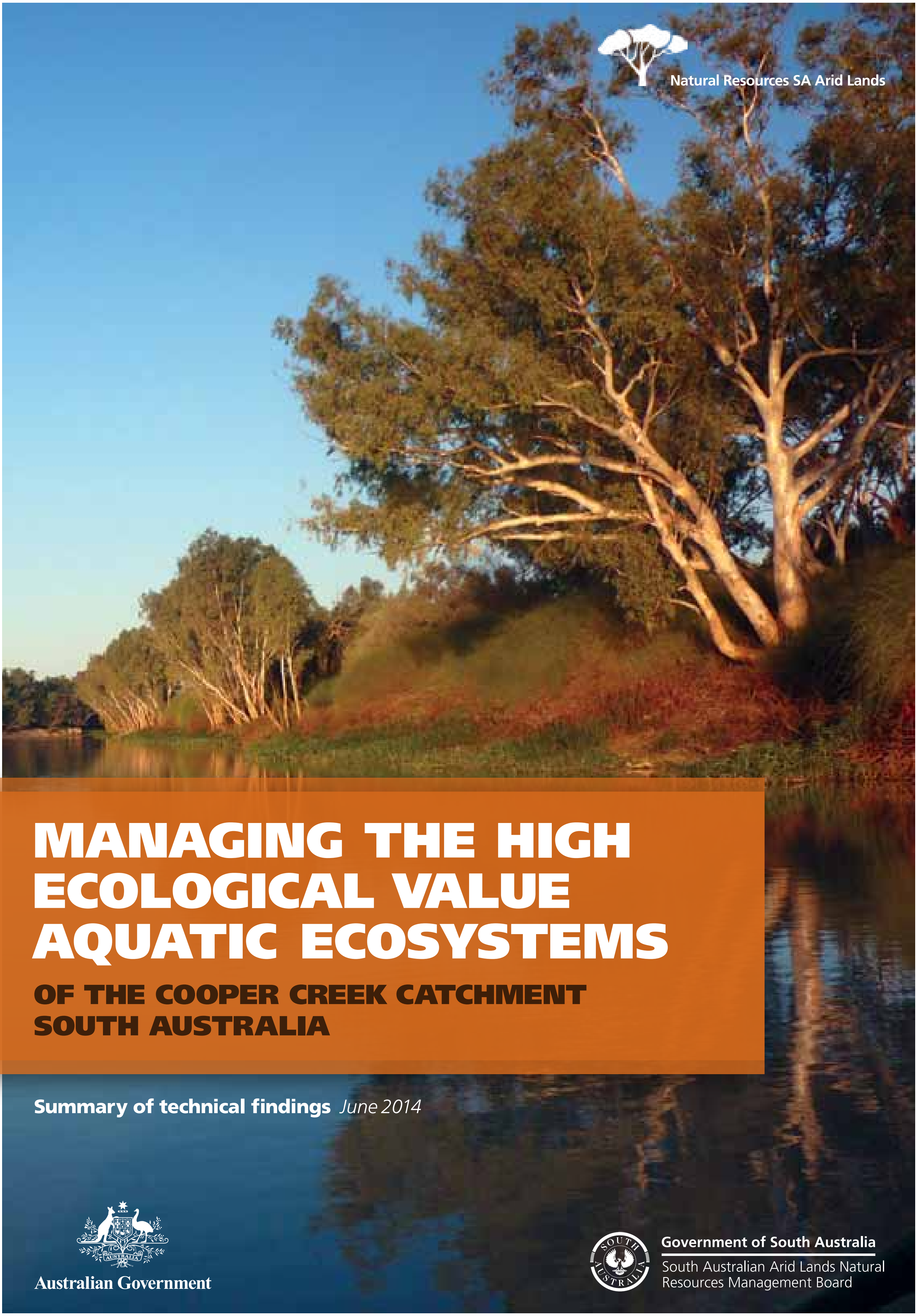

Natural Resources SA Arid Lands

MANAGING THE HIGH ECOLOGICAL VALUE AQUATIC ECOSYSTEMS

OF THE COOPER CREEK CATCHMENT SOUTH AUSTRALIA

Summary of technical findings *June 2014*

Australian Government

Government of South Australia
South Australian Arid Lands Natural Resources Management Board

Report to the South Australian Arid Lands Natural Resources Management Board, June 2014

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Cover photograph: Henry Mancini,
Cooper Creek channel, South Australia

All photos in this document were sourced from: the Technical Reports, Natural Resources SA Arid Lands, and others as specifically stated.

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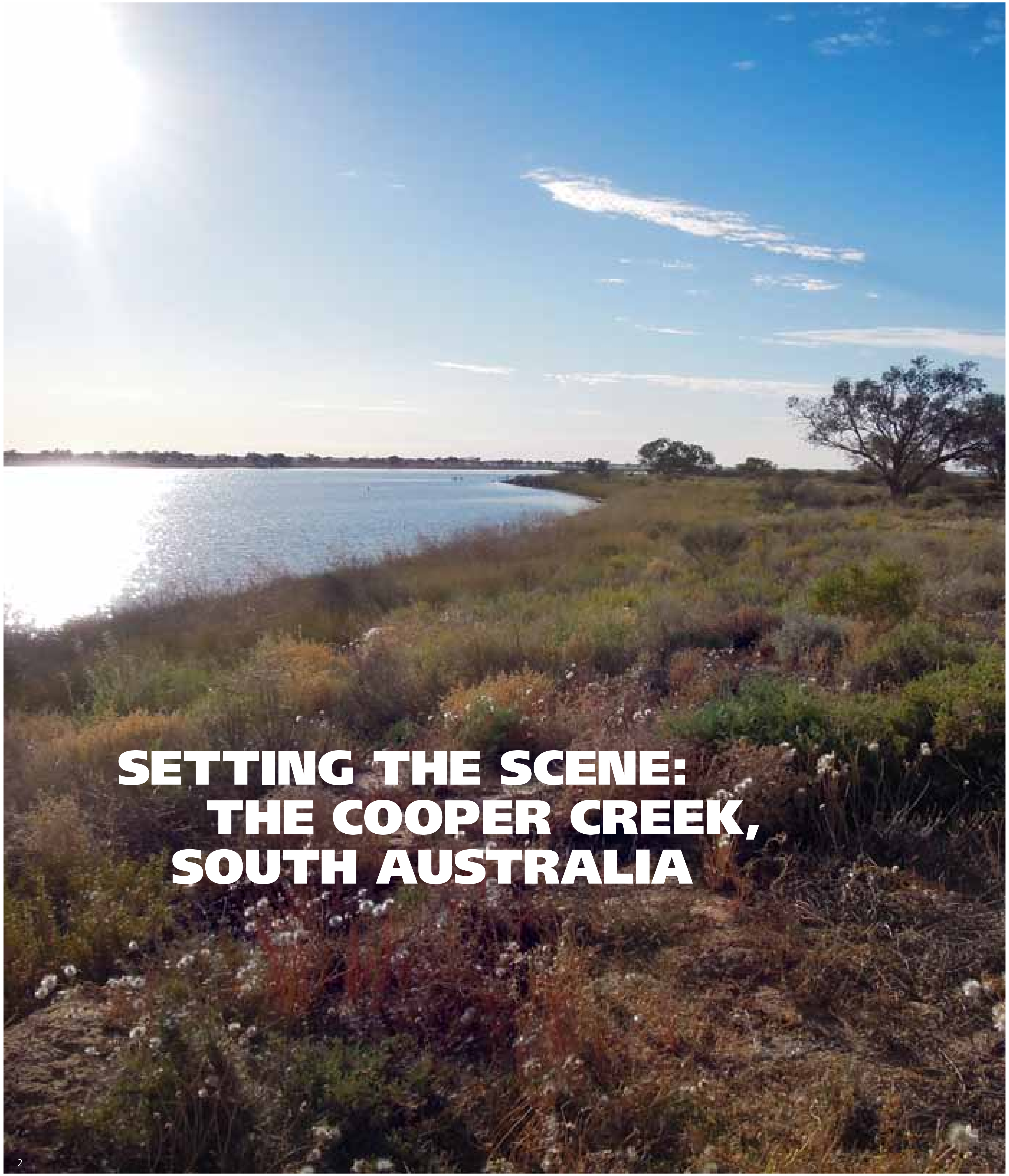


