bridges have been observed by SARDI staff to bottleneck flow with significant backing up of flood waters above the bridge. Alterations to the natural flow pattern include:

- Increasing water levels immediately upstream of the bridge increases the level of floodplain inundation and terrestrial connectivity in this area.
- Channelling of high velocity water through this artificial pinch point adds a scouring effect altering bathymetry directly beneath and immediately downstream of the bridge.
- Increasing the velocity of water beneath the bridge reduces capacity for upstream movement of aquatic biota during strong flow.
- Reducing the rate of flow past the bridge decreases floodplain inundation and terrestrial connectivity below the bridge.

It is anticipated that hydrological and bathymetric effects from these infrastructures will be localised. Perhaps of more concern is the potential for the bridge to create an impassable velocity barrier to upstream movement under most flow conditions. This would create biotic segregation in the Cooper Creek centred on these two structures. This effect is likely protracted as flood waters are constrained and channelled artificially over time, maintaining velocity at the pinch point. In Cooper Creek, fish movement is complex and poorly understood.

Figure 26. Beach Bridge (top) and Walker's Crossing Bridge (bottom) on Cooper Creek main branch.

Grazing

Grazing is widespread throughout the Cooper Creek region and is likely to impact the aquatic biota primarily through increased nutrient inputs. These impacts will increase in focus and intensity as the system dries with focus increasingly placed on the most permanent, and hence critical, waterholes in the system. It is expected that the mechanism of impact will be twofold with riparian vegetation being removed through pugging and herbivory (reducing nutrient removal from the water) and manure inputs into the waterhole (increasing nutrient load and primary productivity).

Gwydir's Crossing site was an example of a heavily impacted waterhole. Here heavy livestock access had resulted in manure and pugging with more rapid degradation than would have occurred in the absence of livestock. This impact is unlikely to have systemic effects except under very specific flow patterns which reintroduce connectivity and fresh flows to the waterhole immediately pre-drying.

Given the specificity of damage, implementing measures to limit the impacts of grazing on waterholes should be assessed on a site by site basis. There were no sites identified during this study which warranted interventions based on the aquatic biota and it is important to note that Gwydir's Crossing already had an off-channel watering point which was ineffective in limiting damage because stock had free access to the waterhole. As such it is suggested that off-channel watering points be coupled with exclusion fencing if they are designed to protect the waterhole.

Tourism

Like mining, tourism requires significant transport infrastructure to maximise landscape access. While very large bridges like the Nappa Merrie Bridge in Queensland are unlikely to impact the aquatic biota, the smaller Innamincka Causeway has already been observed to impede movement patterns in fish and crustaceans (Darren Wilson, pers. comm.). Natural Resource Management authorities are proactive in their attempts to ameliorate the impacts of tourism and works are currently underway investigating the restoration of fish passage at the Innamincka Causeway (Zampatti and Mallen-Cooper 2011).

This study has been nested in an intensely wet period for Cooper Creek, however, tourism spans wet and dry periods. Arid tourism frequently focuses on the most permanent waterholes and hence the most critical sites for aquatic organisms. Impacts will be proportional to site popularity and will include alterations to terrestrial and riparian vegetation, increased local erosion, as well as the more direct effects of litter and fishing.

Ongoing adaptive management by rangers in the Innamincka Regional Reserve is the best mechanism possible.

Recreational Fishing

Recreational fishing is a significant activity in the system with almost half of the tourists surveyed participating during their stay at the Innamincka Regional Reserve. This extends to the reserve acting as an entry point for one group of first time fishers. Under this level of recreational fishing interest a strong responsibility exists to ensure participants can readily educate themselves on the legalities of the activity. This will not only optimise legal compliance but will also support the scientific and ecological goals implicit in size and bag restrictions. Of the 20 individuals fishing, only two were aware that bag and size limits existed within the region. This awareness was only slightly increased by signage at the Cullyamurra toilet block which had informed a second group of two fishers of their responsibilities. While this may suggest low effectiveness in signage, this is somewhat misleading as groups were surveyed from three sites within the region (Cullyamurra and Minkie Waterholes and the town common). Of these three sites only Cullyamurra has fishing signage making resources for self-education scant. Given these results, the current education measures are most likely unsuccessful in educating tourists about the legal limits imposed on fishing activities.

Fishing signage should be placed at the toilet blocks of all camp sites with a fishing focus. Priority should be given to the town common as one of the busier sites observed with Minkie Waterhole also deserving consideration. The Innamincka Trading post should also be considered a focal point for fishing supplies and for the dissemination of information. Consideration should be given to facilitate stocking of the store with information brochures. A further suggestion sourced from the survey was to include this information in the Desert Parks Pass brochure and application.

The process of staff survey provided valuable insights into behaviours and attitudes within the park however the efficiency of this approach is questionable. Physical approach of tourists was found to be time consuming and ultimately rate-limited by the number of tourists present on the day. Tourists were relaxed and generally pleased to be given the opportunity to provide feedback about the park and 10 of the 11 groups responded positively to the concept of a written survey placed centrally at toilet blocks. It is anticipated that future surveys of this kind could be more efficiently based on a toilet block survey model where the advantages would include:

- Low staffing requirements – staff facilitate rather than carry out the survey.

- Low infrastructure requirements – limited to sturdy containers, survey forms and pens/pencils.
- Adaptive approach – this approach could be readily adapted and changes rapidly implemented.
- Stimulated interest in nearby information signage – it is anticipated that participants are more likely to seek out nearby signage after completing a survey.

This approach harnesses the toilet block as a central focal point for camping activities, and as such this should continue to be the location of choice for recreational fishing signage. Signage should also; highlight the presence of tagged fish in the system, the importance of tag returns to ecological studies and inform of a reward for reporting of total length measures to Suntag. Future recreational fishing surveys should also include these details and may be further tailored to address specific aspects of tourist behaviour.

Key Sites

Two sites have been singled out for special mention in this discussion. Cullyamurra Waterhole and Lake Hope are both important indicators of Cooper Creek ecosystem health, but operate in quite different ways and face different management issues.

Cullyamurra Waterhole

Cullyamurra Waterhole is the largest and deepest waterhole in Innamincka Regional Reserve. The site is acknowledged as the deepest and one of the most permanent waterholes in Lake Eyre Basin. This is corroborated by the presence of flora and fauna indicative of permanence at this site. The waterhole provides a range of habitat types including snags, submerged and emergent macrophytes, and rocky and sandy substrates. The size and depth of the waterhole provides high water quality values even during drought. The fish fauna was dominated by bony herring consistent with high primary productivity. At different times during the study yellowbelly, Hyrtl's tandan, spangled perch, desert glassfish, carp gudgeon, Welch's grunter, goldfish and gambusia also proliferated. In autumn 2011 most species increased in numbers, however, by spring of the same year the fish fauna diversity and abundance had decreased. Despite that instance, Cullyamurra remains the most important waterhole in the system due to its permanence and high fish diversity. The fish populations found there also consisted of a higher proportion of larger mature adult fish compared with downstream sites indicating that this site is a long-term refuge for large adult fish.

Cullyamurra Waterhole is one of the most intensively studied waterholes in the region, yet the long-term patterns in fish population dynamics are still poorly understood. This study, in combination with the Lake Eyre Basin Rivers Assessment, will provide that long-term outlook. As the most permanent and largest waterhole in the area, Cullyamurra is also one of the most popular for tourists. In addition to regular fish surveys, it is important that a thorough assessment of the impacts from tourism and recreational fishing on the waterhole is conducted to ensure that the waterhole is not overfished and the riparian habitat isn't degraded from overuse.

Lake Hope

Lake Hope is a large, ephemeral, off-channel lake which holds particular interest in the study as it hosts the Lake Eyre Basin's only commercial fishery. This provides unique challenges and opportunities for operation and research. Positioned on Mulka Station, Garry Overton has fished this location intermittently since the early 1990s. While the lake itself is about 12 km long this study has focussed on the fisher's camp, positioned on the lake's southern edge.

This site is one of the most intensively sampled in the study. The simple microhabitat value is boosted by extensive submerged terrestrial vegetation. Water quality has been good and the water column was well mixed on each sampling occasion. Salinity has been gradually increasing throughout the period.

Over the course of this study two sites have been sampled within Lake Hope (Lake Hope Inlet and Lake Hope Camp) as well as the neighbouring 'Red Lake' (Lake Walpayapeninna) which is included in the fishery. Between these three sites, seven sampling events are incorporated, catching a total of 24,650 fish from 12 species.

Bony herring and carp gudgeon numbers appeared to increase over time while other species like the spangled perch dwindled. Both gambusia and desert glassfish appeared to boom and bust over the course of sampling. Despite supporting a commercial fishery for yellowbelly and grunters, these fish were only caught in low numbers and appear to be utilising different habitats at this site (most likely the very deep water sites where fyke nets are unable to be deployed effectively). The numbers of fish captured in the small areas sampled indicate that Lake Hope supports an enormous biomass of fish. This is supported by the large numbers of waterbirds residing in the Lake. Prior to 2010, Lake Hope was completely dry, with the present boom in this aquatic ecosystem indicative of the resilience and health of the lower Cooper Creek.

Whilst Lake Hope was one of the most intensively sampled sites in this study, our findings do not represent a thorough understanding of the fishery dynamics and its potential impacts on the environment. The fishery is managed under quota with a number of provisions for allowing fish to move back upstream if subsequent floods occur. Further studies that would benefit our understanding of the fishery include: a comprehensive fish age/length/weight study to determine growth rates, fishery and natural mortality figures, origin of the stock (locally spawned vs. migration from upstream); catch and effort analyses to determine patterns in catch rate through the life of the fishery; and a nutrient cycle study to determine where the nutrients from the remaining dead fish end up in the ecosystem.

Key Recommendations

1. Maintaining natural flow regimes in Cooper Creek should remain a priority. Activities that threaten natural flow regimes should be avoided or thoroughly assessed before implementation.

2. Environmental impacts applying to the South Australian Cooper Creek catchment should be independently considered over four spatial management units; permanent upper refugia, semi-permanent main branch reaches, semi-permanent northwest branch reach, and ephemeral lower refugia.

3. Ongoing fish monitoring in the Innamincka area should be conducted using volunteer stakeholders or interagency staff and detailed monitoring programs tailored to their workload and availability. An important component of this will be tagging of large-bodied fish including yellowbelly (*Macquaria ambigua*), Barcoo grunter (*Scortum barcoo*) and Welch's grunter (*Bidyanus welchi*).

4. An expanded recreational fishing survey should be conducted in the Innamincka Regional Reserve. Options for this survey should include survey forms located in each toilet block in the reserve or surveys circulated with the Desert Parks Pass.

5. Interpretive signage with information related to fish size and bag limits, other aquatic fauna, and protection of aquatic ecosystems should be installed at a greater number of locations and made more prominent.

6. Specific interactions between the Cooper Creek aquatic biota and cane toad (*Bufo marinus*) eggs and tadpoles need further investigation.

7. The impact of activities such as road and bridge building on fish passage and floodplain function warrants further investigation. Detailed modelling of altered floodplain inundation and diversion of flow, as well as on-ground monitoring of fish movement will enable these impacts to be quantified.

8. Future construction of transport infrastructure with potential to affect water regimes should be preceded by greater consultation with SAALNRMB.

9. Research funding through the Fisheries Research and Development Corporation (FRDC) and PIRSA Fisheries should be sought to collect comprehensive fisheries data for the Lake Hope fishery.

10. Research through the Lake Eyre Basin Rivers Assessment should be ongoing in order to monitor trends in aquatic ecosystem condition and inform adaptive management of key refugia such as Coongie Lakes and Cullyamurra Waterhole.

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Appendix 1 – Cooper Creek Recreational Fishing Survey

Cooper Creek Recreational Fishing Survey

Guide for interviewer

Conduct the survey between 8 am and 6 pm. You'll have to judge when people are more likely to be around. If there are a number of campers, you may be able to organise a survey at a later time if they like.

Approach each vehicle at camp, introduce yourself, tell them you are working for the SAALNRMB, and explain that we are conducting fish research in the Cooper and part of that is to conduct a recreational fishing survey in the area to help understand how much fishing takes place there.

If there are multiple people at the vehicle, interview an adult and if they are fishers, ask who the main fisher is.

Tell them it is a short 10 minute survey and completely voluntary. Their answers will help with our understanding of the factors influencing fish in the area, but if they don't want to answer, that is OK. Explain that honest results are essential. Responses are completely confidential and anonymous. There will be no recourse for anything that they reveal. Reiterate this point during the survey if they seem reluctant to answer certain questions.

Ask if they are willing to be recorded during the survey for ease of data entry and interpretation later.

Survey

Survey #:______________ Gender:_________Age Range:______ S-E Status:____________

1. Are you willing to answer a 10 minute survey on recreational fishing in the Innamincka Regional Reserve?____________
2. What is the length of your stay in the Innamincka Regional Reserve?____
3. Do you intend to fish during your stay/ have you already fished?____

3a. If so, how many days did you fish?_____________________________________

4. Do you normally fish in your home location (Where they live)?

   ____

5. If you have fished on this trip:

5a. What species did you target?____

5b. What species did you catch?____

5c. How many fish did you catch?____

6. Are you aware of the bag and size limits in the area? (Responses are confidential).____
7. Did you keep, eat or return the fish you caught? Were they legal size?____
8. Have you fished in this area before? How often? Have you noticed any changes over that time?____
   ____
   ____
9. Show them the proposed "toilet-block" survey. If you encountered this survey placed in toilet blocks around the Reserve, would you be inclined to complete it?____
10. Would you agree to be contacted at a later date via phone or email regarding the fishing you conduct after this survey?

    ____
    Phone:________________
    Email:____

    Any comments or questions about this survey?

For further information about this project, call David Schmarr from SARDI Aquatic Sciences on 0421 446 747.

Appendix 2 – Cooper Creek Site Assessment Sheets

Nappapethera

Nappapethera Waterhole looking upstream in spring 2011.

Site Data:

GPS: 54J 339088 6906657
Date(s) sampled: 14/11/2011
Site type: Leasehold (Pastoral)
Aquatic habitat type: Permanent main channel waterhole (Silcock 2009)
Sample area dimensions: 250m long, 50m wide
Elevation: 55m
Average yearly rainfall: 181.8mm

Vegetation characteristics at Nappapethera Waterhole.

Date	Flora Type	Cover	Dominant Species
14/11/2011	Submerged	0%	None Observed
	Emergent	0%	None Observed
	Riparian	75%	Lignum (*Muehlenbeckia florulenta*)

Aquatic habitat characteristics at Nappapethera Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
14/11/2011	<1	95%	70	0%

Hydrological characteristics at Nappapethera Waterhole.