SETTING THE SCENE: THE COOPER CREEK, SOUTH AUSTRALIA

A Snapshot

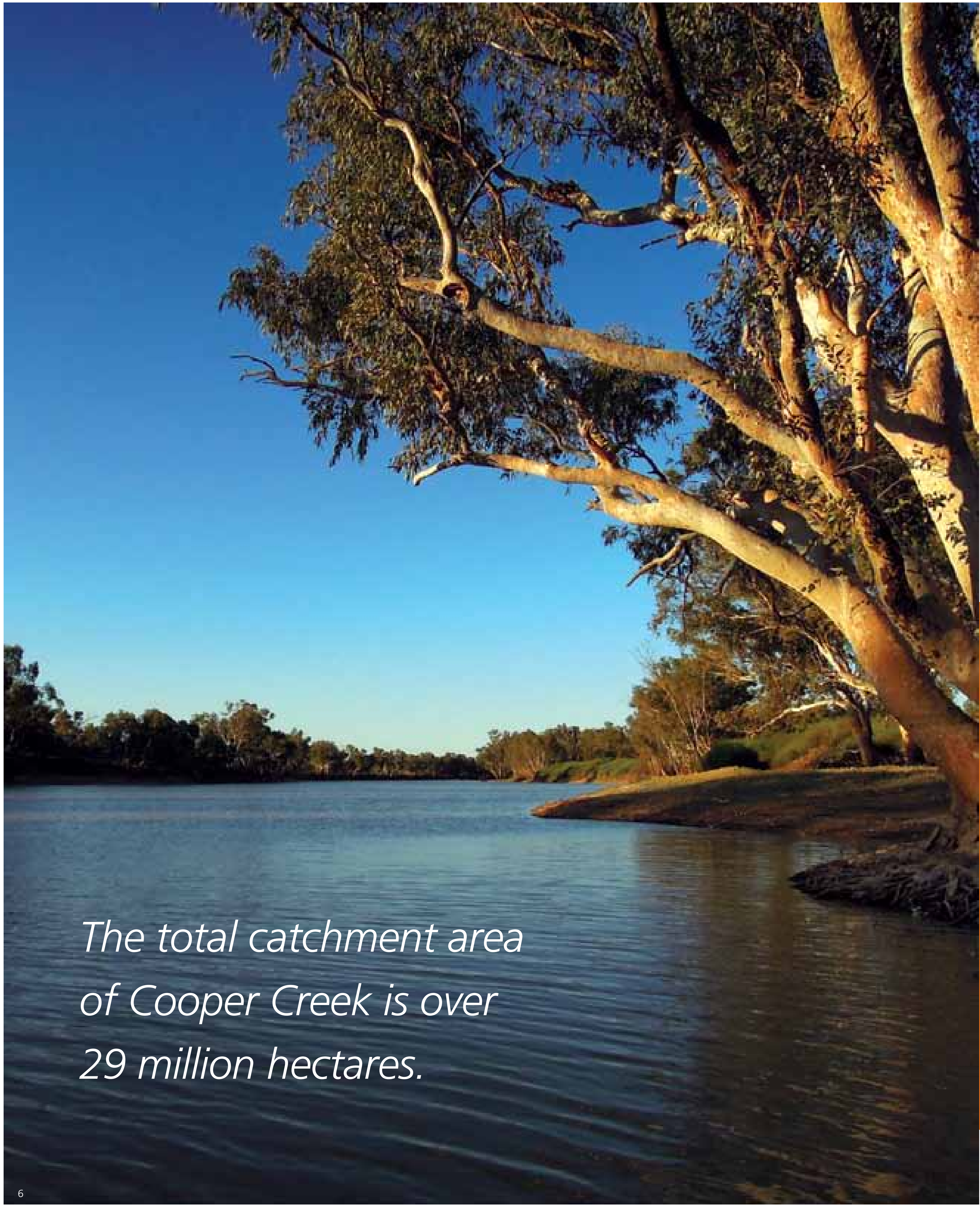
THE COOPER CREEK *is an icon of inland Australia. Its irregular "boom and bust" cycles of bounteous floods and difficult droughts have become embedded in the national psyche as something typically Australian.*

The Cooper Creek's significance extends well beyond national boundaries. With its unregulated flow regime and minimal levels of water extraction, Cooper Creek is an internationally recognised reference example of a low gradient, intermittent, dry-land river system. The South Australian reaches of the Cooper Creek include the internationally recognised Ramsar-listed Coongie Lakes wetlands. These wetlands are the focus of large waterbird congregations and provide important habitat for other fauna, such as fish, turtles and macro-invertebrates.

Historically, Cooper Creek was of enormous importance to Indigenous Australians. It also featured prominently in early European exploration in the mid-1800s. Named by Charles Sturt in 1845 after Charles Cooper, South Australia's then Chief Justice, the Cooper Creek featured in the demise of explorers, Burke and Wills, in 1861.

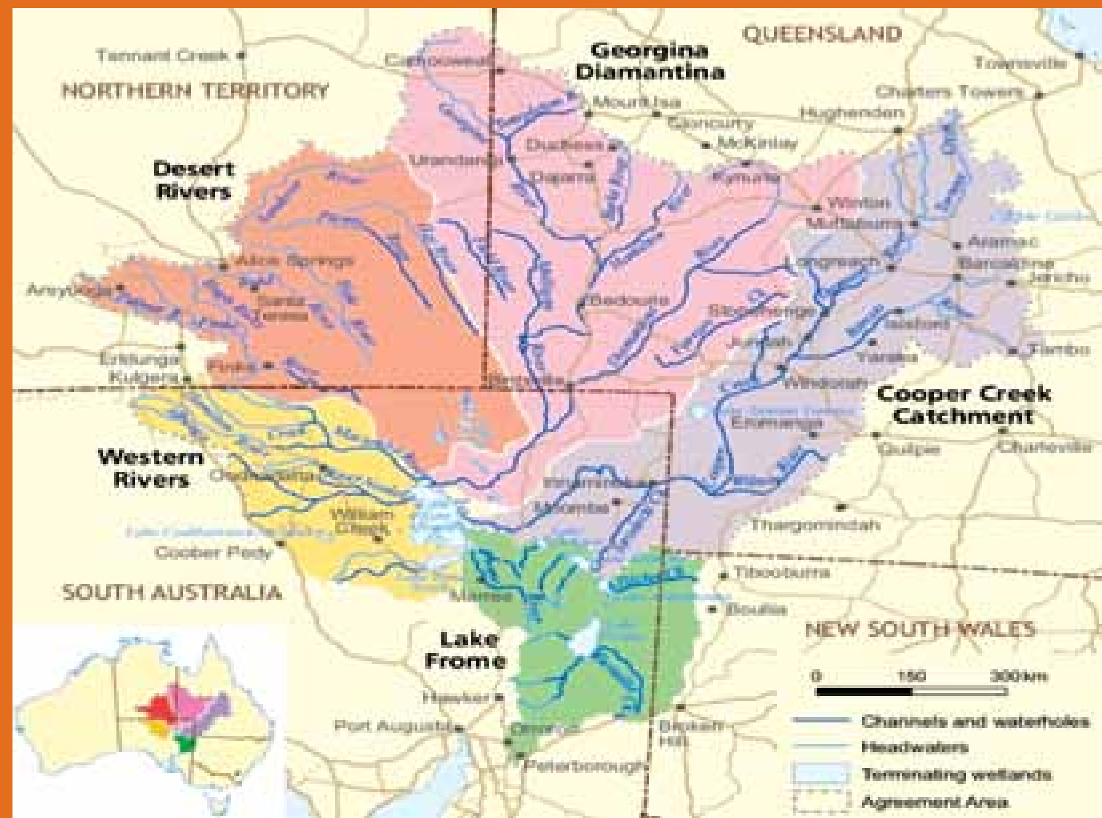
Europeans have operated pastoral enterprises on the floodplains since the 1860s, fattening cattle on lush natural pasture after floods, and using the numerous waterholes, bore water and upland grassland during dry times. More recently, oil and gas exploration and extraction associated with the Cooper Basin petroleum and natural gas deposits have become established in the area. Tourism activity has expanded since about the 1970s.