Date	Max Depth (m)	Connectivity	Flow
14/11/2011	5	Isolated	Still

Water quality at Nappapethera Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE Cond (mS/cm)	AVERAGE pH	AVERAGE Turbidity (NTU)	Max Depth (cm)
14/11/2011	11.89	2.22	25.21	0.702	0.34	9.1	40.9

Total fish catch at Nappapethera Waterhole.

Nappapethera Waterhole		
Common Name	Species	14/11/2011
Desert glassfish	*A. mulleri*	0
Welch's grunter	*B. welchi*	2
Lake Eyre hardyhead	*C. eyresii*	0
Carp gudgeon spp.	*Hypseleotris spp.*	13
Spangled perch	*L. unicolor*	10
Yellowbelly	*M. ambigua*	12
Desert rainbowfish	*M. splendida tatei*	0
Bony herring	*N. erebi*	496
Cooper Creek catfish	*N. cooperensis*	0
Hyrtl's catfish	*N. hyrtlii*	3
Silver tandan	*P. argenteus*	5
Australian smelt	*R. semoni*	0
Barcoo grunter	*S. barcoo*	0
Goldfish	*C. auratus*	5
Gambusia	*G. holbrooki*	4
Total		550

Additional fauna observations.

Date	Species Observed
14/11/2011	Cooper turtle (*Emydura sp.*), water rat (*Hydromys chrysogaster*), freshwater mussel (*Velesunio sp.*), shrimp (Infraorder Caridea)

Nappapethera Waterhole is a large, main channel waterhole on Nappa Merrie Station just over the Queensland border. The presence of turtles and large freshwater mussels is strongly suggestive of permanence at this site. Habitat here was simple with no emergent or submerged vegetation but high densities of complex snags bolstered the otherwise depauperate fish microhabitats. The water was deep and turbid with stratification evident in the water column. Surface dissolved oxygen was suggestive of moderate microalgal loading. A total of seven native and two exotic fish species were recorded. The fish fauna was dominated by bony herring consistent with high primary productivity. The six other native species were observed in low numbers, as were both gambusia and goldfish.

Feral pigs were noted at this site as were ghost fishing nets. One small piece of scrap net contained two long dead turtles.

Nappapethera Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 0 species observed High number of snags
2	Additional Fauna	4/6 indicator species present **Freshwater mussels and Turtles**
3	Hydrology	Very deep Relatively frequent freshes and flushes
4	Water Quality	Low Salinity Relatively neutral pH
5	Aquatic Refuge	High indication of permanency Refuge fauna present High hydrological value Moderate habitat value
6	Native Fish Diversity	7/11 native species recorded in 'Upper Cooper' reach Moderate abundance of fish
7	Invasive Fish Species	2/2 invasive fish species identified in the Cooper catchment were recorded at this site
8	Potential Threats	Impacts from cattle Invasive weeds Illegal fish netting Recreational Fishing Water Extraction Feral Pigs

Upper Cooper Main Branch

Cullyamurra Waterhole

Cullyamurra Waterhole looking upstream in autumn 2012.

Site Data:

GPS: 54 J 484321 6935885
Date(s) sampled: 14/12/2010, 4/06/2011, 20/11/2011, 13-18/04/2012
Site type: Tourist Area, Leasehold (Pastoral)
Aquatic habitat type: Permanent main channel waterhole (Silcock 2009)
Sample area dimensions: 450m long, 70m wide
Elevation: 52m
Average yearly rainfall: 189mm

Vegetation characteristics at Cullyamurra Waterhole.

Date	Flora Type	Cover	Dominant Species
14/12/2010	Submerged	0%	None Observed
	Emergent	10%	Velvet knotweed (*Persicaria attenuata*)
	Riparian	50%	Red Gum (*Eucalyptus camaldulensis*)
4/06/2011	Submerged	0%	None Observed
	Emergent	1%	Velvet knotweed (*Persicaria attenuata*)
	Riparian	50%	Coolabah (*Eucalyptus coolabah*)

Date	Flora Type	Cover	Dominant Species
20/11/2011	Submerged	0%	None Observed
	Emergent	1%	Velvet knotweed (*Persicaria decipiens*)
	Riparian	45%	Lignum (*Muehlenbeckia florulenta*)
13/04/2012	Submerged	0%	None Observed
	Emergent	1%	Velvet knotweed (*Persicaria attenuata*)
	Riparian	40%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Cullyamurra Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
14/12/2010	<1	90	0	0%
4/06/2011	<1	80	0	0%
20/11/2011	<1	99	1	0%
13/04/2012	<1	99	6	0%

Hydrological characteristics at Cullyamurra Waterhole.

Date	Max Depth (m)	Connectivity	Flow
14/12/2010	5.1	Connected	Moderate
4/06/2011	7.3	Connected	High
20/11/2011	5	Isolated	Still
13/04/2012	6.1	Connected	High

Water quality at Cullyamurra Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
14/12/2010	5.98	3.67	28.08	0.208	7.71	160.11	510
4/06/2011	8.99	8.36	14.77	0.166	8.87	62.56	730
20/11/2011	7.31	6.22	25.31	0.404	9.44	9.08	500

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
13/04/2012	7.23	6.53	22.28	0.162	7.76	35.32	610

Total fish catch at Cullyamurra Waterhole.

Cullyamurra Waterhole									
Common Name	Species	14/12 2010	4/06 2011	20/11 2011	14/04 2012	15/04 2012	16/04 2012	17/04 2012	18/04 2012
Desert glassfish	*A. mulleri*	0	391	0	120	627	532	218	381
Welch's grunter	*B. welchi*	69	9	0	44	40	15	16	27
Lake Eyre hardyhead	*C. eyresii*	0	0	0	0	0	0	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	2	1	27	62	55	54	95	73
Spangled perch	*L. unicolor*	67	726	0	0	6	0	10	0
Yellowbelly	*M. ambigua*	45	136	0	76	67	18	38	36
Desert rainbowfish	*M. splendida tatei*	0	233	0	2	25	35	2	0
Bony herring	*N. erebi*	49	36	138	21	112	135	58	150
Cooper Creek catfish	*N. cooperensis*	0	0	0	0	0	0	0	0
Hyrtl's catfish	*N. hyrtlii*	212	186	7	13	42	7	15	7
Silver tandan	*P. argenteus*	144	11	0	0	0	0	0	0
Australian smelt	*R. semoni*	0	0	0	0	0	0	0	0
Barcoo grunter	*S. barcoo*	0	3	0	0	0	0	0	0
Goldfish	*C. auratus*	2	254	1	6	3	8	5	2
Gambusia	*G. holbrooki*	5	738	42	1	22	0	0	0
Total		595	2724	215	345	999	804	457	676

Additional fauna observations.

Date	Species Observed
14/12/2010	Cooper turtle (*Emydura sp.*), water rat (*Hydromys chrysogaster*), freshwater mussel (*Velesunio sp.*), Yabby (*Cherax destructor*)
4/06/2011	Cooper turtle *(Emydura sp.)*, freshwater mussel *(Velesunio sp.)*, Shrimp (Infraorder Caridea)
20/11/2011	Cooper turtle (*Emydura sp.*), water rat (Hydromys chrysogaster), freshwater mussel (Velesunio sp.)
13/04/2012	Cooper turtle *(Emydura sp.)*, freshwater mussel *(Velesunio sp.)*, Shrimp (Infraorder Caridea)

Cullyamurra Waterhole is a large, very deep, main channel waterhole in Innamincka Regional Reserve. The site is acknowledged as the deepest and one of the most permanent waterholes in Lake Eyre Basin. This is corroborated by the presence of flora and fauna indicative of permanence at this site. While no submerged vegetation was noted, a 5 metre fringe of emergent vegetation (velvet knotweed) was present surrounding the waterhole throughout the sample period. Physical structure was mostly simple with some large snags focussed on the river's edge. Water quality was good on all occasions with low salinity, and good dissolved oxygen levels. No stratification was evident in the 4 - 6m depth profile. A total of ten native and two exotic fish species were recorded. The fish fauna was dominated by bony herring consistent with high primary productivity. At times, yellowbelly, Hyrtl's tandan, spangled perch, desert glassfish, carp gudgeon, Welch's grunter, goldfish and gambusia also proliferated. In autumn 2011 most species boomed in numbers.

Cullyamurra Waterhole Ecosystem Value & Threats.

	Indicator	**Description**
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: Very high number of snags
2	Additional Fauna	5/6 species present ***Turtles and Freshwater Mussels***
3	Hydrology	Depth: Very Deep Frequent freshes and flushes
4	Water Quality	Low salinity pH neutral Low-moderate turbidity
5	Aquatic Refuge	Permanent waterhole High habitat value High hydrological value Very long term refuge value
6	Native Fish Diversity	10/11 native species recorded in 'Upper Cooper' reach No cryptic species present Moderate- high abundance of fish

	Indicator	Description
7	Invasive Fish Species	2/2 invasive fish species identified
8	Potential Threats	Impacts from tourism Invasive weeds Invasive animals Impacts from fishing

Burke's Waterhole

Burke's Waterhole looking upstream in autumn 2012.

Site Data:

GPS: 54 J 511916 6947760
Date(s) sampled: 3/04/2011, 14/04/2012
Site type: Tourist Area, Leasehold (Pastoral)
Aquatic habitat type: Permanent main channel waterhole (Silcock 2009)
Sample area dimensions: 250m long, 100m wide
Elevation: 50m
Average yearly rainfall: 189mm

Burke's Waterhole Vegetation characteristics.

Date	Flora Type	Cover	Dominant Species
3/04/11	Submerged	0%	None Observed
	Emergent	20%	Velvet knotweed (*Persicaria attenuata*)
	Riparian	35%	Lignum (*Muehlenbeckia florulenta*)
14/04/12	Submerged	0%	None Observed
	Emergent	90%	Velvet knotweed (*Persicaria attenuata*)
	Riparian	30%	Red Gum (*Eucalyptus camaldulensis*)

Burke's Waterhole Aquatic habitat characteristics.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
3/04/11	<1	95%	23	0%
14/04/12	<1	99%	23	0%

Burke's Waterhole Hydrological characteristics.

Date	Max Depth (m)	Connectivity	Flow
3/04/11	6	Connected	High
14/04/12	5.5	Connected	High

Burke's Waterhole Water quality.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
3/04/11	7.45	7.26	25.40	0.213	8.50	39.01	600
14/04/12	7.75	7.41	20.66	0.156	7.82	42.75	550

Total fish catch at Burke's Waterhole.

Burke's Waterhole			
Common Name	**Species**	**3/04/2011**	**14/04/2012**
Desert glassfish	*A. mulleri*	18356	230
Welch's grunter	*B. welchi*	24	8
Lake Eyre hardyhead	*C. eyresii*	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	17	156
Spangled perch	*L. unicolor*	460	8
Yellowbelly	*M. ambigua*	10	5
Desert rainbowfish	*M. splendida tatei*	370	26
Bony herring	*N. erebi*	37	36
Cooper Creek catfish	*N. cooperensis*	0	0
Hyrtl's catfish	*N. hyrtlii*	67	12
Silver tandan	*P. argenteus*	10	0

Burke's Waterhole			
Common Name	**Species**	**3/04/2011**	**14/04/2012**
Australian smelt	*R. semoni*	0	0
Barcoo grunter	*S. barcoo*	2	0
Goldfish	*C. auratus*	13	1
Gambusia	*G. holbrooki*	27	3
Total		19393	485

Additional fauna observations.

Date	Species Observed
3/04/11	Cooper turtle (*Emydura sp.*), Shrimp (Infraorder Caridea), Yabby (*Cherax destructor*)
14/04/12	Cooper turtle (*Emydura sp.*), freshwater mussel (*Velesunio sp.*), Shrimp (Infraorder Caridea)

Burke's Waterhole is a main channel waterhole with maintained camping facilities near Innamincka. The presence of turtles and large freshwater mussels is suggestive of near permanence at this site, though the volume of the waterhole appears highly variable over time. While no submerged vegetation was noted, healthy emergent vegetation was present and increasing. Physical structure was mostly simple with no submerged vegetation and some snags focussed on the river's edge. Water quality was good on both occasions with low salinity, and good dissolved oxygen levels. No stratification was evident in the 5 - 6m depth profile.

A remarkable population boom event was observed here in April 2011 when 18,356 desert glassfish were caught. This was an order of magnitude higher than was observed anywhere else in this study. A total of ten native and two exotic species were identified here between the two sampling events.

Burke's Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 1 species observed Snags: Moderate number of snags
2	Additional Fauna	4/6 species present **freshwater mussels and Turtles**
3	Hydrology	Very deep Relatively frequent freshes and flushes
4	Water Quality	Low Salinity Neutral pH
5	Aquatic Refuge	High indication of permanency Refuge fauna present

	Indicator	Description
		High hydrological value High habitat value
6	Native Fish Diversity	10/11 native species recorded in 'Upper Cooper' reach No cryptic species present Very High-Moderate abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded
8	Potential Threats	Impacts from public/tourists Invasive weeds Recreational Fishing Feral Pigs

Upper Cooper Main Branch

Minkie Waterhole

Minkie Waterhole looking upstream in autumn 2012.

Site Data:

GPS: 54 J 464472 6927297
Date(s) sampled: 16/12/2010, 4/04/2011, 15/04/2012
Site type: Public Recreation
Aquatic habitat type: Permanent main channel waterhole (Silcock 2009)
Sample area dimensions: 250m long, 100m wide
Elevation: 50m
Average yearly rainfall: 189mm

Vegetation characteristics at Minkie Waterhole.

Date	Flora Type	Cover	Dominant Species
16/12/2010	Submerged	0%	None Observed
	Emergent	40%	Velvet knotweed (*Persicaria attenuata*)
	Riparian	40%	Lignum (*Muehlenbeckia florulenta*)
4/04/2011	Submerged	0%	None Observed
	Emergent	60%	Velvet knotweed (*Persicaria attenuata*)
	Riparian	60%	Red Gum (*Eucalyptus camaldulensis*)

Date	Flora Type	Cover	Dominant Species
15/04/2012	Submerged	0%	None Observed
	Emergent	90%	Velvet knotweed (*Persicaria attenuata*)
	Riparian	35%	Lignum (*Muehlenbeckia florulenta*)

Aquatic habitat characteristics at Minkie Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
16/12/2010	<1	100%	20	0%
4/04/2011	<1	100%	106	0%
15/04/2012	<1	90%	Not Recorded	0%

Hydrological characteristics at Minkie Waterhole.

Date	Max Depth (m)	Connectivity	Flow
16/12/2010	6.73	Connected	Low
4/04/2011	8.5	Connected	High
15/04/2012	5.5	Connected	Moderate

Water quality at Minkie Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
16/12/2010	5.41	4.83	28.54	0.210	7.71	160.95	670
4/04/2011	7.75	7.23	24.59	0.211	8.58	41.58	850
15/04/2012	7.31	7.18	20.42	0.154	7.72	41.74	550

Total fish catch at Minkie Waterhole.

Minkie Waterhole				
Common Name	Species	16/12/2010	4/04/2011	15/04/2012
Desert glassfish	*A. mulleri*	1	2773	226
Welch's grunter	*B. welchi*	58	0	10
Lake Eyre hardyhead	*C. eyresii*	0	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	1	1	31
Spangled perch	*L. unicolor*	55	42	1
Yellowbelly	*M. ambigua*	18	15	4
Desert rainbowfish	*M. splendida tatei*	7	36	2
Bony herring	*N. erebi*	89	6	9
Cooper Creek catfish	*N. cooperensis*	0	0	0
Hyrtl's catfish	*N. hyrtlii*	145	55	32
Silver tandan	*P. argenteus*	127	3	1
Australian smelt	*R. semoni*	1	0	0
Barcoo grunter	*S. barcoo*	0	0	0
Goldfish	*C. auratus*	2	93	3
Gambusia	*G. holbrooki*	30	11	0
Total		534	3035	319

Additional fauna observations.

Date	Species Observed
16/12/2010	Not Recorded
4/04/2011	Cooper turtle (*Emydura sp.*), freshwater mussel (*Velesunio sp.*), Shrimp (Infraorder Caridea)
15/04/2012	Cooper turtle (*Emydura sp.*), Shrimp (Infraorder Caridea)

Minkie Waterhole is a large main channel waterhole on the upper Cooper Creek. No submerged vegetation was observed at Minkie waterhole but the emergent *Persicaria sp*. was present and increasing over the sampling occasions. Water quality was good with no stratification, low salinity and good dissolved oxygen levels. The presence of mussels and turtles is strongly suggestive of near permanence at this site. A total of ten native and two exotic species were recorded. The larger bodied fishes were at their highest during 2010 and appeared to reduce in number over the course of the study while the smaller bodied fishes peaked in 2011 and reduced in number thereafter.

Minkie Waterhole Ecosystem Value & Threats.

	Indicator	**Description**
1	Aquatic Habitat	Aquatic Veg: 1 species observed Snags: Large number of snags observed 2011
2	Additional Fauna	3/6 species present **freshwater mussels and Turtles**
3	Hydrology	Very deep Relatively frequent freshes and flushes
4	Water Quality	Low salinity Neutral pH
5	Aquatic Refuge	High indication of permanency Refuge fauna present High hydrological value High habitat value
6	Native Fish Diversity	10/11 native species recorded in ‘Upper Cooper’ reach 1 cryptic species present (*R. semoni*) High-Moderate abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded on 2/3 occasions
8	Potential Threats	Impacts from public/tourists Invasive weeds Recreational Fishing

North West Branch

Tirrawarra Waterhole

Tirrawarra Waterhole looking upstream in spring 2011.

Site Data:

GPS: 54J 415958 6965261
Date(s) sampled: 15/11/2011, 19/04/2012
Site type: Private (Leasehold (Pastoral))
Aquatic habitat type: Permanent waterhole (Silcock 2009)
Sample area dimensions: 250m long, 55m wide
Elevation: 50m
Average yearly rainfall: 185.9mm

Vegetation characteristics at Tirrawarra Waterhole.

Date	Flora Type	Cover	Dominant Species
15/11/2011	Submerged	0%	None Observed
	Emergent	0%	None Observed
	Riparian	90%	Lignum (*Muehlenbeckia florulenta*)

Date	Flora Type	Cover	Dominant Species
19/04/2012	Submerged	0%	None Observed
	Emergent	10%	Lignum (*Muehlenbeckia florulenta*) Marsh millet (*Echinochloa inundata*)
	Riparian	87.5%	Wattle (*Acacia sp.*)

Aquatic habitat characteristics at Tirrawarra Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
15/11/2011	<1	100%	70	0%
19/04/2012	<1	100%	60	0%

Hydrological characteristics at Tirrawarra Waterhole.

Date	Max Depth (m)	Connectivity	Flow
15/11/2011	3.2	Isolated	Still
19/04/2012	3.5	Connected	Low

Water quality at Tirrawarra Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
15/11/2011	6.76	4.42	21.37	0.397	7.68	48.08	320
19/04/2012	7.37	2.42	25.18	0.160	8.81	110	350

Total fish catch at Tirrawarra Waterhole.

Tirrawarra Waterhole			
Common Name	Species	15/11/2011	19/04/2012
Desert glassfish	*A. mulleri*	1	83
Welch's grunter	*B. welchi*	0	24
Lake Eyre hardyhead	*C. eyresii*	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	382	57

Tirrawarra Waterhole			
Common Name	Species	15/11/2011	19/04/2012
Spangled perch	*L. unicolor*	13	4
Yellowbelly	*M. ambigua*	15	6
Desert rainbowfish	*M. splendida tatei*	5	7
Bony herring	*N. erebi*	715	93
Cooper Creek catfish	*N. cooperensis*	0	0
Hyrtl's catfish	*N. hyrtlii*	21	6
Silver tandan	*P. argenteus*	9	3
Australian smelt	*R. semoni*	0	0
Barcoo grunter	*S. barcoo*	0	2
Goldfish	*C. auratus*	6	2
Gambusia	*G. holbrooki*	3	67
Total		1170	354

Additional fauna observations.

Date	Species Observed
15/11/2011	Yabby (*Cherax destructor*), Shrimp (Infraorder Caridea), Cooper turtle (*Emydura sp.*)
19/04/2012	Shrimp (Infraorder Caridea), Cooper turtle (*Emydura sp.*)

Tirrawarra Waterhole is a permanent site on the Upper Cooper. Instream flora was minimal but site complexity was bolstered by high numbers of snags. Water quality was generally good though stratification was apparent during 2012 sampling. A total of ten native and two exotic fish species were observed with numbers higher in 2011 than in 2012. The presence of turtles is strongly suggestive of permanence at this site. Tirrawarra contained the highest number of turtles caught in this study.

Tirrawarra Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: Large number of snags
2	Additional Fauna	3/6 species present **Turtles**
3	Hydrology	Moderately deep Intermittent freshes and flushes

	Indicator	Description
4	Water Quality	Low salinity Neutral pH
5	Aquatic Refuge	High indication of permanency One species of refuge fauna present Moderate hydrological value High habitat value
6	Native Fish Diversity	10/11 native species recorded in 'North West Branch' reach No cryptic species present High-Moderate abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded on each occasion
8	Potential Threats	Impacts from grazing Invasive weeds Feral Pigs

North West Branch

Kudriemitchie Waterhole

Kudriemitchie Waterhole looking across stream from eastern entry point in autumn 2012.

Site Data:

GPS: 54J 420831 6974481
Date(s) sampled: 20/04/2012
Site type: Public Recreation (Camping)
Aquatic habitat type: Almost permanent waterhole (Silcock 2009)
Sample area dimensions: 250m long, 55m wide
Elevation: 35m
Average yearly rainfall: 186mm

Vegetation characteristics at Kudriemitchie Waterhole.

Date	Flora Type	Cover	Dominant Species
20/04/2012	Submerged	0%	None Observed
	Emergent	20%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	65%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Kudriemitchie Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
20/04/2012	<1	100%	12	0%

Hydrological characteristics at Kudriemitchie Waterhole.

Date	Max Depth (m)	Connectivity	Flow
20/04/2012	5	Connected	High

Water quality at Kudriemitchie Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
20/04/2012	6.15	6.05	20.32	0.156	7.56	37.41	500

Total fish catch at Kudriemitchie Waterhole.

Kudriemitchie Waterhole		
Common Name	Species	20/04/2012
Desert glassfish	*A. mulleri*	62
Welch's grunter	*B. welchi*	28
Lake Eyre hardyhead	*C. eyresii*	0
Carp gudgeon spp.	*Hypseleotris spp.*	117
Spangled perch	*L. unicolor*	15
Yellowbelly	*M. ambigua*	28
Desert rainbowfish	*M. splendida tatei*	2
Bony herring	*N. erebi*	64
Cooper Creek catfish	*N. cooperensis*	0
Hyrtl's catfish	*N. hyrtlii*	14
Silver tandan	*P. argenteus*	1
Australian smelt	*R. semoni*	0

Kudriemitchie Waterhole		
Common Name	Species	20/04/2012
Barcoo grunter	*S. barcoo*	0
Goldfish	*C. auratus*	6
Gambusia	*G. holbrooki*	2
Total		339

Additional fauna observations.

Date	Species Observed
20/04/2012	Yabby (*Cherax destructor*), Shrimp (Infraorder Caridea), Cooper turtle (*Emydura sp.*)

Kudriemitchie is a channel waterhole on the North West Branch. Structure was primarily simple with low levels of emergent vegetation and low numbers of snags with some large simple snags focussed on the river's edge. Water quality was good with no stratification evident and low salinity.

A total of nine native and two exotic fish species were identified at this site with no clear dominance within the fish community. Both gambusia and goldfish were present at this site.

Kudriemitchie Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: Moderate number of snags
2	Additional Fauna	3/6 species present ** Turtles**
3	Hydrology	Very deep Intermittent freshes and flushes
4	Water Quality	Low salinity Neutral pH
5	Aquatic Refuge	High indication of permanency One species of refuge fauna present High hydrological value High habitat value
6	Native Fish Diversity	9/11 native species recorded in 'North West Branch' reach No cryptic species present Moderate abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded
8	Potential Threats	Impacts from tourists Invasive weeds Feral Pigs

North West Branch

Lake Daer Inlet

Lake Daer Inlet looking across channel in autumn 2012.

Site Data:

GPS: 54J 410544 699091
Date(s) sampled: 23/04/2012
Site type: Conservation
Aquatic habitat type: Ephemeral lake inlet (anabranch)
Sample area dimensions: 250m long, 20m wide
Elevation: 35m
Average yearly rainfall: 186mm

Vegetation characteristics at Lake Daer Inlet .

Date	Flora Type	Cover	Dominant Species
23/04/2012	Submerged	0%	None Observed
	Emergent	0%	None Observed
	Riparian	12.5%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Lake Daer Inlet .

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
23/04/2012	<1	100%	14	0%

Hydrological characteristics at Lake Daer Inlet .

Date	Max Depth (m)	Connectivity	Flow
23/04/2012	0.75	Connected	Low

Water quality at Lake Daer Inlet .

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
23/04/2012	7.28	6.83	18.38	0.592	9.38	287.67	75

Total fish catch at Lake Daer Inlet .

Lake Daer Inlet		
Common Name	Species	23/04/2012
Desert glassfish	*A. mulleri*	149
Welch's grunter	*B. welchi*	0
Lake Eyre hardyhead	*C. eyresii*	0
Carp gudgeon spp.	*Hypseleotris spp.*	336
Spangled perch	*L. unicolor*	24
Yellowbelly	*M. ambigua*	0
Desert rainbowfish	*M. splendida tatei*	3
Bony herring	*N. erebi*	147
Cooper Creek catfish	*N. cooperensis*	0
Hyrtl's catfish	*N. hyrtlii*	0

Lake Daer Inlet		
Common Name	**Species**	**23/04/2012**
Silver tandan	*P. argenteus*	0
Australian smelt	*R. semoni*	14
Barcoo grunter	*S. barcoo*	0
Goldfish	*C. auratus*	0
Gambusia	*G. holbrooki*	20
Total		693

Additional fauna observations.

Date	Species Observed
23/04/2012	Shrimp (Infraorder Caridea), Cooper turtle (*Emydura sp.*)

Lake Daer Inlet is positioned in the entrance to an off-channel lake on the North West Branch. It was sampled on a single occasion as flow was increasing. This site is shallow (1m deep) and impermanent. At this time huge numbers of Caridea were present as well as six species of small bodied native fishes in high numbers. A total of six native and one exotic fish species were recorded. The observation of 14 smelt at this site was unexpected. Goldfish were not present at this site, however gambusia were. Water quality was good with low salinity. There was no stratification in this shallow well-mixed site.

Lake Daer Inlet Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: Moderate number of snags
2	Additional Fauna	2/6 species present Extreme abundance of shrimp ** Turtles**
3	Hydrology	Shallow Terminal Occasional freshes and flushes
4	Water Quality	Low salinity Neutral pH High turbidity
5	Aquatic Refuge	No indication of permanency One species of refuge fauna present Low hydrological value Low habitat value
6	Native Fish Diversity	6/11 native species recorded in 'North West Branch' reach One cryptic species present Moderate abundance of fish

	Indicator	Description
7	Invasive Fish Species	One invasive fish species identified in the Cooper catchment was recorded
8	Potential Threats	Invasive weeds

North West Branch

Coongie Lake Inflow

Coongie Lake Inflow looking upstream in autumn 2012.

Site Data:

GPS: 54J 415859 6993267
Date(s) sampled: 16/11/2011, 24/04/2012
Site type: Public Recreation (Camping)
Aquatic habitat type: Infrequently dry lake (Silcock 2009)
Sample area dimensions: 250m long, 55m wide
Elevation: 35m
Average yearly rainfall: 186mm

Vegetation characteristics at Coongie Lake Inflow.

Date	Flora Type	Cover	Dominant Species
16/11/2011	Submerged	0%	None Observed
	Emergent	1%	Sedge (*Cyperus sp.*)
	Riparian	60%	Lignum (*Muehlenbeckia florulenta*)
24/04/2012	Submerged	0%	None Observed
	Emergent	80%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	92%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Coongie Lake Inflow.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
16/11/2011	<1	100	40	0%
24/04/2012	<1	100	70	0%

Hydrological characteristics at Coongie Lake Inflow.

Date	Max Depth (m)	Connectivity	Flow
16/11/2011	2	Connected	Still
24/04/2012	3	Connected	Moderate

Water quality at Coongie Lake Inflow.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
16/11/2011	2.55	1.79	25.24	0.461	8.88	79.08	200
24/04/2012	6.97	5.81	20.31	0.158	7.78	28.6	300

Total fish catch at Coongie Lake Inflow.

Coongie Lake Inflow				
Common Name	Species	16/11/2011	24/04/2012	26/04/2012
Desert glassfish	*A. mulleri*	151	709	480
Welch's grunter	*B. welchi*	10	23	16
Lake Eyre hardyhead	*C. eyresii*	0	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	614	183	300
Spangled perch	*L. unicolor*	16	6	22
Yellowbelly	*M. ambigua*	8	27	32
Desert rainbowfish	*M. splendida tatei*	6	204	94
Bony herring	*N. erebi*	335	34	52
Cooper Creek catfish	*N. cooperensis*	0	0	0
Hyrtl's catfish	*N. hyrtlii*	39	123	40

Coongie Lake Inflow				
Common Name	Species	16/11/2011	24/04/2012	26/04/2012
Silver tandan	*P. argenteus*	22	5	6
Australian smelt	*R. semoni*	0	0	0
Barcoo grunter	*S. barcoo*	0	0	0
Goldfish	*C. auratus*	0	5	5
Gambusia	*G. holbrooki*	43	75	182
Total		1244	1394	1229

Additional fauna observations.