Environmental conservation measures have been formally undertaken in the Cooper Creek Catchment over the past 40-45 years.



The Cooper Creek is a significant feature of the Lake Eyre Basin in the centre of the Australian continent (Fig.1). In the South Australian section of the Cooper Creek Catchment annual rainfall is very low and highly variable in timing, duration and intensity. The area receives median annual rainfall of 100-150 mm and mean annual pan evaporation of 3,500 mm. Cooper Creek receives water via the Thomson River from monsoonal rainfall to the north and via the Barcoo River from monsoonal and easterly rain systems in Queensland. There is enormous year-to-year variability in the size of floods in Cooper Creek. Floods large enough to reach Kati Thanda-Lake Eyre occur on average every ten years. In most years flows terminate in the Coongie Lakes system and Embarka Swamp (Main Branch).

Figure 1.
Lake Eyre Basin, showing Cooper Creek Catchment (Map source: State of the Basin 2008: Rivers Assessment (DEWHA))



The Cooper Creek Catchment in South Australia lies within two IBRA (Interim Biogeographic Regionalisation for Australia) bioregions: the Channel Country and the Simpson-Strzelecki Dunefields. The wetlands of the Cooper experience 'boom and bust' cycles; frequent and often protracted dry periods are punctuated by infrequent and relatively short periods of inundation during which biological production is spectacular. During large floods wetlands fill along the length of the system, through vast swamp and channel networks that provide vital habitat for aquatic flora and fauna. In dry times, the waterholes become discontinuous and hydrologically isolated from one another.

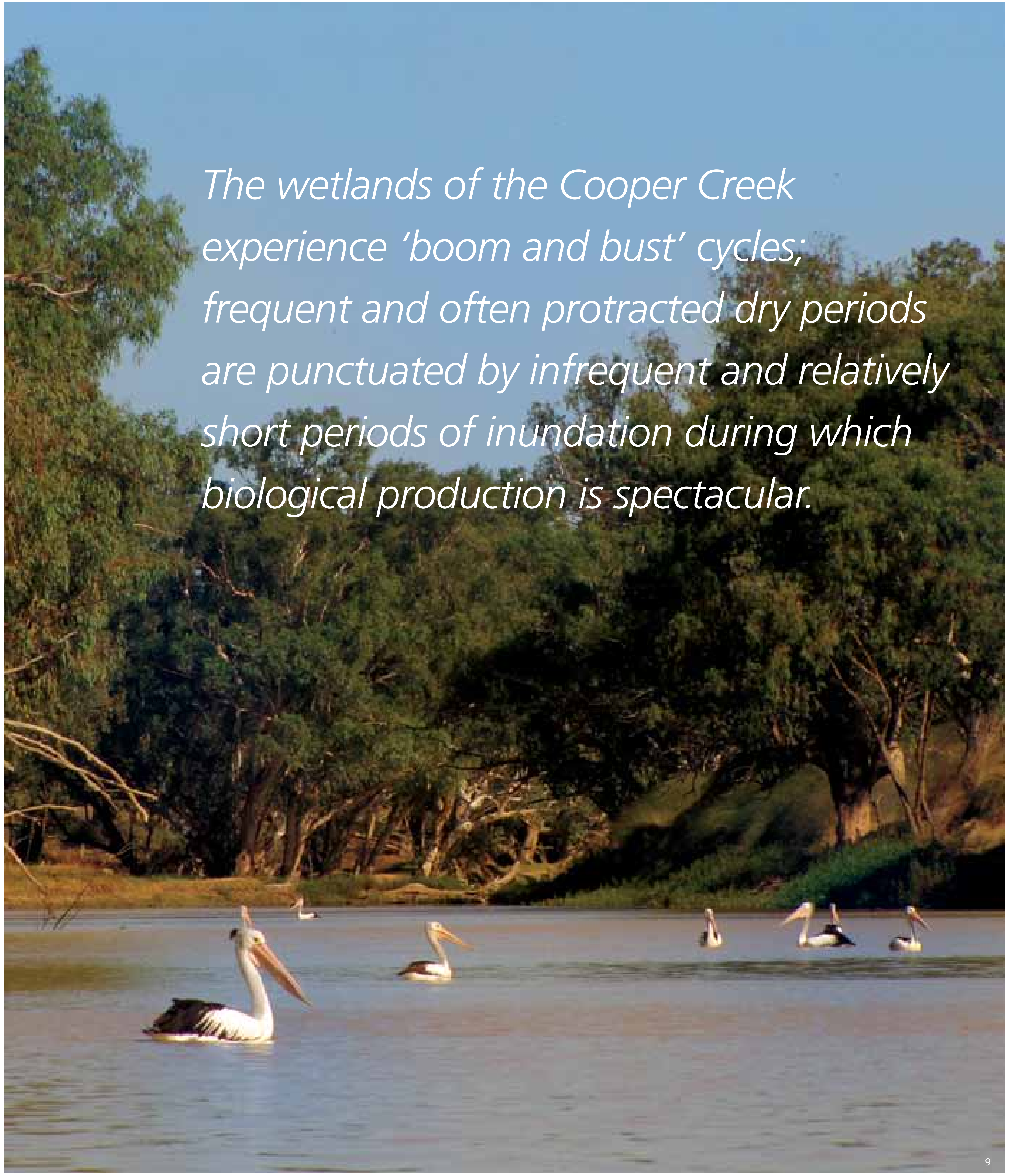
BIRD LIFE

For waterbirds, the Cooper Creek floodplains are of global importance:

- ➔ Over 80 species have been recorded including more than a dozen migratory (Asian-breeding) species,
- ➔ Systematic surveys have documented huge numbers of waterbirds: conservatively 3-4 million during some flood events,
- ➔ Around 50 species have been found nesting of which 20 species breed in colonies in the floodplain wetlands

Approximately 70 species of land-bird have been recorded in riparian vegetation.