Date	Species Observed
16/11/2011	Shrimp (Infraorder Caridea), Cooper turtle (*Emydura sp.*)
24/04/2012	Yabby (*Cherax destructor*), Shrimp (Infraorder Caridea), Cooper turtle (*Emydura sp.*)

Coongie Lake Inflow was positioned in the inlet channel where water from the North West Branch enters the semi-permanent Coongie Lake. High flow events excluded access to this priority site during the early stages of the study. A total of three sampling events were possible here, all during the final two rounds of sampling. Water quality was variable between the two seasons with low dissolved oxygen and high turbidity during spring 2011 which had normalised by autumn 2012. Habitat here was good with a variety of snag sizes present in good density. There was no submerged vegetation noted on either occasion but emergent and riparian vegetation was well represented.

A total of nine native and two exotic species were observed here, most in good numbers. Turtles were also present as well as large amounts of freshly broken freshwater mussel shells, which is indicative of permanence and the presence of feral pigs.

Coongie Lake Inflow Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: High number of snags
2	Additional Fauna	3/6 species present **Turtles**
3	Hydrology	Deep Occasional freshes and flushes
4	Water Quality	Poor water quality during spring 2011. Water quality better during autumn 2012 Low salinity
5	Aquatic Refuge	Indication of permanence One species of refuge fauna present Moderate hydrological value

	Indicator	Description
		High habitat value
6	Native Fish Diversity	9/11 native species recorded in 'North West Branch' reach No cryptic species present Moderate-High Abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded in 2012
8	Potential Threats	Impacts from tourists Invasive weeds Feral Pigs

Lake Toontoowarannie

Panoramic photo from Lake Toontoowarannie in spring 2011.

Site Data:

GPS: 54J 415859 6993267
Date(s) sampled: 17/11/2011
Site type: Conservation
Aquatic habitat type: Regularly dry lake (Silcock 2009)
Sample area dimensions: 250m long, 200m wide
Elevation: 30m
Average yearly rainfall: 186mm

Vegetation characteristics at Lake Toontoowarannie.

Date	Flora Type	Cover	Dominant Species
17/11/2011	Submerged	0%	None Observed
	Emergent	10%	Sedge (*Cyperus sp.*)
	Riparian	95%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Lake Toontoowarannie.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
17/11/2011	<1	100	40	0%

Hydrological characteristics at Lake Toontoowarannie.

Date	Max Depth (m)	Connectivity	Flow
17/11/2011	0.9	Connected	Still

Water quality at Lake Toontoowarannie.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
17/11/2011	13.27	12.28	26.84	0.435	9.71	67.5	90

Total fish catch at Lake Toontoowarannie.

Lake Toontoowarannie		
Common Name	Species	17/11/2011
Desert glassfish	*A. mulleri*	10
Welch's grunter	*B. welchi*	3
Lake Eyre hardyhead	*C. eyresii*	0
Carp gudgeon spp.	*Hypseleotris spp.*	30
Spangled perch	*L. unicolor*	2
Yellowbelly	*M. ambigua*	4
Desert rainbowfish	*M. splendida tatei*	0
Bony herring	*N. erebi*	498
Cooper Creek catfish	*N. cooperensis*	0
Hyrtl's catfish	*N. hyrtlii*	0
Silver tandan	*P. argenteus*	1
Australian smelt	*R. semoni*	0
Barcoo grunter	*S. barcoo*	0
Goldfish	*C. auratus*	1

Lake Toontoowarannie		
Common Name	Species	17/11/2011
Gambusia	*G. holbrooki*	67
Total		616

Additional fauna observations.

Date	Species Observed
17/11/2011	Shrimp (Infraorder Caridea), Cooper turtle (*Emydura sp.*)

Lake Toontoowaranie is the second lake in the Coongie Lakes complex. This site is intermittently inundated and at the time of sampling appeared to have been only recently inundated. The presence of partially submerged Coolabahs and cyperus sp. bolstered the complexity of aquatic microhabitats at the site. Oxygen and turbidity was high reflecting strong algal communities fed by novel nutrient inputs. This strong primary productivity in turn supported a large community of bony herring, which dominated the fish community at this site. A total of seven native fish species were caught in addition to both invasive fish species.

Lake Toontoowarannie Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 1 species observed Snags: High number of snags
2	Additional Fauna	3/6 species present ** Turtles**
3	Hydrology	Deep Occasional freshes and flushes
4	Water Quality	Low salinity Neutral pH Moderate-Low turbidity
5	Aquatic Refuge	Terminal No species of refuge fauna present Moderate hydrological value High habitat value
6	Native Fish Diversity	7/11 native species recorded in 'North West Branch' reach No cryptic species present Moderate abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded
8	Potential Threats	Invasive animals Invasive plants

Main Branch

Embarka Waterhole

Panoramic photo of Embarka Waterhole in spring 2011.

Site Data:

GPS: 54 J 420814 6938207
Date(s) sampled: 19/11/2011, 21/04/2012
Site type: Gas/Leasehold (Pastoral)
Aquatic habitat type : Almost permanent waterhole (Main Branch)
Sample area dimensions: 250m long, 40m wide
Elevation: 40m
Average yearly rainfall: 186mm

Vegetation characteristics at Embarka Waterhole.

Date	Flora Type	Cover	Dominant Species
19/11/2011	Submerged	0%	None Observed
	Emergent	5%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	90%	Coolabah (*Eucalyptus coolabah*)
21/04/2012	Submerged	0%	None Observed
	Emergent	5%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	90%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Embarka Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
19/11/2011	<1	100	14	1%
21/04/2012	<1	100	40	0%

Hydrological characteristics at Embarka Waterhole.

Date	Max Depth (m)	Connectivity	Flow
19/11/2011	2.5	Isolated	Still
21/04/2012	5	Connected	High

Water quality at Embarka Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
19/11/2011	6.29	5.44	26.74	0.438	9.28	9.03	250
21/04/2012	8.13	8.07	22.4	0.164	7.93	44.14	500

Total fish catch at Embarka Waterhole.

Embarka Waterhole			
Common Name	Species	19/11/2011	21/04/2012
Desert glassfish	*A. mulleri*	242	171
Welch's grunter	*B. welchi*	0	2
Lake Eyre hardyhead	*C. eyresii*	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	5087	304
Spangled perch	*L. unicolor*	89	58
Yellowbelly	*M. ambigua*	3	33
Desert rainbowfish	*M. splendida tatei*	605	11
Bony herring	*N. erebi*	125	30
Cooper Creek catfish	*N. cooperensis*	0	0
Hyrtl's catfish	*N. hyrtlii*	0	5
Silver tandan	*P. argenteus*	0	7
Australian smelt	*R. semoni*	0	0
Barcoo grunter	*S. barcoo*	0	0
Goldfish	*C. auratus*	0	18
Gambusia	*G. holbrooki*	44	0
Total		6151	621

Additional fauna observations.

Date	Species Observed
19/11/2011	Cooper turtle (*Emydura sp.*), water rat (*Hydromys chrysogaster*), freshwater mussel (*Velesunio sp.*), Shrimp (Infraorder Caridea)
21/04/2012	Cooper turtle (*Emydura sp.*), Yabby (*Cherax destructor*), freshwater mussel (*Velesunio sp.*), Shrimp (Infraorder Caridea)

Embarka Waterhole is a large deep waterhole next to the homestead on Gidgealpa station. This site was identified as a priority for sampling but access was impossible (due to flooding) until spring 2011. The presence of turtles and mussels at this site is strongly suggestive of permanence. Water quality was good at this site regardless of connectivity with no stratification evident on either sampling event.

Spring 2011 sampling observed a boom in carp gudgeon numbers (reaching 5,087) but this had normalised by autumn 2012. A total of nine native species of fish and the two exotic species (though only one on each of the two trips) were observed at this site.

Embarka Waterhole Ecosystem Value & Threats.

	Indicator	**Description**
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: Moderate-High number of snags
2	Additional Fauna	5/6 species present **Freshwater Mussels & Turtles**
3	Hydrology	Deep-Very deep Occasional freshes and flushes
4	Water Quality	Low salinity Neutral pH Moderate-Low turbidity
5	Aquatic Refuge	Indication of permanency Two species of refuge fauna present High hydrological value High habitat value
6	Native Fish Diversity	9/12 native species recorded in ‘Main Channel’ reach No cryptic species present Very High-High abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded
8	Potential Threats	Impacts from cattle Impacts from industry Invasive weeds Invasive animals

Main Branch

Embarka Outflow

Embarka Outflow in autumn 2011 (above) and spring 2011 (below).

Site Data:

GPS: 54 J 412315 6950487
Date(s) sampled: 6/04/2011, 2/06/2011
Site type: Gas/Leasehold (Pastoral)
Aquatic habitat type: Ephemeral swamp (Main Branch)
Sample area dimensions: 250m long, 200m wide
Elevation: 35m
Average yearly rainfall: 186mm

Vegetation characteristics at Embarka Outflow.

Date	Flora Type	Cover	Dominant Species
6/04/2011	Submerged	1%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	1%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	5%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Embarka Outflow.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
6/04/2011	<1	100	53	0%

Hydrological characteristics at Embarka Outflow.

Date	Max Depth (m)	Connectivity	Flow
6/04/2011	3.4	Connected	High

Water quality at Embarka Outflow.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
6/04/2011	8.69	8.53	21.69	0.197	8.72	19.14	340
2/6/2011	10.15	10.08	14.44	0.155	9.10125	10.525	490

Total fish catch at Embarka Outflow.

Embarka Outflow			
Common Name	Species	6/04/2011	2/06/2011
Desert glassfish	*A. mulleri*	4587	1485
Welch's grunter	*B. welchi*	68	13
Lake Eyre hardyhead	*C. eyresii*	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	14	91
Spangled perch	*L. unicolor*	22	9
Yellowbelly	*M. ambigua*	26	81
Desert rainbowfish	*M. splendida tatei*	5	17
Bony herring	*N. erebi*	36	137
Cooper Creek catfish	*N. cooperensis*	0	0
Hyrtl's catfish	*N. hyrtlii*	49	8
Silver tandan	*P. argenteus*	2	0
Australian smelt	*R. semoni*	1	0
Barcoo grunter	*S. barcoo*	0	0
Goldfish	*C. auratus*	0	48
Gambusia	*G. holbrooki*	8791	13665
Total		13601	15554

Additional fauna observations.

Date	Species Observed
6/04/2011	Yabby (*Cherax destructor*), Shrimp (Infraorder Caridea)

Embarka Outflow was a contingency site visited on two occasions when other sites were inaccessible. Attempts to retain this as a site were impossible as flood waters had receded by spring 2011, returning this ephemeral floodplain to an arid basin. This sparsely vegetated floodplain was sampled on two temporally similar events, and as such most of the above data tables consider this site as a single visit.

This site was interesting for fish consideration and highlights the way in which small bodied fishes are able to rapidly occupy novel floodplain habitats and undergo population booms. This can be seen in desert glassfish and gambusia numbers which had both exploded in this recently inundated habitat. The capacity for gambusia to undergo repeated spawning events is apparent as their numbers continue to increase in June 2011 while glassfish numbers have begun to normalise. A total of 10 native and two exotic fish species were recorded.

Embarka Outflow Ecosystem Value & Threats.

	Indicator	**Description**
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: High number of snags
2	Additional Fauna	2/6 species present **Crustaceans only**
3	Hydrology	Deep Occasional freshes and flushes
4	Water Quality	Low salinity Neutral pH Moderate-Low turbidity
5	Aquatic Refuge	Not permanent Both species of refuge fauna present High hydrological value High habitat value
6	Native Fish Diversity	10/12 native species recorded in 'Main Channel' reach One cryptic species present Very High-High abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded **Extreme numbers of Gambusia**
8	Potential Threats	Impacts from cattle Impacts from industry Invasive weeds Invasive animals

Main Branch

Gidgealpa Waterhole

Gidgealpa Waterhole in autumn 2011.

Site Data:

GPS: 54 J 416449 6921896
Date(s) sampled: 17/12/2010, 5/04/2011, 9/05/2012
Site type: Gas/Leasehold (Pastoral)
Aquatic habitat type: Infrequently dry waterhole (Small Anabranch)
Sample area dimensions: 250m long, 200m wide
Elevation: 35m
Average yearly rainfall: 186mm

Vegetation characteristics at Gidgealpa Waterhole.

Date	Flora Type	Cover	Dominant Species
17/12/2010	Submerged	0%	None Observed
	Emergent	0%	None Observed
	Riparian	40%	Coolabah (*Eucalyptus coolabah*)
5/04/2011	Submerged	0%	None Observed
	Emergent	0%	None Observed
	Riparian	40%	Coolabah (*Eucalyptus coolabah*)

Date	Flora Type	Cover	Dominant Species
9/05/2012	Submerged	0%	None Observed
	Emergent	0%	None Observed
	Riparian	40%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Gidgealpa Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
17/12/2010	Not Recorded	Not Recorded	Not Recorded	Not Recorded
5/04/2011	<1	100	50	0%
9/05/2012	<1	100	5	0%

Hydrological characteristics at Gidgealpa Waterhole.

Date	Max Depth (m)	Connectivity	Flow
17/12/2010	Not Recorded	Not Recorded	Not Recorded
5/04/2011	3.3	Connected	Still
9/05/2012	1.5	Isolated	Still

Water quality at Gidgealpa Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
17/12/2010	7.06	6.72	25.35	0.296	8.96	193.83	100
5/04/2011	9.25	0.67	21.63	0.392	8.17	51.58	330
9/05/2012	12.49	11.85	20.13	0.265	9.33	512.9	100

Total fish catch at Gidgealpa Waterhole.

Gidgealpa Waterhole				
Common Name	Species	17/12/2010	5/04/2011	9/05/2012
Desert glassfish	*A. mulleri*	3	2398	7
Welch's grunter	*B. welchi*	58	0	0
Lake Eyre hardyhead	*C. eyresii*	0	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	0	44	77
Spangled perch	*L. unicolor*	166	22	14
Yellowbelly	*M. ambigua*	17	47	0
Desert rainbowfish	*M. splendida tatei*	35	17	1
Bony herring	*N. erebi*	329	0	1243
Cooper Creek catfish	*N. cooperensis*	0	0	1
Hyrtl's catfish	*N. hyrtlii*	3	1	0
Silver tandan	*P. argenteus*	8	3	0
Australian smelt	*R. semoni*	0	0	0
Barcoo grunter	*S. barcoo*	0	0	0
Goldfish	*C. auratus*	0	0	0
Gambusia	*G. holbrooki*	0	6386	5
Total		619	8918	1348

Additional fauna observations.