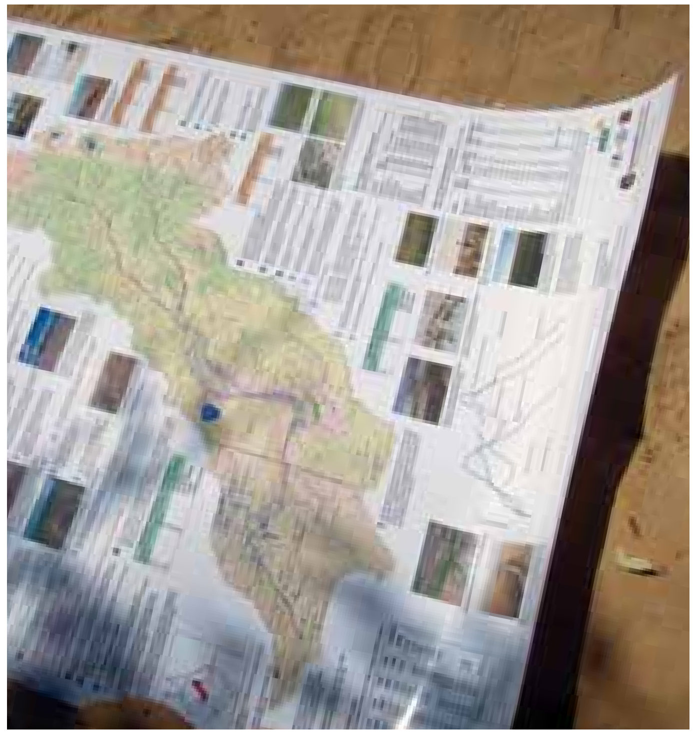
Additional information for this section was sourced from Jeansch, R., 2009, Floodplain Wetlands of the Channel Country. South Australian Arid Lands Natural Resources Management Board.



This Cooper Creek Project adopted a broad, holistic approach and integrated expert knowledge from a range of scientific disciplines.

The Project

THIS 2010-13 *Australian Government funded project titled 'Managing the high ecological value aquatic ecosystems of the Cooper Creek Catchment (SA Section)' is referred to as 'The Cooper Creek Project'.*



This Cooper Creek Project adopted a broad, holistic approach and integrated expert knowledge from a range of scientific disciplines. Inter-connected investigations were undertaken in the 2010-13 time frame, comprising:

- geomorphological assessment and analysis
- hydrological monitoring and analysis
- vegetation and soil assessments
- aquatic ecology (fish monitoring)
- riparian bird assemblage monitoring
- cultural landscape assessments
- riparian condition assessments

The project focuses on priorities for future management – action needed to protect the features of the Cooper Creek system in South Australia. Well informed management improves the longevity of the Cooper Creek ecosystems and services they provide, benefiting the pastoral, mining and tourism industries, sites of cultural value, and the broader community.

The Cooper Creek Project contributes to the outcomes sought in the Regional Natural Resources Management Plan 2010 prepared by the South Australian Arid Lands Natural Resources Management Board. It also links with a range of other previous and current projects, initiatives and programs operating in the region.

Main Findings

***THE MULTI-DISCIPLINARY APPROACH** emphasises interconnections (Fig. 2). It shows the links between landforms, hydrology and ecosystem functionality, and illustrates relationships between natural systems and human activity.*

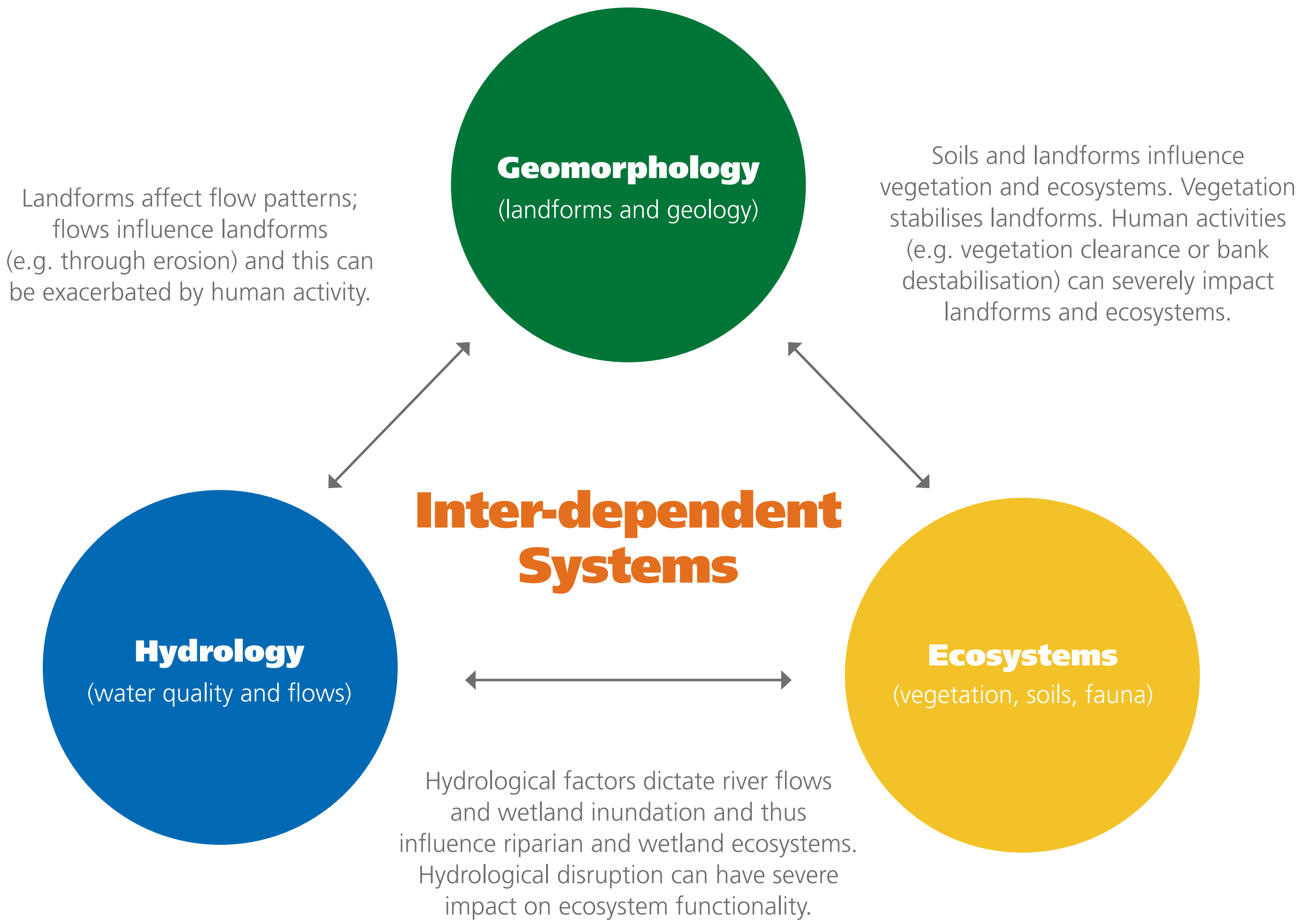


Figure 2. *Representation of interdependency between systems of the Cooper Creek*

Several common themes have emerged – issues that are vital to the health of the Cooper Creek system, and which must have priority in management decisions:

The river must run free

Maintenance of unregulated flow regimes is vital for the ecology of the system, the survival of many species and the environmental, social and economic benefits that stem from that (e.g. pastoralism, tourism, commercial and recreational fishing).

- ➜ Dams, diversions, water extraction and infrastructure such as roads, bridges, buildings and other structures all have potential to impact severely on the system, affecting natural ecosystems and also economic and cultural values.