Date	Species Observed
17/12/2010	Freshwater crab (*Austrothelphusa transversa*)
5/04/2011	Shrimp (Infraorder Caridea)
9/05/2012	Shrimp (Infraorder Caridea)

Gidgealpa Waterhole is an off channel waterhole reminiscent of a temperate billabong. This site has been accessible throughout the study and is one of the best temporally represented sites in the study. It gives some insight into the variability of fish community in arid waterholes.

A total of ten native and one exotic fish species were recorded. Desert glassfish and gambusia were barely present in 2010, boomed in 2011 and crashed again by 2012. Bony herring followed boom bust cycles as well but were successionally distinct, booming before and again after the smaller species. The majority of other species underwent steady declines over time.

While salinity remained low throughout, turbidity and surface dissolved oxygen were variable across sampling events. Stratification was evident on only a single sampling instance (2011).

The impacts of livestock and terrestrial weeds were notable at this site. Walkers Crossing track passes right by the waterhole, but was inaccessible to tourists throughout the sample period. When the track eventually reopens, tourism may again be a threat.

Gidgealpa Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: High number of snags
2	Additional Fauna	2/6 species present **Only site with Freshwater Crabs**
3	Hydrology	Moderately Deep-Shallow Infrequent freshes and flushes
4	Water Quality	Low salinity Neutral pH Moderate-High turbidity
5	Aquatic Refuge	Appears non-permanent Low hydrological value Moderate habitat value
6	Native Fish Diversity	10/12 native species recorded in 'Main Channel' reach One cryptic species present **Cooper Catfish** High-moderate abundance of fish
7	Invasive Fish Species	One invasive fish species identified in the Cooper catchment were recorded **No records of goldfish to date**
8	Potential Threats	Impacts from cattle Impacts from industry Invasive weeds Invasive animals Tourism Walkers Crossing track passes right by the waterhole

Main Branch

Narie Waterhole

Narie Waterhole looking downstream in autumn 2012.

Site Data: GPS: 54 J 408456 6962930
Date(s) sampled: 18/11/2011, 26/04/2012
Site type: Leasehold (Pastoral)
Aquatic habitat type: Infrequently dry waterhole (Main Channel)
Sample area dimensions: 250m long, 35m wide
Elevation: 37m
Average yearly rainfall: 186mm

Vegetation characteristics at Narie Waterhole.

Date	Flora Type	Cover	Dominant Species
18/11/2011	Submerged	0%	None Observed
	Emergent	0%	None Observed
	Riparian	95%	Coolabah (*Eucalyptus coolabah*)
26/04/2012	Submerged	0%	None Observed
	Emergent	10%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	95%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Narie Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
18/11/2011	<1	100	5	0%
26/04/2012	<1	100	32	0%

Hydrological characteristics at Narie Waterhole.

Date	Max Depth (m)	Connectivity	Flow
18/11/2011	2	Isolated	Still
26/04/2012	4.5	Connected	Moderate

Water quality at Narie Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
18/11/2011	8.26	3.31	27.57	0.452	9	56	200
26/04/2012	9.01	8.76	17.94	0.165	8.58	72.26	450

Total fish catch at Narie Waterhole.

Narie Waterhole			
Common Name	Species	18/11/2011	26/04/2012
Desert glassfish	*A. mulleri*	8	491
Welch's grunter	*B. welchi*	4	3
Lake Eyre hardyhead	*C. eyresii*	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	762	60
Spangled perch	*L. unicolor*	1	591
Yellowbelly	*M. ambigua*	3	10
Desert rainbowfish	*M. splendida tatei*	36	0
Bony herring	*N. erebi*	208	152
Cooper Creek catfish	*N. cooperensis*	2	0
Hyrtl's catfish	*N. hyrtlii*	34	4
Silver tandan	*P. argenteus*	5	0
Australian smelt	*R. semoni*	0	1
Barcoo grunter	*S. barcoo*	0	0
Goldfish	*C. auratus*	3	170
Gambusia	*G. holbrooki*	11	0
Total		1077	1482

Additional fauna observations.

Date	Species Observed
18/11/2011	Cooper turtle (*Emydura sp.*), Shrimp (Infraorder Caridea)
26/04/2012	Cooper turtle (*Emydura sp.*), Yabby (*Cherax destructor*), Shrimp (Infraorder Caridea)

Narie Waterhole is a site of semi-permanence. Habitat was primarily simple, banks were steep and the water quality was generally good with slightly elevated oxygen and high turbidity.

A total of eleven native and two exotic fish species were recorded. The fish community varied between sampling events with 12 species identified on the first visit and only nine on the second. This included five species which were identified on only one of the two visits. Within these species both Cooper Catfish and smelt were identified.

Narie Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: High number of snags
2	Additional Fauna	2/6 species present **Freshwater Turtles**
3	Hydrology	Moderately Deep-Deep Infrequent freshes and flushes
4	Water Quality	Low salinity Neutral pH Low turbidity
5	Aquatic Refuge	Appears permanent High hydrological value High habitat value
6	Native Fish Diversity	11/12 native species recorded in 'Main Channel' reach Both cryptic species present **Cooper Catfish AND Smelt** High abundance of fish on both occasions
7	Invasive Fish Species	Both invasive fish species identified in the cooper catchment were recorded Relatively high number of goldfish
8	Potential Threats	Impacts from cattle Invasive weeds Invasive animals

Main Branch

Cuttapirie Corner Waterhole

Panoramic photo of Cuttapirie Corner Waterhole looking downstream in autumn 2012.

Site Data:

GPS: 54 J 390410 6947133
Date(s) sampled: 22/04/2012
Site type: Leasehold (Pastoral)/Gas
Aquatic habitat type: Frequently dry waterhole (Main channel)
Sample area dimensions: 250m long, 30m wide
Elevation: 32m
Average yearly rainfall: Approximately 186mm

Vegetation characteristics at Cuttapirie Corner Waterhole.

Date	Flora Type	Cover	Dominant Species
22/04/2012	Submerged	0%	None Observed
	Emergent	5%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	62%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Cuttapirie Corner Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
22/04/2012	<1	100	23	0%

Hydrological characteristics at Cuttapirie Corner Waterhole.

Date	Max Depth (m)	Connectivity	Flow
22/04/2012	4	Connected	Moderate

Water quality at Cuttapirie Corner Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
22/04/2012	6.91	6.57	21.61	0.185	8.05	67	400

Total fish catch at Cuttapirie Corner Waterhole.

Cuttapirie Corner Waterhole		
Common Name	Species	22/04/2012
Desert glassfish	*A. mulleri*	147
Welch's grunter	*B. welchi*	0
Lake Eyre hardyhead	*C. eyresii*	0
Carp gudgeon spp.	*Hypseleotris spp.*	93
Spangled perch	*L. unicolor*	177
Yellowbelly	*M. ambigua*	3
Desert rainbowfish	*M. splendida tatei*	17
Bony herring	*N. erebi*	31
Cooper Creek catfish	*N. cooperensis*	0
Hyrtl's catfish	*N. hyrtlii*	3
Silver tandan	*P. argenteus*	2
Australian smelt	*R. semoni*	0
Barcoo grunter	*S. barcoo*	0
Goldfish	*C. auratus*	11
Gambusia	*G. holbrooki*	320
Total		804

Additional fauna observations.

Date	Species Observed
22/04/2012	Cooper turtle (*Emydura sp.*), Shrimp (Infraorder Caridea)

Cuttapirie Corner Waterhole is a semi-permanent main channel waterhole that verges the edge of the Innamincka Regional Reserve. This was notable as the furthest downstream site that Red Gum *(Eucalyptus camaldulensis)*, silver tandans and turtles were identified. Dissolved oxygen was ambient and salinity low with no stratification apparent in the four metre water column.

A total of eight native and two exotic fish species were captured.

Cuttapirie Corner Waterhole Ecosystem Value & Threats.

	Indicator	**Description**
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: Moderate number of snags ***Furthest downstream site with Red Gums***
2	Additional Fauna	2/6 species present **Furthest downstream site with turtles**
3	Hydrology	Deep Infrequent freshes and flushes
4	Water Quality	Low salinity Neutral pH Low turbidity
5	Aquatic Refuge	Appears permanent High hydrological value Moderate habitat value
6	Native Fish Diversity	8/12 native species recorded in ‘Main Channel’ reach No cryptic species present Moderate abundance of fish
7	Invasive Fish Species	Both invasive fish species identified in the Cooper catchment were recorded
8	Potential Threats	Impacts from cattle Invasive weeds Invasive animals

Lower Cooper

Eaglehawk Waterhole

Aerial photo of Eaglehawk Waterhole in spring 2011.

Site Data:

GPS: 54 J 343166 6908968
Date(s) sampled: 07/04/2011
Site type: Gas (Mining)/Leasehold (Pastoral)
Aquatic habitat type: Ephemeral waterhole (Off channel)
Sample area dimensions: 250m long, 30m wide
Elevation: 24m
Average yearly rainfall: Approximately 146mm

Vegetation characteristics at Eaglehawk Waterhole.

Date	Flora Type	Cover	Dominant Species
07/04/2011	Submerged	1%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	20%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	80%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Eaglehawk Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
07/04/2011	<1	100	27	0%

Hydrological characteristics at Eaglehawk Waterhole.

Date	Max Depth (m)	Connectivity	Flow
07/04/2011	3.9	Connected	High

Water quality at Eaglehawk Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
07/04/2011	9.14	3.79	20.52	0.68	8.99	225.33	390

Total fish catch at Eaglehawk Waterhole.

Eaglehawk Waterhole		
Common Name	Species	7/04/2011
Desert glassfish	*A. mulleri*	0
Welch's grunter	*B. welchi*	1
Lake Eyre hardyhead	*C. eyresii*	0
Carp gudgeon spp.	*Hypseleotris spp.*	1
Spangled perch	*L. unicolor*	9
Yellowbelly	*M. ambigua*	10
Desert rainbowfish	*M. splendida tatei*	32
Bony herring	*N. erebi*	132
Cooper Creek catfish	*N. cooperensis*	1
Hyrtl's catfish	*N. hyrtlii*	1
Silver tandan	*P. argenteus*	0
Australian smelt	*R. semoni*	0

Eaglehawk Waterhole		
Common Name	Species	7/04/2011
Barcoo grunter	*S. barcoo*	1
Goldfish	*C. auratus*	0
Gambusia	*G. holbrooki*	1
Total		189

Additional fauna observations.

Date	Species Observed
07/04/2011	Shrimp (Infraorder Caridea)

Eaglehawk Waterhole is a small ephemeral waterhole on a minor offshoot of the Cooper main channel. It is on both the Beach Energy Lease and Mungeranie Station. Turbidity was very high and some stratification was apparent in the 3.9 metre water column. Despite this, surface oxygen readings were elevated indicating microalgal loading which is apparent in the strong representation of bony herring at the site.

A total of nine native and one exotic fish species were recorded. Fish diversity at this site was relatively high with the nine species of native fish present though typically in very low numbers. Notable here is the presence of a Cooper catfish. Only a single exotic fish was captured.

Eaglehawk Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 1 species observed Snags: Moderate number of snags
2	Additional Fauna	Only shrimp present
3	Hydrology	Deep Very Infrequent freshes and flushes
4	Water Quality	Low salinity Neutral pH High turbidity
5	Aquatic Refuge	Appears permanent High hydrological value High habitat value
6	Native Fish Diversity	9/12 native species recorded in 'Main Channel' reach One cryptic species present **Cooper Catfish*** Low abundance of fish
7	Invasive Fish Species	Only a single individual of one invasive fish species identified in the Cooper catchment was recorded.

	Indicator	Description
8	Potential Threats	Impacts from cattle Impacts from industry Invasive weeds Invasive animals

Beach Bridge

Beach Bridge viewed from upstream in autumn 2011.

Site Data:

GPS: 54 J 339088 6906657
Date(s) sampled: 14/11/2011 (2xBF only), 10/05/2012 (Seine Only)
Site type: Gas (Mining)/Leasehold (Pastoral)
Aquatic habitat type: Ephemeral flood out (Main Channel)
Sample area dimensions: 50m long, 20m wide
Elevation: 19m
Average yearly rainfall: Approximately 146mm

Vegetation characteristics at Beach Bridge.

Date	Flora Type	Cover	Dominant Species
14/11/2011	Submerged	0%	None Observed
	Emergent	40%	Lignum (*Muehlenbeckia florulenta*)
	Riparian	40%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Beach Bridge.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
14/11/2011	<1	100	0	0%

Hydrological characteristics at Beach Bridge.

Date	Max Depth (m)	Connectivity	Flow
14/11/2011	2.5	Connected	Low

Water quality at Beach Bridge.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
14/11/2011	1.36	0.66	22.94	0.556	9.45	38.93	250
10/05/2012	1.92	0.56	15.39	1.43	9.29	910.95	200

Total fish catch at Beach Bridge.

Beach Bridge			
Common Name	Species	14/11/2011	10/05/2012
Desert glassfish	*A. mulleri*	12	69
Welch's grunter	*B. welchi*	0	0
Lake Eyre hardyhead	*C. eyresii*	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	0	33
Spangled perch	*L. unicolor*	111	1
Yellowbelly	*M. ambigua*	0	0
Desert rainbowfish	*M. splendida tatei*	2	19
Bony herring	*N. erebi*	63	0
Cooper Creek catfish	*N. cooperensis*	0	0
Hyrtl's catfish	*N. hyrtlii*	0	0
Silver tandan	*P. argenteus*	0	0
Australian smelt	*R. semoni*	0	0
Barcoo grunter	*S. barcoo*	0	0
Goldfish	*C. auratus*	131	0
Gambusia	*G. holbrooki*	0	0
Total		319	122

Additional fauna observations.

Date	Species Observed
14/11/2011	Shrimp (Infraorder Caridea)

The Beach Bridge site is beneath a recently constructed bridge on Mungeranie station. It was constructed over the Cooper Creek to allow Beach Energy vehicles access to the Callawonga Work Camp during 2010 floods. This bridge was a one lane approximately 20 metre span bridge with culverts in series and to one side of the main span. The bridge worked in concert with long levy banks to channel flood waters beneath the bridge. This altered habitat had created large pools beneath the bridge which were simple but had also inundated areas of floodplain habitat nearby that boosted local habitat values.

Dissolved oxygen was remarkably low on both occasions being 1.3 and 1.9mg/L maximum respectively.