All waterholes are important; deep, permanent waterholes are vital

The waterholes of the Cooper Creek system provide vital habitat for a range of fish and other native species. Permanent waterholes such as Cullyamurra Waterhole, near Innamincka township, are particularly important as refuges for fauna in times of drought, providing the only habitat to sustain aquatic species through extended dry periods.

- ➜ Maintaining healthy waterholes is highly dependent upon natural flows – which periodically flush the system and promote recolonisation from permanent waterholes to other wetlands.
- ➜ Any significant water extraction from waterholes should be avoided.
- ➜ More localised actions can also have significant impact and require sensitive management. Vehicle and walking tracks can cause erosion, leading to siltation of waterholes, as can vegetation removal (e.g. by grazing animals or firewood collection).

Riparian vegetation is particularly important

Riparian vegetation is a key component of the Cooper, particularly perennial, long-lived structural canopy species such as coolibah *(Eucalyptus coolabah)* and river red gum (*Eucalyptus camaldulensis*). The episodic establishment of these species after the recession of large floods is critical.

- ➜ Riparian vegetation is the key to bank stability and to conservation of many plant and animal communities. Riparian vegetation is highly vulnerable to any shift away from natural flow patterns. In addition, localised human impacts and overgrazing can negatively affect riparian soils and vegetation.

Pest plants and animals require active management

Feral animals such as rabbits and pigs destroy native vegetation and disturb the soil. They disrupt ecosystems, prevent natural regeneration, create erosion and siltation, and impact upon stock grazing systems. They represent a major threat to local landforms and landscapes and require active management. Invasive plants, such as buffel grass *(Cenchrus ciliaris)*, can out-compete native plants and modify native plant populations.

- ➜ Public and private landholders invest in weed and pest animal control on an ongoing basis. Additional support is needed however, to ensure detection and rapid response to new pest invasions. Assistance is also required to implement a strategic, coordinated, approach that ensures effective management of well-established pest populations.
- ➜ Currently, the main aquatic pests are the exotic fish species - Gambusia and goldfish. It appears native fish are surviving despite competition from these introduced species and this is partly attributed to the natural flow regimes that presently prevail. Careful monitoring of this situation is essential.
- ➜ Cane toads have not yet been recorded in the Cooper Creek system in South Australia. Geomorphological assessment shows that the Cooper system is, contrary to some predictions, vulnerable to incursion by cane toads; strategies and contingency plans must be established.

Care needed not to bite the hand that feeds

There is potential for inappropriate actions in the pastoral and tourism sectors and for the construction of poorly designed mining infrastructure to have negative economic, as well as environmental, outcomes.

- ➜ Stock grazing has generally been managed conservatively, and this must continue to avoid impacts such as vegetation damage, erosion and contamination of waterholes.
- ➜ Tourism impacts have, likewise, been pro-actively managed in many instances but can be difficult to influence. Tracks and firewood collection can impact upon ecosystem function and contribute to erosion and siltation into waterholes.
- ➜ Mining activity has also been generally well managed but there is evidence that some built-up roads and bridges which cross the main flow paths of the Cooper have retarded or changed the flow of high-volume flood peaks.

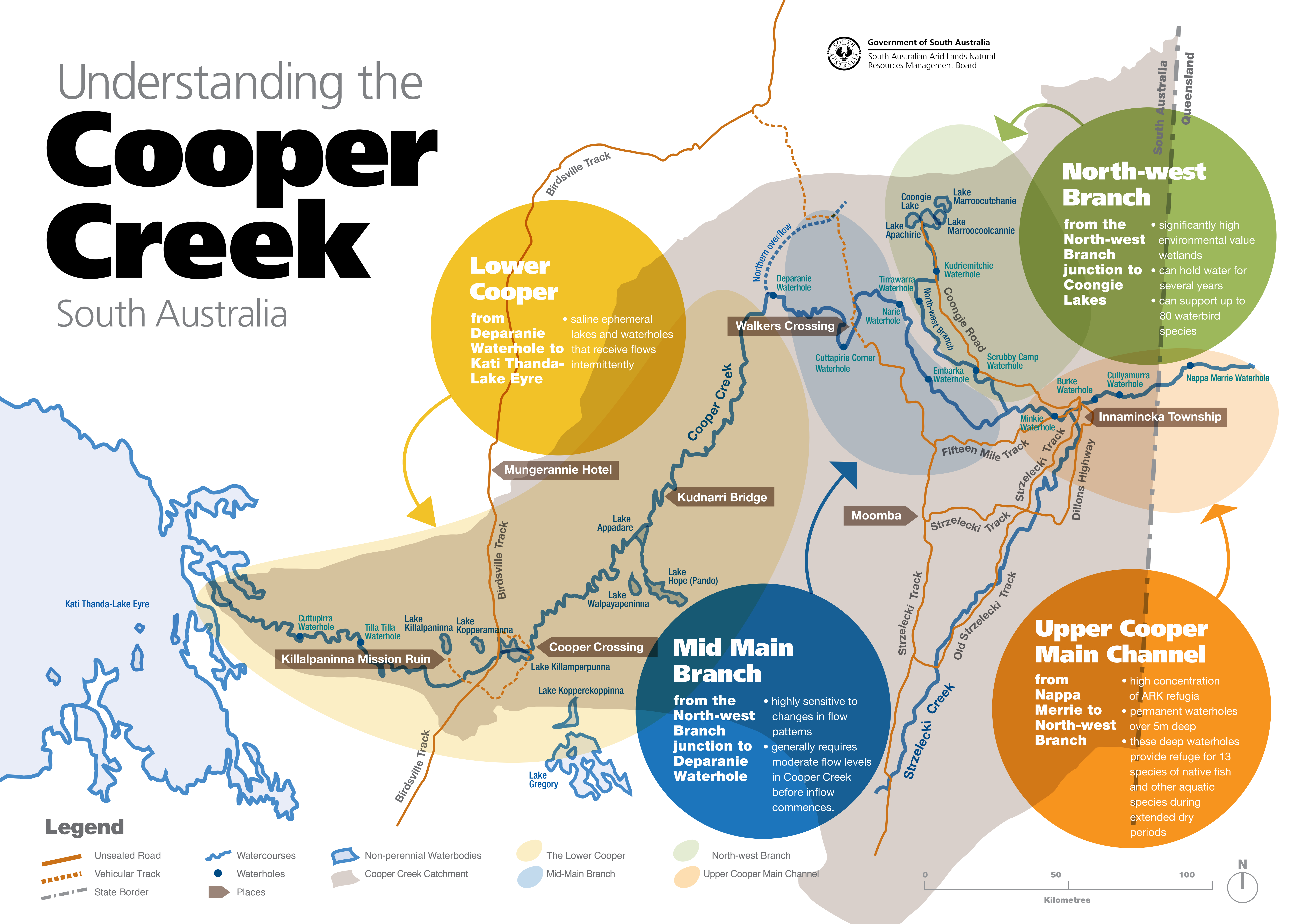
Right *Summary of management recommendations*

Management Objective	Existing or Potential Barriers to Objectives	Impacts if Objective not Achieved	Recommended Management Approaches
Natural flow regimes (temporal, longitudinal and lateral) maintained	• Upstream dams, diversions and water extractions • Infrastructure such as roads, bridges and buildings on watercourses or floodplains • Vegetation loss or gullying on watercourses, floodplains, swamps of the main flow pathways	• Disruption of geomorphological and hydrological processes • Disruption of hydrological connectivity and potentially, loss of permanent refugia • Loss of native fish and other aquatic biota (and potentially, the decline of Lake Hope fishery) • Loss of waterbirds • Loss of riparian vegetation and diminished natural regeneration • Damage to pastoral and tourism industries	• Collaborative agreements at national / interstate level to safeguard natural flows through regulation • Intrastate action, if necessary, to regulate extractions • Ensure that adequate environmental impact assessment processes are in place for proposed new infrastructure by all stakeholders, and promote best practice infrastructure development • Develop a centralised information resource
Waterholes and aquatic biota protected, particularly permanent waterholes that are the only refuge for aquatic biota during dry times	• As above • Soil and vegetation disturbance (e.g. from tourism activities) • Excessive recreational fishing • Aquatic and terrestrial pests • Excessive grazing pressure	• As above • Siltation of waterholes (e.g. from local erosion) • Water contamination • Depleted fish populations • Native fish and other aquatics displaced by introduced pests	• As above • Ensure no significant water extraction from waterholes • Provide information to tourists/ visitors and encourage best practice • Support pastoral lessees in best practice management, including alternative water-points and fencing of waterholes where appropriate
Riparian soils, landforms, vegetation and bird assemblages in good condition.	• Activities (as above) that affect natural flows • Vegetation removal / physical clearance (e.g. firewood removal) • Excessive grazing pressure (e.g. by stock or pest herbivores) limiting natural regeneration processes • Human and animal tracks to water promote gullying	• Loss of native vegetation and associated ecosystems • Inability of key structural vegetation species to recruit • Increased siltation of waterholes • Loss of plant succession through natural regeneration • Flow-on effects for amenity values (affecting tourism) and for pastoralism	• Actions as above to maintain natural flow regimes • Actions as above to support best practice tourism and pastoralism
Pest species having minimal impact	• Rabbits and feral pigs currently having significant impact in some areas • Gambusia and Goldfish present in many waterholes • Pest plants, such as buffel grass, competing with native plants in some areas • Potential for cane toad incursion	• Loss of native vegetation and associated ecosystems • Increased siltation of waterholes • Loss of plant succession through natural regeneration • Potential loss of native fish and other aquatic fauna • Native plants displaced by weeds – loss of biodiversity and, potentially, increased fire risk	• Maintain and expand programs for feral animal control • Monitor (for the time being) Gambusia and goldfish populations • Develop strategies and contingency plans to counter potential cane toad incursions. • Maintain and expand buffel grass/ invasive weed control program

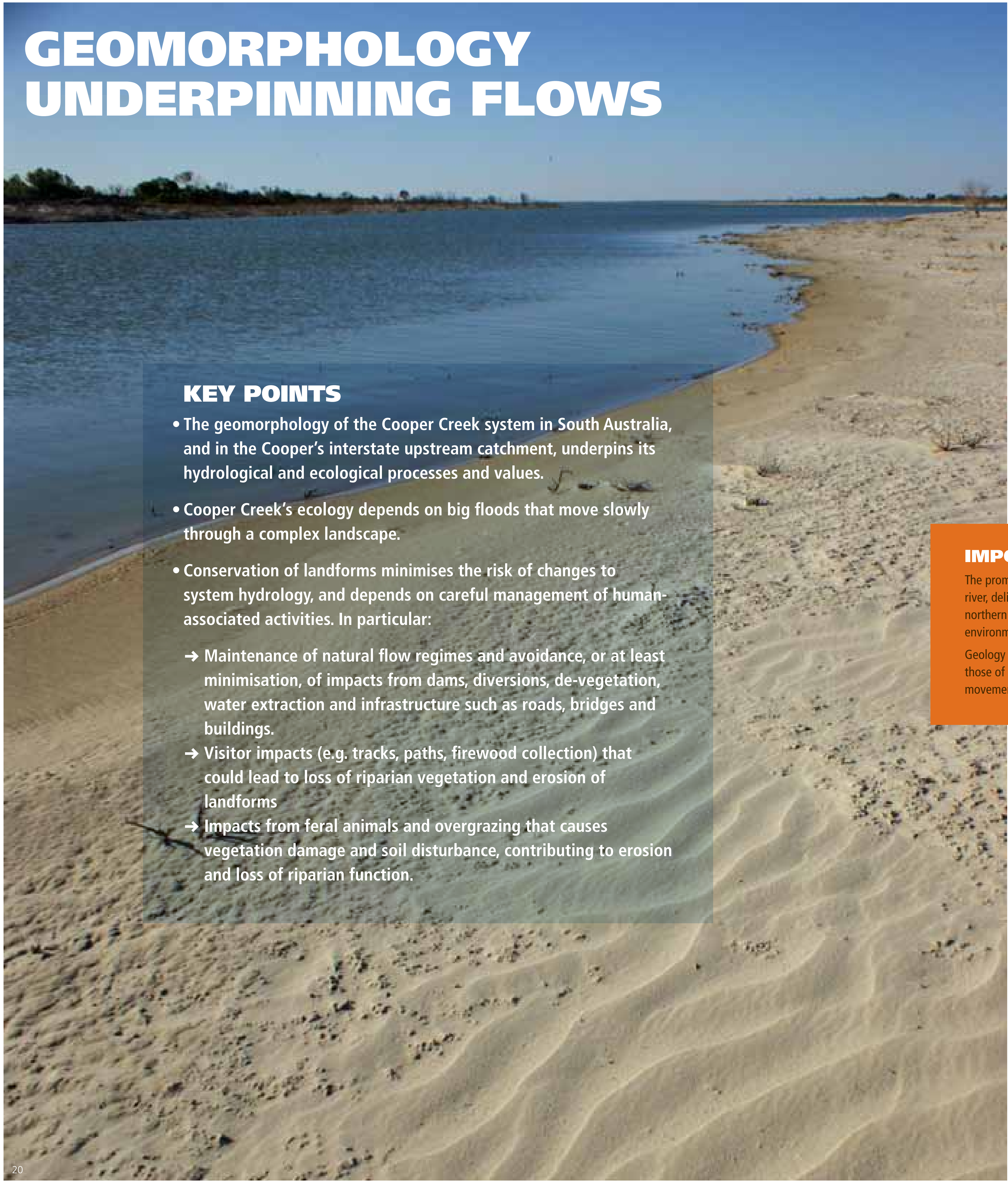
Understanding the

Cooper Creek

South Australia



GEOMORPHOLOGY UNDERPINNING FLOWS



KEY POINTS

- The geomorphology of the Cooper Creek system in South Australia, and in the Cooper's interstate upstream catchment, underpins its hydrological and ecological processes and values.
- Cooper Creek's ecology depends on big floods that move slowly through a complex landscape.
- Conservation of landforms minimises the risk of changes to system hydrology, and depends on careful management of human-associated activities. In particular:
  - ➜ Maintenance of natural flow regimes and avoidance, or at least minimisation, of impacts from dams, diversions, de-vegetation, water extraction and infrastructure such as roads, bridges and buildings.
  - ➜ Visitor impacts (e.g. tracks, paths, firewood collection) that could lead to loss of riparian vegetation and erosion of landforms
  - ➜ Impacts from feral animals and overgrazing that causes vegetation damage and soil disturbance, contributing to erosion and loss of riparian function.

GEOMORPHOLOGY *is the scientific study of landforms and the processes that shape them. This study seeks to understand why the Cooper Creek catchment looks and acts the way it does, to understand the catchment's history and dynamics, and to predict changes that may occur in the future.*

A major aim was to assess the physical fluvial features of the Cooper Creek which contribute to the resilience of waterhole ecosystems, and to identify the spatial and temporal range of ecological refugia. A specific component of the study was to assess landforms in terms of their potential for harbouring cane toads.