On both occasions this site was sampled using modified techniques. During spring 2011 the site was flowing and appeared to be a corridor for relocating fishes. A total of five native and one exotic fish species were recorded. The most strongly represented were spangled perch, goldfish and bony herring. By the following sampling round in autumn 2012 flow had ceased and the fish community had undergone a shift to the small and fecund species (glassfish, carp gudgeon and rainbowfish).

Beach Bridge Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 0 species observed Snags: Low number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Shallow-Moderate Very Infrequent freshes and flushes Altered hydrology may have reduced flood zone habitats
4	Water Quality	Low salinity pH neutral – Avg. alkalinity of terminal lake Low-High turbidity
5	Aquatic Refuge	Not Permanent Anthropogenic alterations to flow have reduced refuge value significantly Declining habitat value
6	Native Fish Diversity	5/12 native species recorded in 'Lower Midstream' reach No cryptic species present Low abundance of fish (Low Sample Effort)
7	Invasive Fish Species	1/2 invasive fish species identified ***Goldfish Recruits***

	Indicator	Description
8	Potential Threats	Impacts from cattle Impacts from industry ***Change in Hydrological Pattern*** ***Altered floodplain inundation*** Invasive weeds Invasive animals

Lower Cooper

Lake Hope Inlet

Lake Hope Inlet in autumn 2011.

Site Data:

GPS: 54 J 322984 6875519
Date(s) sampled: 11/04/2011, 28/04/2012
Site type: Leasehold (Pastoral)/Commercial Fishery
Aquatic habitat type: Ephemeral off channel lake inlet
Sample area dimensions: 250m long, 20m wide
Elevation: 11m
Average yearly rainfall: Approximately 130mm

Vegetation characteristics at Lake Hope Inlet.

Date	Flora Type	Cover	Dominant Species
11/04/2011	Submerged	25%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	5%	Sedge (*Cyperus sp.*)
	Riparian	5%	Coolabah (*Eucalyptus coolabah*)
28/04/2012	Submerged	50%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	0%	None Observed

Riparian	5%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Lake Hope Inlet.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
11/04/2011	<1	100	1	0%
28/04/2012	<1	100	0	0%

Hydrological characteristics at Lake Hope Inlet.

Date	Max Depth (m)	Connectivity	Flow
11/04/2011	1.9	Connected	Moderate
28/04/2012	0.75	Connected	Still

Water quality at Lake Hope Inlet.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
11/04/2011	9.26	9.11	22.11	0.398	9.56	74.28	190
28/04/2012	8.52	8.09	17.01	2.612	9.94	25.07	75

Total fish catch at Lake Hope Inlet.

Lake Hope Inlet			
Common Name	Species	11/04/2011	28/04/2012
Desert glassfish	*A. mulleri*	249	230
Welch's grunter	*B. welchi*	19	0
Lake Eyre hardyhead	*C. eyresii*	0	2
Carp gudgeon spp.	*Hypseleotris spp.*	34	124
Spangled perch	*L. unicolor*	26	0
Yellowbelly	*M. ambigua*	79	0
Desert rainbowfish	*M. splendida tatei*	2441	31
Bony herring	*N. erebi*	774	8080
Cooper Creek catfish	*N. cooperensis*	0	0
Hyrtl's catfish	*N. hyrtlii*	0	0
Silver tandan	*P. argenteus*	0	0
Australian smelt	*R. semoni*	3	0
Barcoo grunter	*S. barcoo*	0	0
Goldfish	*C. auratus*	0	0
Gambusia	*G. holbrooki*	5005	90
Total		8630	8557

Additional fauna observations.

Date	Species Observed
11/04/2011	Shrimp (Infraorder Caridea)
28/04/2012	Shrimp (Infraorder Caridea)

The inlet to Lake Hope (from Lake Appadare) has been sampled on two occasions. This channel has contained dense populations of aquatic milfoil on both sampling occasions. This temporarily inundated channel, highlights the importance of shallow ephemeral habitats as nurseries for fishes during flood pulses and also highlights the remarkable fecundity of some fishes in this system notably rainbowfish, bony herring and gambusia. Each of these three species boomed during the study reaching some of the highest densities observed at any site.

A total of nine native and one exotic fish species were recorded. The large bodied fishes present during autumn 2011 (Welch's grunter and yellowbelly) appear to have moved to the deeper more permanent waters of Lake Hope by autumn 2012.

A feral cat was noted at this site.

Lake Hope Inlet Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 1 species observed Snags: Very low number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Shallow Very Infrequent freshes and flushes
4	Water Quality	Low salinity (increased in 2012) pH neutral – Avg. alkalinity of terminal lake Low turbidity
5	Aquatic Refuge	Not permanent Provides access to large (Terminal) lake No immediate refuge value
6	Native Fish Diversity	9/12 native species recorded in 'Lower Midstream' reach One cryptic species present High abundance of fish (Gambusia 2011 and Juvenile Bony herring in 2012)
7	Invasive Fish Species	1/2 invasive fish species identified on both sampling occasions
8	Potential Threats	Impacts from cattle Invasive weeds Cats

Lake Hope

Panoramic photo of Lake Hope from main campsite in spring 2011.

Site Data:

GPS: 54 J 328455 6859435
Date(s) sampled: 13/12/2010, 10/04/2011, 31/05/2011, 13/11/2011, 28/04/2012, 30/04/2012, 1/05/2012
Site type: Leasehold (Pastoral)/Commercial Fishery
Aquatic habitat type: Ephemeral terminal Lake (Off Channel)
Sample area dimensions: 250m long, 70m wide
Elevation: 8m
Average yearly rainfall: Approximately 130mm

Vegetation characteristics at Lake Hope.

Date	Flora Type	Cover	Dominant Species
13/12/2010	Submerged	0%	None Observed
	Emergent	1%	Sedge (*Cyperus sp.*)
	Riparian	10%	Coolabah (*Eucalyptus coolabah*)
10/04/2011	Submerged	1%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	0%	Sedge (*Cyperus sp.*)
	Riparian	10%	Coolabah (*Eucalyptus coolabah*)
13/11/2011	Submerged	5%	Wattle (*Acacia sp.*)
	Emergent	1%	Watermilfoil (*Myriophyllum sp.*)
	Riparian	10%	Coolabah (*Eucalyptus coolabah*)

Date	Flora Type	Cover	Dominant Species
28/04/2012	Submerged	5%	Wattle (*Acacia sp.*)
	Emergent	0%	None Observed
	Riparian	10%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Lake Hope.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
13/12/2010	<1	100	100	0%
10/04/2011	<1	100	101	0%
13/11/2011	<1	100	101	0%
30/04/2012	<1	100	50	0%

Hydrological characteristics at Lake Hope.

Date	Max Depth (m)	Connectivity	Flow
13/12/2010	>4.2	Connected	Still
10/04/2011	>5.3	Connected	Still
13/11/2011	>5.3	Connected	Low
30/04/2012	>1.7	Isolated	Still

Water quality at Lake Hope.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
13/12/2010	8.28	8.12	24.61	0.968	9.25	66.93	420
10/04/2011	11.22	10.54	14.01	1.457	9.73	13.68	530
31/05/2011	11.22	10.54	14.00	1.11	9.72	16.21	530
13/11/2011	11.03	10.79	25.85	1.84	9.92	4.73	530
30/04/2012	9.94	9.81	17.95	2.219	9.78	12.2	170

Total fish catch at Lake Hope.

Lake Hope									
Common Name	Species	13/12 2010	10/04 2011	11/04 2011	31/05 2011	13/11 2011	28/04 2012	30/04 2012	1/05 2012
Desert glassfish	*A. mulleri*	1	8	249	1	0	230	1	26
Welch's grunter	*B. welchi*	9	15	19	0	4	0	4	4
Lake Eyre hardyhead	*C. eyresii*	0	0	0	0	0	2	3	5
Carp gudgeon spp.	*Hypseleotris spp.*	0	0	34	1	26	124	186	57
Spangled perch	*L. unicolor*	48	2	26	2	1	0	0	0
Yellowbelly	*M. ambigua*	43	7	79	2	1	0	0	2
Desert rainbowfish	*M. splendida tatei*	25	15	2441	53	51	31	1	20
Bony herring	*N. erebi*	45	432	774	428	71	8080	1051	2874
Cooper Creek catfish	*N. cooperensis*	0	0	0	0	0	0	0	0
Hyrtl's catfish	*N. hyrtlii*	0	0	0	1	0	0	1	2
Silver tandan	*P. argenteus*	0	0	0	0	0	0	0	0
Australian smelt	*R. semoni*	0	0	3	0	0	0	0	0
Barcoo grunter	*S. barcoo*	0	2	0	0	0	0	0	0
Goldfish	*C. auratus*	0	0	0	0	4	0	0	0
Gambusia	*G. holbrooki*	0	33	5005	208	16	90	22	25
Total		171	514	8630	696	174	8557	1269	3015

Additional fauna observations.

Date	Species Observed
13/12/2010	Shrimp (Infraorder Caridea)
10/04/2011	Shrimp (Infraorder Caridea)
13/11/2011	Shrimp (Infraorder Caridea)
30/04/2012	Shrimp (Infraorder Caridea)

Lake Hope is a large, ephemeral, off-channel lake and is the central site of Cooper Creek's iconic commercial fishery. Positioned on Mulka Station, Gary and son Paul Overton have fished this location intermittently since the early 1990's. While the lake itself is about 12 km long this study has focussed on the fisher's camp, positioned on the lake's southern edge.

This site is one of the most intensively sampled in the study. The simple microhabitat value is boosted by extensive submerged terrestrial vegetation. Water quality has been good and the water column was well mixed on each sampling occasion. Salinity has been gradually increasing through the course of this study.

A total of eleven native and two exotic fish species were recorded. Bony herring and carp gudgeon numbers appear to increase over time while other species like the spangled perch have dwindled. Both gambusia and desert glassfish appear to boom and bust over the course of sampling. Despite supporting a commercial fishery for yellowbelly and grunters, these fish were only caught sparingly and appear to be utilising different habitats than this site (most likely the very deep water sites where fyke nets are unable to be deployed effectively).

Lake Hope Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: Very high number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Deep Very Infrequent freshes and flushes
4	Water Quality	Low salinity (greater levels of salinity compared with upstream sites in 2012) pH neutral Low turbidity
5	Aquatic Refuge	Terminal Lake High habitat value Low hydrological value Short term refuge value
6	Native Fish Diversity	11/12 native species recorded in 'Lower Midstream' reach One cryptic species present Moderate- high abundance of fish
7	Invasive Fish Species	2/2 invasive fish species identified **Goldfish recorded on one occasion (Juveniles)**
8	Potential Threats	Impacts from cattle Invasive weeds Invasive animals Impacts from fishery unknown

Lower Cooper

Red Lake (Lake Walpayapeninna)

Red Lake (Lake Walpayapeninna) in autumn 2012.

Site Data:

GPS: 54 J 323079 6860269
Date(s) sampled: 6/05/2012
Site type: Leasehold (Pastoral)/Commercial Fishery
Aquatic habitat type: Ephemeral terminal lake (Off Channel)
Sample area dimensions: 250m long, 70m wide
Elevation: 10m
Average yearly rainfall: Approximately 130mm

Vegetation characteristics at Lake Walpayapeninna (Red Lake).

Date	Flora Type	Cover	Dominant Species
6/05/2012	Submerged	30%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	75%	Sedge (*Cyperus sp.*)
	Riparian	80%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Lake Walpayapeninna (Red Lake).

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
6/05/2012	<1	100	0	0%

Hydrological characteristics at Lake Walpayapeninna (Red Lake).

Date	Max Depth (m)	Connectivity	Flow
6/05/2012	2.7	Isolated	Still

Water quality at Lake Walpayapeninna (Red Lake).

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
6/05/2012	11.03	8.57	16.42	3.231	9.57	22.1	270

Total fish catch at Lake Walpayapeninna (Red Lake).

Red Lake		
Common Name	Species	6/05/2012
Desert glassfish	*A. mulleri*	14
Welch's grunter	*B. welchi*	0
Lake Eyre hardyhead	*C. eyresii*	26
Carp gudgeon spp.	*Hypseleotris spp.*	1174
Spangled perch	*L. unicolor*	0
Yellowbelly	*M. ambigua*	1
Desert rainbowfish	*M. splendida tatei*	0
Bony herring	*N. erebi*	364
Cooper Creek catfish	*N. cooperensis*	0
Hyrtl's catfish	*N. hyrtlii*	0
Silver tandan	*P. argenteus*	0
Australian smelt	*R. semoni*	9
Barcoo grunter	*S. barcoo*	0
Goldfish	*C. auratus*	1
Gambusia	*G. holbrooki*	7
Total		1596

Additional fauna observations.

Date	Species Observed
6/05/2012	Shrimp (Infraorder Caridea)

Neighbouring Lake Hope, Red Lake (Lake Walpayapeninna) is the second site included in the iconic Lake Hope fishery. This lake is considerably smaller than Lake Hope and the fisher Garry Overton reports that its deterioration precedes Lake Hope.

At the time of sampling, this lake included dense populations of red milfoil which harboured strong populations of small fishes, notably a booming population of carp gudgeon.

A total of six native and two exotic fish species were recorded. This site contained one of the few records of Australian smelt in the system and individuals were large and in spawning condition. Salinity had begun to rise at this site which appeared to be favouring the proliferation of the salt tolerant hardyhead. The fisher stopped harvesting Red Lake one week after our sample due to deteriorating water quality.

Low numbers of both exotic fish species were observed here.

Red Lake Ecosystem Value & Threats.

	Indicator	**Description**
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: Low number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Moderately Deep Very Infrequent freshes and flushes
4	Water Quality	Salinity higher than previous sites pH neutral – alkaline Low turbidity
5	Aquatic Refuge	Terminal Moderate-low habitat value Low hydrological value Short term refuge value
6	Native Fish Diversity	6/12 native species recorded in ‘Lower Midstream’ reach One cryptic species present High abundance of fish **Furthest downstream site where Cooper Catfish have been observed** (Pers. Comms. Gary Overton)
7	Invasive Fish Species	2/2 invasive fish species identified
8	Potential Threats	Impacts from cattle Invasive weeds Impacts from fishery unknown

Lake Pandruannie

Lake Pandruannie in autumn 2012.

Site Data:

GPS: 54 J 307411 6854620
Date(s) sampled: 13/11/2011
Site type: Leasehold (Pastoral)
Aquatic habitat type: Ephemeral Lake (On/Off Channel)
Sample area dimensions: 250m long, 70m wide
Elevation: 10m
Average yearly rainfall: Approximately 130mm

Vegetation characteristics at Lake Pandruannie.

Date	Flora Type	Cover	Dominant Species
13/11/2011	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	1%	Sedge (*Cyperus gymnocaulos*)
	Riparian	1%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Lake Pandruannie.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
13/11/2011	<1	100	2	2

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Hydrological characteristics at Lake Pandruannie.