The study area encompasses the Cooper Creek catchment within South Australia, including a 30 km section of the Innamincka Valley extending into Queensland. In addition, an area extending northeast ~400 km upstream from the South Australia-Queensland border was assessed by remote study, as the geomorphology of this extended area is of direct relevance downstream in South Australia.

IMPORTANCE OF THE CATCHMENT'S GEOMORPHOLOGY

The prominence of the Cooper Creek in Australian history and South Australian ecology lies in its catchment-scale geomorphology. It's a long river, delivering monsoonal floodwaters of sufficient volume that flood pulses routinely travel as far as the driest part of the continent in northern South Australia. Its unregulated and extremely variable hydrology underpins the very high ecological value of the river and its major environmental assets.

Geology is important to how and where flood waters flow. The Cooper Creek catchment in South Australia lies on sedimentary rocks, including those of the Eromanga Basin (part of the Great Artisan Basin (GAB)). The rocks have experienced subdued tectonic activity (earth crust movements), creating the Lake Eyre Basin as it is today, with uplifted hills and domes, and subsiding river valleys.

THE INNAMINCKA VALLEY IN THE INNAMINCKA DOME

The Cooper Creek enters South Australia east of the township of Innamincka. It flows through an irregular valley in the Innamincka Dome, where it is confined within the rocky walls and steep slopes. The Innamincka Valley was created by Cooper Creek cutting its way down against the slow uplift of the Innamincka Dome.

This part of the Cooper is extremely important for two reasons;

- Ecologically, the main refuge waterholes are here (e.g. Cullyamurra Waterhole). The higher stream power caused by this valley's narrowness carved deeper and longer waterholes than elsewhere in the study area.
- Geologically, the path of the river through the uplifting Innamincka Dome defines the base level and river character of the Cooper Creek for hundreds of kilometres upstream.

THE STRZELECKI PLAIN

The Cooper's flow, and the size and frequency of its floods, is extremely variable. Its low-gradient topography and complex landforms retain floodwaters in lakes, swamps, channels, and waterholes, allowing rich ecosystems to flourish. Between floods, dry periods are a necessary part of the balance for landforms as well as for living things.

Most of the Cooper's catchment in South Australia falls within the Strzelecki Plain, which is surrounded on all sides by stony and sandy uplands. Overall, the Plain has very low relief and this is a strong determinant of river behaviour and drainage network development.

Leaving the Innamincka Dome, the Cooper Creek enters the Strzelecki Plain through the Cooper Creek Fan, a low-angle alluvial fan with its apex near the township of Innamincka (Fig. 1). The Cooper Creek Fan has a significantly greater gradient than other parts of the Strzelecki Plain, and the river is partly confined within terraces of older fluvial deposits. The Cooper Creek's potential stream power is therefore greater here than elsewhere on the Strzelecki Plain, forming a string of important waterholes. Within the Fan the parent Cooper channel splits into three main branches:

- Main Branch, which shows marked changes of direction, flowing northwest, west, then southwest until it reaches the narrow zone between the Gason and Cooryanna Domes. At this point it enters the Tirari Desert through the Kopperamanna Floodout, then flows west-northwest to Lake Eyre.
- North-west Branch, which dissipates among the Coongie Lakes (Fig. 2)
- Strzelecki Creek, which flows south-southwest to Lakes Blanche and Callabonna. Strzelecki Creek only receives water infrequently and at relatively low volumes.

WHAT YOU SEE - FLATS AND DUNES OF THE STRZELECKI PLAIN

The dominant topographic features in the study area are the sand dunes, and the broad, mostly dune-free "flats" which are particularly a feature of the Cooper Creek Fan and Coongie Lakes area. Figure 3 shows the topography of the Strzelecki Plain. The distribution and relationships of the sand dunes and the broad "flats" are amongst the strongest determinants of Cooper Creek's ecosystems and drainage network. Whereas dunes modify the river by impeding flow, the flats give best expression of the underlying slope of the Strzelecki Plain, and allow water to be transmitted.

The dune fields in the Strzelecki Plain are dominated by either longitudinal or compound dunes.

- Longitudinal dunes are long but very narrow (from one kilometre to scores of kilometres long, but only 150-300 m wide). Their crests run roughly north-south, parallel to the dominant wind direction at the time of their formation. Typically their flanks are well-vegetated (therefore, anchored against migration or movement) while the narrow crests are often un-vegetated and locally mobile. The longitudinal dune fields are of geologically recent origin and where their presence constrains the drainage network (such as Strzelecki Creek), the fluvial geography is also relatively young.
- Compound dunes are a mix of transverse and longitudinal dunes formed by the same prevailing winds. Transverse dunes are perpendicular to wind direction and are created by sediment blown northwards from rivers or lakes, deposited immediately adjacent to the sediment source (referred to as being "source-bordering"). Their length is scaled to the channel or lake from which they arose. The Cooper Creek Fan and the Coongie Lakes area are dominated by compound dunes.

Figure 1.

Aerial photograph of Cooper Creek as it flows across the Cooper Creek Fan, from Queerbiddie Waterhole and the Town Common on the right, to the Main Branch – North-west Branch split on the left.

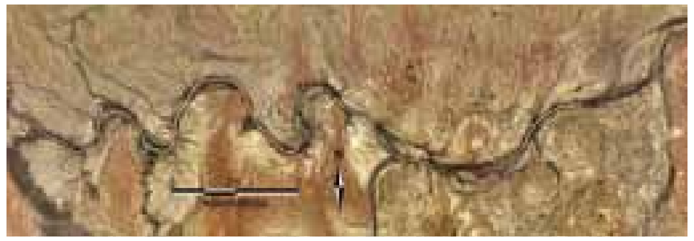
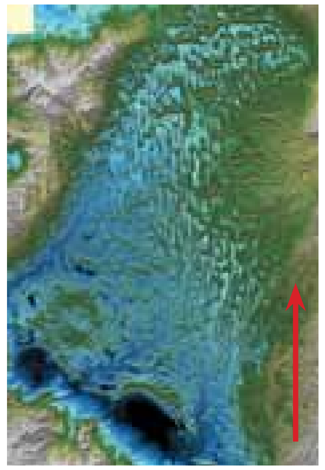


Figure 3.

Topography of the Strzelecki Plain: This digital elevation model image has high elevation white, grading through green, down to low elevations dark blue and black. The red north arrow is ~50 km long.

Figure 2.

Aerial photograph showing the complex flow path in the North-west Branch. The channel comes from the southeast (bottom right) and splits into two discontinuous channels amongst the dunes. From centre to top left, the flow path is through networks of small channels, and unchannelised swamps.



COOPER CREEK'S FLOW PATH IN THE STRZELECKI PLAIN: CHANNELS, WATERHOLES, LAKES AND SWAMPS

Cooper Creek flows across the "flats" of the Strzelecki Plain. Sometimes the flow path is a clearly defined large channel (or group: a large channel plus smaller channels operating at different flood heights), with waterholes at intervals along the channel's length. Sometimes the flow path is several widely-separated medium-sized channels, or a network of very small channels, or discontinuous channels, or a channel-free swamp. The floodplain is usually an active part of the main flow path. Where channels are discontinuous, the floodplain is the flow path. The main flow path is not always obvious to the eye.