Date	Max Depth (m)	Connectivity	Flow
13/11/2011	>1	Connected	Still

Water quality at Lake Pandruannie.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
13/11/2011	11.46	10.77	25.29	1.126	10.13	10.2	100

Total fish catch at Lake Pandruannie.

Lake Pandruannie Common Name	Species	13/11/2011
Desert glassfish	*A. mulleri*	4
Welch's grunter	*B. welchi*	0
Lake Eyre hardyhead	*C. eyresii*	0
Carp gudgeon spp.	*Hypseleotris spp.*	213
Spangled perch	*L. unicolor*	5
Yellowbelly	*M. ambigua*	7
Desert rainbowfish	*M. splendida tatei*	11
Bony herring	*N. erebi*	371
Cooper Creek catfish	*N. cooperensis*	0
Hyrtl's catfish	*N. hyrtlii*	0
Silver tandan	*P. argenteus*	0
Australian smelt	*R. semoni*	0
Barcoo grunter	*S. barcoo*	0

Lake Pandruannie Common Name	Species	13/11/2011
Goldfish	*C. auratus*	2
Gambusia	*G. holbrooki*	15
Total		628

Additional fauna observations.

Date	Species Observed
13/11/2011	Shrimp (Infraorder Caridea)

Lake Pandruannie is a sprawling main channel lake with a distal outflow that meets the road to Lake Hope. It was at this intersection that sampling was undertaken. This shallow site contained a healthy population of red milfoil. Dissolved oxygen was high probably due to a combination of aquatic macrophytes and microalgae. Salinity was low and there was no stratification at this shallow (1m deep) site.

A total of six native and two exotic fish species were recorded. The fish community was dominated by small bodied carp gudgeons with other small bodied fishes (desert glassfish, rainbowfish and gambusia) also present. The strong aquatic microalgal component supported large populations of primarily small bony herring. This site also supported several large and healthy yellowbelly.

Both exotic fishes were present here, though neither displayed any level of dominance at the time of sampling.

Lake Pandruannie Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: Low number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Moderate-shallow Very Infrequent freshes and flushes
4	Water Quality	Low salinity pH neutral – alkaline Low turbidity
5	Aquatic Refuge	Terminal Moderate-low habitat value Low hydrological value Short term refuge value
6	Native Fish Diversity	6/12 native species recorded in ‘Lower Midstream’ reach No cryptic species present Moderate abundance of fish
7	Invasive Fish Species	2/2 invasive fish species identified

	Indicator	Description
8	Potential Threats	Impacts from cattle Invasive weeds

Lower Cooper

Gwydirs Crossing

Gwydir's Crossing waterhole in spring 2011.

Site Data:

GPS: 54 J 274056 6832509
Date(s) sampled: 9/12/2010, 8/04/2011, 8/11/2011, 5/05/2012
Site type: Leasehold (Pastoral)
Aquatic habitat type: Ephemeral waterhole (Main Channel)
Sample area dimensions: 250m long, 50m wide
Elevation: 12m
Average yearly rainfall: Approximately 160mm

Vegetation characteristics at Gwydirs Crossing.

Date	Flora Type	Cover	Dominant Species
9/12/2010	Submerged	20%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	0%	None Observed
	Riparian	3%	Coolabah (*Eucalyptus coolabah*)
8/04/2011	Submerged	1%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	1%	Sedge (*Juncus usitatus*)
	Riparian	7.5%	Coolabah (*Eucalyptus coolabah*)

Date	Flora Type	Cover	Dominant Species
8/11/2011	Submerged	85%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	5%	
	Riparian	27.5%	Coolabah (*Eucalyptus coolabah*)
5/05/2012	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	0%	None Observed
	Riparian	2.5%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Gwydirs Crossing.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
9/12/2010	<1	100	2	0%
8/04/2011	<1	100	3	0%
8/11/2011	<1	99	6	0%
5/05/2012	<1	100	0	0%

Hydrological characteristics at Gwydirs Crossing.

Date	Max Depth (m)	Connectivity	Flow
9/12/2010	2	Connected	Low
8/04/2011	1.3	Isolated	Still
8/11/2011	2.1	Connected	Low
5/05/2012	2	Isolated	Still

Water quality at Gwydirs Crossing.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (ppt)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
9/12/2010	8.70	8.26	25.60	0.33	10.15	39.48	200
8/04/2011	8.42	7.61	22.04	0.73	10.04	386.83	130
8/11/2011	17.41	14.42	27.56	0.42	10.86	0.5	200
5/05/2012	25.15	24.16	19.77	2.45	10.53	108.95	200

Total fish catch at Gwydirs Crossing.

Gwydirs Crossing **Common Name**	Species	9/12/2010	8/04/2011	8/11/2011	5/05/2012
Desert glassfish	*A. mulleri*	0	1	0	1
Welch's grunter	*B. welchi*	0	0	0	0
Lake Eyre hardyhead	*C. eyresii*	0	0	6	167
Carp gudgeon spp.	*Hypseleotris spp.*	0	0	2	5
Spangled perch	*L. unicolor*	7	2320	32	29
Yellowbelly	*M. ambigua*	20	0	2	0
Desert rainbowfish	*M. splendida tatei*	9	1071	92	4
Bony herring	*N. erebi*	253	1536	19	3
Cooper Creek catfish	*N. cooperensis*	0	0	0	0
Hyrtl's catfish	*N. hyrtlii*	0	0	0	0
Silver tandan	*P. argenteus*	0	0	0	0
Australian smelt	*R. semoni*	1	0	0	0
Barcoo grunter	*S. barcoo*	0	0	2	0
Goldfish	*C. auratus*	0	0	183	39
Gambusia	*G. holbrooki*	0	2	11	176
Total		290	4930	349	424

Additional fauna observations.

Date	Species Observed
9/12/2010	Shrimp (Infraorder Caridea), Yabby (*Cherax destructor*)
8/04/2011	Shrimp (Infraorder Caridea), Yabby (*Cherax destructor*)
8/11/2011	Shrimp (Infraorder Caridea)
5/05/2012	Shrimp (Infraorder Caridea), Yabby (*Cherax destructor*)

Gwydirs Crossing is a small waterhole at the end of a dune named for the memorial to stockman Bill Gwydir at the site. This site was one of the best sampled and variable sites in the study, displaying dramatically variable vegetation, bathymetry, fish community and water quality. Proportions of red milfoil varied between 1 and 85% of the submerged surface area. This variability extended to water quality. During spring 2011, when milfoil levels were at their peak (85%) dissolved oxygen was highly elevated (17mg/L) whilst turbidity was almost nonexistent (0.5NTU). By the following season this site had shifted to a microalgal dominated system with dissolved oxygen even higher (25mg/L) but clouding of the water due to the *in situ* microalgal communities (108.95NTU).

A total of nine native and two exotic fish species were identified over the course of the study. This was variable through time with six of the nine species present on two or fewer occasions. Both exotic species were present at the site.

Goldfish appeared to flourish under the macrophyte dominated period while gambusia flourished under the microalgal phase. On the final sampling event salinity was noted to climb favouring an increase in the hardyhead population.

Gwydirs Crossing Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: Low number of snags
2	Additional Fauna	2/6 species present **Only lower midstream/downstream site with yabbies recorded**
3	Hydrology	Depth: Moderate-shallow Rarely receives freshes or flushes
4	Water Quality	Low salinity (Greatly increased salinity in 2012 compared with upstream sites) pH – most alkaline site on average High DO in 2010 and autumn 2011 Low- very high turbidity
5	Aquatic Refuge	Not permanent Moderate-low habitat value Low hydrological value Very short term refuge value
6	Native Fish Diversity	9/11 native species recorded in 'Downstream Cooper' reach 1/1 cryptic species present Moderate abundance of fish
7	Invasive Fish Species	2/2 invasive fish species identified ***Furthest downstream record of goldfish***
8	Potential Threats	***Impacts from cattle*** Invasive weeds

Lake Kopperamanna

Lake Kopperamanna in spring 2010.

Site Data:

GPS: 54 J 272635 6836589
Date(s) sampled: 10/12/2010, 6/05/2012
Site type: Leasehold (Pastoral)
Aquatic habitat type: Ephemeral terminal lake (off channel)
Sample area dimensions: 250m long, 100m wide
Elevation: 10m
Average yearly rainfall: Approximately 160mm

Vegetation characteristics at Lake Kopperamanna.

Date	Flora Type	Cover	Dominant Species
10/12/2010	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	10%	Sedge (*Cyperus gymnocaulos*)
	Riparian	5%	Wattle (*Acacia sp.*)
6/05/2012	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	0%	None Observed

Riparian	30%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Lake Kopperamanna.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
10/12/2010	<1	100	43	0%
6/05/2012	<1	100	15	0%

Hydrological characteristics at Lake Kopperamanna.

Date	Max Depth (m)	Connectivity	Flow
10/12/2010	3	Connected	Still
6/05/2012	1.2	Isolated	Still

Water quality at Lake Kopperamanna.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
10/12/2010	8.78	8.41	24.98	0.27	9.08	107.46	300
6/05/2012	11.15	10.26	16.45	0.76	9.73	54.1	120

Total fish catch at Lake Kopperamanna.

Lake Kopperamanna			
Common Name	Species	10/12/2010	6/05/2012
Desert glassfish	*A. mulleri*	0	0
Welch's grunter	*B. welchi*	0	0
Lake Eyre hardyhead	*C. eyresii*	0	52
Carp gudgeon spp.	*Hypseleotris spp.*	0	71
Spangled perch	*L. unicolor*	8	0
Yellowbelly	*M. ambigua*	53	1
Desert rainbowfish	*M. splendida tatei*	7	1
Bony herring	*N. erebi*	80	621
Cooper Creek catfish	*N. cooperensis*	0	0
Hyrtl's catfish	*N. hyrtlii*	0	0
Silver tandan	*P. argenteus*	0	0
Australian smelt	*R. semoni*	2	0
Barcoo grunter	*S. barcoo*	1	0
Goldfish	*C. auratus*	0	0
Gambusia	*G. holbrooki*	0	249
Total		151	995

Additional fauna observations.

Date	Species Observed
9/12/2010	Not Recorded
6/05/2012	Shrimp (Infraorder Caridea)

This site was sampled at the commencement and completion of the study. During the initial sampling round flood waters were elevated and the fish community appeared to be a motile community dominated by strong migrants. A total of eight native and one exotic fish species were recorded. At the final round of sampling the community had shifted to slightly saline microalgal driven system dominated by bony herring and hardyhead.

Lake Kopperamanna Ecosystem Value & Threats.

	Indicator	**Description**
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: High-low number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Deep Rarely receives freshes or flushes
4	Water Quality	Low salinity Neutral pH Moderate-low turbidity
5	Aquatic Refuge	Terminal Lake High habitat value Low hydrological value Short term refuge value
6	Native Fish Diversity	8/11 native species recorded in 'Downstream Cooper' reach 1/1 cryptic species present Moderate abundance of fish
7	Invasive Fish Species	1/2 invasive fish species identified
8	Potential Threats	Impacts from cattle Invasive weeds

Lower Cooper

Lake Killalpaninna

Lake Killalpaninna viewed from mission site in autumn 2011.

Site Data:

GPS: 54 J 260382 6836650
Date(s) sampled: 12/12/2010, 9/04/2011, 9/11/2011, 2/05/2012
Site type: Leasehold (Pastoral)/Tourist (Mission Ruins)
Aquatic habitat type: Ephemeral terminal lake (Off Channel)
Sample area dimensions: 250m long, 200m wide
Elevation: 6m
Average yearly rainfall: Approximately 160mm

Vegetation characteristics at Lake Killalpaninna.

Date	Flora Type	Cover	Dominant Species
12/12/2010	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent		Sedge (*Cyperus sp.*)
	Riparian	18%	Wattle (*Acacia sp.*)
9/04/2011	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent		Sedge (*Cyperus sp.*)
	Riparian	18%	Wattle (*Acacia sp.*)

Date	Flora Type	Cover	Dominant Species
9/11/2011	Submerged		Watermilfoil (*Myriophyllum sp.*)
	Emergent		Sedge (*Cyperus sp.*)
	Riparian		Wattle (*Acacia sp.*)
2/05/2012	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent		Sedge (*Cyperus sp.*)
	Riparian	18%	Wattle (*Acacia sp.*)

Aquatic habitat characteristics at Lake Killalpaninna.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
12/12/2010	<1	100	40	0%
9/04/2011	<1	100	40	0%
9/11/2011	<1	100	40	0%
2/05/2012	<1	100	40	0%

Hydrological characteristics at Lake Killalpaninna.

Date	Max Depth (m)	Connectivity	Flow
12/12/2010	4.1	Isolated	Still
9/04/2011	3.9	Isolated	Still
9/11/2011	4	Connected	Low
2/05/2012	3.5	Isolated	Still

Water quality at Lake Killalpaninna.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
12/12/2010	10.34	6.33	25.97	1.424	9.39	26.40	410
9/04/2011	10.71	7.87	21.82	2.033	9.43	20.63	390
9/11/2011	9.41	8.33	25.5	2.609	9.72	3.63	400
2/05/2012	13.47	8.74	19.79	3.2	9.31	21.88	350

Total fish catch at Lake Killalpaninna.

Lake Killalpaninna					
Common Name	Species	12/12/2010	9/04/2011	9/11/2011	2/05/2012
Desert glassfish	*A. mulleri*	0	0	0	1
Welch's grunter	*B. welchi*	10	1	0	1
Lake Eyre hardyhead	*C. eyresii*	0	2	19	1070
Carp gudgeon spp.	*Hypseleotris spp.*	0	4	91	1086
Spangled perch	*L. unicolor*	6	4	5	0
Yellowbelly	*M. ambigua*	38	19	3	9
Desert rainbowfish	*M. splendida tatei*	178	92	147	16
Bony herring	*N. erebi*	35	242	126	1089
Cooper Creek catfish	*N. cooperensis*	0	0	0	0
Hyrtl's catfish	*N. hyrtlii*	0	0	1	0
Silver tandan	*P. argenteus*	0	0	0	0
Australian smelt	*R. semoni*	0	0	0	0
Barcoo grunter	*S. barcoo*	2	0	0	0
Goldfish	*C. auratus*	0	0	0	0
Gambusia	*G. holbrooki*	0	4	0	211
Total		269	368	392	3483

Additional fauna observations.

Date	Species Observed
12/12/2010	Not Recorded
9/04/2011	Shrimp (Infraorder Caridea)
9/11/2011	Shrimp (Infraorder Caridea)
2/05/2012	Shrimp (Infraorder Caridea)

Lake Killalpaninna is a site of historical, ecological and tourism importance.

Positioned on the lake's eastern bank are the ruins of a Lutheran mission closed since 1915. This site is frequented by tourist groups travelling the Birdsville Track.

Microhabitat complexity has been reasonable and has included submerged terrestrial vegetation and snags. Water quality has remained high at this site throughout sampling with good surface dissolved oxygen, reasonable microalgal communities and no significant stratification.

A total of nine native and one exotic fish species were recorded, though most were in low numbers and several were caught infrequently. Overall the fish community has been dominated by rainbowfish and algivorous bony herring. Over time the numbers of carp gudgeon, hardyhead, bony herring and gambusia have been steadily increasing while numbers of rainbowfish and yellowbelly have been decreasing.

Salinity has been gradually increasing through the study which may be favouring the halophilic hardyhead.

Lake Killalpaninna Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: Moderate number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Deep Rarely receives freshes or flushes
4	Water Quality	Average salinity increasing overtime pH neutral Average DO Low turbidity
5	Aquatic Refuge	Not permanent High habitat value Low hydrological value Short term refuge value
6	Native Fish Diversity	9/11 native species recorded in 'Downstream Cooper' reach 1/1 cryptic species present Moderate- high abundance of fish
7	Invasive Fish Species	1/2 invasive fish species identified
8	Potential Threats	Impacts from tourists Recreational fishing Impacts from cattle Invasive weeds

Tilla Tilla Waterhole

Aerial photo of Tilla Tilla crossing in spring 2011.

Site Data:

GPS: 54 J 228649 6836010
Date(s) sampled: 6/12/2010
Site type: Leasehold (Pastoral)
Aquatic habitat type: Ephemeral waterhole (Main Channel)
Sample area dimensions: 250m long, 30m wide
Elevation: 4m
Average yearly rainfall: Approximately 160mm (Nearest gauge is Etadunna)

Vegetation characteristics at Tilla Tilla Waterhole.

Date	Flora Type	Cover	Dominant Species
6/12/2010	Submerged		Not Recorded
	Emergent		Not Recorded
	Riparian		Not Recorded

Aquatic habitat characteristics at Tilla Tilla Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
6/12/2010	<1	100	23	10%

Hydrological characteristics at Tilla Tilla Waterhole.

Date	Max Depth (m)	Connectivity	Flow
6/12/2010	1.4	Connected	Low

Table 2 Water quality at Tilla Tilla Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
6/12/2010	7.75	7.48	26.07	0.78	9.65	73.73	140

Total fish catch at Tilla Tilla Waterhole.

Tilla Tilla Waterhole		
Common Name	Species	6/12/2010
Desert glassfish	*A. mulleri*	0
Welch's grunter	*B. welchi*	3
Lake Eyre hardyhead	*C. eyresii*	0
Carp gudgeon spp.	*Hypseleotris spp.*	0
Spangled perch	*L. unicolor*	14
Yellowbelly	*M. ambigua*	87
Desert rainbowfish	*M. splendida tatei*	1
Bony herring	*N. erebi*	1185
Cooper Creek catfish	*N. cooperensis*	0
Hyrtl's catfish	*N. hyrtlii*	0
Silver tandan	*P. argenteus*	0
Australian smelt	*R. semoni*	0
Barcoo grunter	*S. barcoo*	5

Tilla Tilla Waterhole		
Common Name	Species	6/12/2010
Goldfish	*C. auratus*	0
Gambusia	*G. holbrooki*	0
Total		1295

Additional fauna observations.

Date	Species Observed
6/12/2010	Not Recorded

The Tilla Tilla Waterhole site was situated where the station track crosses the channel upstream from Tilla Tilla Waterhole proper. At the time of sampling this channel had only recently started to flow and probably represents a mobile community of migrant fishes. A total of six native fish species were recorded. The species observed were primarily bony bream, Yellowbelly and spangled perch. This site did not persist in subsequent years.

Tilla Tilla Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: Not Recorded Snags: Moderate number of snags
2	Additional Fauna	Not Recorded
3	Hydrology	Depth: Shallow Very rarely receives freshes or flushes
4	Water Quality	Low salinity pH neutral Average DO Low turbidity
5	Aquatic Refuge	Not permanent Moderate habitat value Low hydrological value Very short term refuge value
6	Native Fish Diversity	6/11 native species recorded in 'Downstream Cooper' reach No cryptic species present High abundance of fish
7	Invasive Fish Species	No invasive fish species identified
8	Potential Threats	Impacts from cattle Invasive weeds

Lower Cooper

Cuttupirra Waterhole

Aerial photo of Cuttupirra Waterhole looking upstream in spring 2011.

Site Data:

GPS: 54 J 214410 6838367
Date(s) sampled: 8/12/2010, 13/04/2011, 10/11/2011, 3/05/2012
Site type: Leasehold (Pastoral)
Aquatic habitat type: Ephemeral waterhole (Main channel)
Sample area dimensions: 250m long, 50m wide
Elevation: 0m
Average yearly rainfall: Approximately 160mm (Nearest gauge : Etadunna)

Vegetation characteristics at Cuttupirra Waterhole.

Date	Flora Type	Cover	Dominant Species
8/12/2010	Submerged		Not Recorded
	Emergent	10%	Sedge (*Cyperus sp.*)
	Riparian	6%	Wattle (*Acacia sp.*)
13/04/2011	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	30%	Sedge (*Cyperus sp.*)
	Riparian	8%	Wattle (*Acacia sp.*)

Date	Flora Type	Cover	Dominant Species
10/11/2011	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	10%	Sedge (*Cyperus sp.*)
	Riparian	3%	*Eucalyptus sp.*
3/05/2012	Submerged		Watermilfoil (*Myriophyllum sp.*)
	Emergent	80%	Sedge (*Cyperus sp.*)
	Riparian	5%	Wattle (*Acacia sp.*)

Aquatic habitat characteristics at Cuttupirra Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
8/12/2010	<1	100	1	0%
13/04/2011	<1	95	1	0%
10/11/2011	<1	100	1	0%
3/05/2012	<1	90	0	0%

Hydrological characteristics at Cuttupirra Waterhole.

Date	Max Depth (m)	Connectivity	Flow
8/12/2010	1.9	Connected	Low
13/04/2011	1.9	Connected	Low
10/11/2011	2	Connected	Low
3/05/2012	1.5	Isolated	Still

Water quality at Cuttupirra Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
8/12/2010	9.07	8.91	28.15	0.792	9.57	62.84	190
13/04/2011	12.43	9.33	19.21	0606	9.89	35.35	190
10/11/2011	10.13	9.93	24.58	0.959	9.84	20.57	200
3/05/2012	12.64	11.1	19.49	7.258	9.73	37.73	150

Total fish catch at Cuttupirra Waterhole.

Cuttupirra Waterhole					
Common Name	Species	8/12/2010	13/04/2011	10/11/2011	3/05/2012
Desert glassfish	*A. mulleri*	0	0	0	0
Welch's grunter	*B. welchi*	0	0	0	0
Lake Eyre hardyhead	*C. eyresii*	8	4468	189	2875
Carp gudgeon spp.	*Hypseleotris spp.*	0	0	14	750
Spangled perch	*L. unicolor*	3	2	3	1
Yellowbelly	*M. ambigua*	4	36	1	0
Desert rainbowfish	*M. splendida tatei*	1	17	20	5
Bony herring	*N. erebi*	514	42	361	930
Cooper Creek catfish	*N. cooperensis*	0	0	0	0
Hyrtl's catfish	*N. hyrtlii*	0	0	0	0
Silver tandan	*P. argenteus*	0	0	0	0
Australian smelt	*R. semoni*	0	2	0	0
Barcoo grunter	*S. barcoo*	3	0	1	0
Goldfish	*C. auratus*	0	0	0	0
Gambusia	*G. holbrooki*	0	1	6	313
Total		533	4568	595	4874

Additional fauna observations.

Date	Species Observed
8/12/2010	Not Recorded
13/04/2011	Not Recorded
10/11/2011	Not Recorded
3/05/2012	Shrimp (Infraorder Caridea)

Cuttupirra Waterhole is the lowest site examined on the Cooper Creek. It lies 30km upstream of Lake Eyre and is a main channel waterhole. This site is also an important fossil deposit.

Due to repeated large flow events in the Cooper, this site was flowing on every visit except autumn 2012. It is anticipated that this site will degrade quickly having reached a salinity of 4.52ppt less than 6 months after the cessation of flow.

A total of eight native and one exotic fish species were recorded. This site has been predominantly hardyhead and bony herring with gambusia and carp gudgeon numbers increasing over time.

Cuttupirra Waterhole Ecosystem Value & Threats.

	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: Very low number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Moderate-Shallow Very rarely receives freshes or flushes ***Closest cooper sample site to Lake Eyre***
4	Water Quality	2012 was the highest recorded salinity at any site excluding Strezlecki Creek pH neutral Average DO Low turbidity
5	Aquatic Refuge	Not permanent low habitat value Low hydrological value Very short term refuge value
6	Native Fish Diversity	8/11 native species recorded in 'Downstream Cooper' reach 1/1 cryptic species present Moderate- high abundance of fish
7	Invasive Fish Species	1/2 invasive fish species identified
8	Potential Threats	Impacts from cattle Invasive weeds

Strzelecki Creek

Yaningurie Waterhole

Yaningurie waterhole in autumn 2012.

Site Data:

GPS: 54 J 414063 6795579
Date(s) sampled: 18/12/2010, 1/04/2011 and 8/05/2012
Site type: Leasehold (Pastoral)/Gas/Tourist
Aquatic habitat type: Ephemeral waterhole (Distributary channel)
Sample area dimensions: 250m long, 50m wide
Elevation: 17m
Average yearly rainfall: Approximately 160mm

Vegetation characteristics at Yaningurie Waterhole.

Date	Flora Type	Cover	Dominant Species
18/12/2010	Submerged	0%	None Observed
	Emergent	10%	Sedge (*Cyperus sp.*)
	Riparian	3%	Coolabah (*Eucalyptus coolabah*)
1/04/2011	Submerged	5%	Watermilfoil (*Myriophyllum sp.*)
	Emergent	0%	None Observed
	Riparian	3%	Coolabah (*Eucalyptus coolabah*)

Date	Flora Type	Cover	Dominant Species
8/05/2012	Submerged	0%	None Observed
	Emergent	60%	Sedge (*Cyperus sp.*)
	Riparian	3%	Coolabah (*Eucalyptus coolabah*)

Aquatic habitat characteristics at Yaningurie Waterhole.

Date	Dom. Substrate Size (mm)	Dom. Substrate Cover	Total Snags Observed	Litter Cover
18/12/2010	<1	100	11	0%
1/04/2011	<1	100	13	0%
8/05/2012	<1	100	3	0%

Hydrological characteristics at Yaningurie Waterhole.

Date	Max Depth (m)	Connectivity	Flow
18/12/2010	2.6	Isolated	Still
1/04/2011	2.62	Isolated	Still
8/05/2012	1	Isolated	Still

Water quality at Yaningurie Waterhole.

Date	DO MAX (mg/L)	DO MIN (mg/L)	AVERAGE TEMP (°C)	AVERAGE SALINITY (mS/cm)	AVERAGE pH	AVERAGE TURBIDITY (NTU)	MAX DEPTH (cm)
18/12/2010	4.93	4.51	24.59	0.65	9.16	9.00	190
1/04/2011	6.58	5.81	22.71	0.62	9.29	22.14	260
8/05/2012	11.65	8.56	15.31	8.36	9.25	60.6	100

Total fish catch at Yaningurie Waterhole.

Yaningurie Waterhole				
Common Name	Species	18/12/2010	1/04/2011	8/05/2012
Desert glassfish	*A. mulleri*	2	1	0
Welch's grunter	*B. welchi*	2	0	0
Lake Eyre hardyhead	*C. eyresii*	0	0	0
Carp gudgeon spp.	*Hypseleotris spp.*	0	0	0
Spangled perch	*L. unicolor*	2781	143	0
Yellowbelly	*M. ambigua*	0	0	0
Desert rainbowfish	*M. splendida tatei*	30	4	2
Bony herring	*N. erebi*	1	121	0
Cooper Creek catfish	*N. cooperensis*	0	0	0
Hyrtl's catfish	*N. hyrtlii*	0	2	0
Silver tandan	*P. argenteus*	0	0	0
Australian smelt	*R. semoni*	0	0	0
Barcoo grunter	*S. barcoo*	0	0	0
Goldfish	*C. auratus*	0	0	0
Gambusia	*G. holbrooki*	0	0	321
Total		2816	271	323

Additional fauna observations.

Date	Species Observed
18/12/2010	Shrimp (Infraorder Caridea)
1/04/2011	Shrimp (Infraorder Caridea)
8/05/2012	None Observed

Yaningurie Waterhole is a small ephemeral waterhole on the Strzelecki Creek. This site constitutes an interesting counterpoint to many of the permanent and near permanent refugia examined elsewhere in the Cooper. Over the period of sampling a total of six native and one exotic fish species were recorded. This site had only recently been inundated when first visited in spring 2010. At this point its community was an early successional fish community dominated by the strong migrant spangled perch. In autumn 2011, deteriorating water quality (triggered by a decrease in water level) caused increases in microalgae and favoured bony bream. This pattern is overlaid with the spangled perch population crashing either due to a lack of prey species or poor tolerance of the reduction in water quality. By the final round of sampling the waterhole was in a state of algal bloom. The only fishes present at this time were two large adult rainbowfish and a large population of gambusia. The dominant taxa in the waterhole at this time were aquatic beetles. Under bloom conditions dissolved aquatic oxygen plummets overnight however water beetles and gambusia persist at the site due to their capacity for alternate respiration strategies (gambusia display aerial surface respiration and beetles fill their elytra with surface air).

Major earthworks were needed at the nearby Strzelecki Crossing to allow access for mining vehicles.

Yaningurie Waterhole Ecosystem Value & Threats.

#	Indicator	Description
1	Aquatic Habitat	Aquatic Veg: 2 species observed Snags: Very low number of snags
2	Additional Fauna	1/6 species present Only shrimp present
3	Hydrology	Depth: Moderate-Shallow Very rarely receives freshes or flushes
4	Water Quality	2012 was the highest recorded salinity at any site pH neutral Low turbidity ***Blue Green Algae Bloom***
5	Aquatic Refuge	Not permanent Low habitat value Low hydrological value Very short term refuge value
6	Native Fish Diversity	6 native species recorded in 'Strzelecki' reach 0 cryptic species present High-moderate abundance of fish
7	Invasive Fish Species	1/2 invasive fish species identified Two rainbowfish and gambusia were the only surviving fish species in 2012
8	Potential Threats	Transport infrastructure Impacts from cattle Invasive weeds