Waterholes are channel segments which are wider and deeper and retain water for longer periods than other parts of the channel or nearby channels. Some waterholes are near-permanent, and a few are actually permanent. Waterholes are most often found along the main flow path but also exist away from channels, along runoff and flood overflow pathways.

Channel and waterhole banks support riparian vegetation including coolibah trees and a dense understory of bushes. During floods, riparian vegetation creates scouring currents that play a key role in maintaining water-body depth.

THE FLOOD SUMPS

The lakes and swamps of the Strzelecki Plain are sumps, and act as local base levels and flow buffers; flood flow does not proceed downstream until the local topography has been filled to a certain level. For example in the south western Strzelecki Plain, the entire flow is abstracted by Lakes Appadare and Hope. Flow enters Lake Appadare and then flows on to Lake Hope. When Lake Hope is sufficiently full, Lake Appadare returns water to Cooper Creek via a poorly-defined north-western exit and a clearly defined western exit. The downstream exits of these sumps are an important part of the Cooper's hydrology, maintaining the "go-slow" flow that nourishes ecosystems.

NATURAL FLOW IS THE GOAL

The management goal for the Cooper Creek must be to ensure the present degree of variability and volumes of flood pulses from Queensland, and the path of these flood waters, is not determined or altered by anthropogenic impacts.

This study identifies the most vulnerable areas in the Cooper Catchment and these in particular must be protected from activities which may promote erosion, or de-vegetation, or lead to restriction or changes in flow pattern. Increased mining and tourist activity leads to infrastructure such as raised roads and bridges. Where these cross the Cooper's water flow they must allow fully natural flow patterns. Such designs are different from standard culvert and bridge designs.

The road system developed to support the resources industry has also provided greater access for pastoralism and tourists. This means grazing pressure is extending over greater areas. Tourism impacts are increased, which accentuates land and water use pressures.

CANE TOADS ARE A RISK

Some published literature on cane toad invasion pathways considers that the Cooper Catchment in South Australia is not at risk. However, these assessments are incorrect because the extent of available water in the Strzelecki Plain has been misunderstood.

Over recent decades, cane toads have expanded widely in Australia, displaying an adaptive capability that is both behavioural and genetic. They have advanced as far as south western Queensland, and if they travel down the Windorah to the Nappa Merrie reach of Cooper Creek they will have access to the permanent and semi-permanent waters of the Innamincka Valley, Cooper Creek Fan, and the Coongie Lakes.

Cane toad life cycles require shallow still water for breeding, access to water or damp ground for rehydration, and daytime shelter. The Cooper Creek in South Australia is rich in potential habitat on all counts. The permanent waterholes (such as Cullyamurra and Nappa Merrie), the nearly-permanent and semi-permanent waterholes and lakes of the Cooper Creek Fan and the Coongie Lakes area support countless places for toad shelter and breeding.

Should toads invade the Strzelecki Plain, it might be assumed that the problem will be only temporary in most places, as most will die during the next drought. However, there are two issues which make this an optimistic expectation. Firstly, even if the toads do not establish a permanent population, attempted toad breeding on the floodplain during flood years is likely to poison the Cooper Creek fish at a critical time in their breeding cycle. Secondly, cane toads are excellent adopters of human environments. If toad populations expand during a wet year and find permanent refuge in (for example) the subfloor space of a demountable building, those toads will probably survive through droughts to reinfect the Strzelecki Plain in later wet years.

Existing bridge design obstructs natural flow pattern

PRIORITIES FOR FUTURE MANAGEMENT

- Any changes to the natural flow variability of Cooper Creek will be detrimental as both landforms and ecology are developed to respond efficiently to floods and droughts. It is essential that Cooper Creek's flow regime continues to be unmodified. Water-affecting activities potentially include both physical changes to the system (e.g. bridges, dams, diversions) and water extraction (e.g. for irrigated agriculture).
- Establishment of resource industry and other infrastructure (including roads and structures) on flow-through drainage lines and in biologically rich or hydrologically sensitive areas can have significant detrimental impact. Environmental impact and risk assessment is an essential pre-requisite to avoiding infrastructure impacts on sensitive sites, and should be required of all stakeholders.
- Flooding during the 2010-2012 wet years inundated unexpected areas. Flood-risk assessments should be applied to existing and proposed new permanent infrastructure, especially concerning procedures for cleaning up chemical contamination, and consideration of the integrity of foundations of large structures if there is any chance they may be inundated.
- The risk of erosion and gullying exists in any place where the land surface goes from a higher to a lower level (such as gibber plain to terrace, or terrace to floodplain). Tourist camping areas should continue to be at the level of the modern floodplain, where occasional floods can refresh sediments. Tracks and roads going into waterholes from terraces or gibber plains should be planned and managed carefully, so as to avoid the creation of gullies along the roadway.
- Vegetation along the riparian zone is critically important for maintaining the steep banks and good depth of waterholes. Tourist camping areas need to be managed to preserve vegetation and rehabilitate degraded areas, for example by rotating the permitted camping spots, discouraging parking vehicles or setting up tents under trees, and encouraging natural regeneration in damaged areas.
- Access to water is the heart of local amenity and the valuable tourist economy. Alternative ways to give people access to water without damaging banks and drainage channels, while preserving the wild experience, should be investigated.
- Due to its difficulty of access, the Northern Overflow is apparently one of the few parts of dryland Australia not substantially affected by grazing. Recently exploration roads have opened up that area, and it would be a missed opportunity not to document the existing conditions while they are still in this near-pristine state.
- Grazing by stock and feral animals (e.g. rabbits, pigs) can have significant impacts on riparian and other native vegetation and can contribute to erosion of landforms. Control of feral pests and ensuring sensitive grazing management are essential.
- Contrary to some predictions, cane toads are potentially a serious threat for the study area. More detailed risk assessment regarding potential cane toad incursion pathways is needed, along with contingency planning for a whole-of-community response in terms of cane toad control.

FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Wakelin-King, Gresley A., 2013, Geomorphological assessment and analysis of the Cooper Creek catchment (SA section), October 2012, Report by Wakelin Associates to the South Australian Arid Lands Natural Resources Management Board.*

Wakelin-King, G.A., 2013, Cane Toads and South Australian Arid Lands Geomorphology. Report by Wakelin Associates to the South Australian Arid Lands Natural Resources Management Board, Port Augusta

HYDROLOGY AND FLOW PATTERNS

KEY POINTS

- The Cooper Creek has an unregulated flow regime with minimal levels of water extraction. It is one of the internationally recognised reference examples of low gradient, intermittent, dryland rivers in the world.
- This hydrological study confirms the outstanding importance of Cullyamurra Waterhole as a critical refuge for aquatic biota, given its ability to hold water and sustain life in extended dry periods.
- Infrastructure development has potential to substantially impact upon the hydrology of the river system.
- Maintenance of unregulated flows is vital for the ecology of the river system and for the environmental, social and economic benefits that depend on healthy ecosystems.

THE COOPER CREEK SYSTEM *in South Australia is characterised by a network of waterholes that provide vital habitat for aquatic flora and fauna. In general terms, waterholes in the area include large permanent waterholes, periodically significant but ephemeral waterholes, and other water-bodies that can become saline in dry conditions. In dry times, the waterholes are discontinuous: disconnected conditions are common and the river is more often a series of isolated wetlands and waterholes.*

As the Cooper Creek is unregulated, natural associations between the ecology and flow patterns are largely intact, and are characterised by the 'boom and bust' dynamics that are the hallmark of arid and semi-arid environments. The boom-bust sequence is driven by the variability in flow with Cooper Creek having one of the most variable flow regimes in the world.

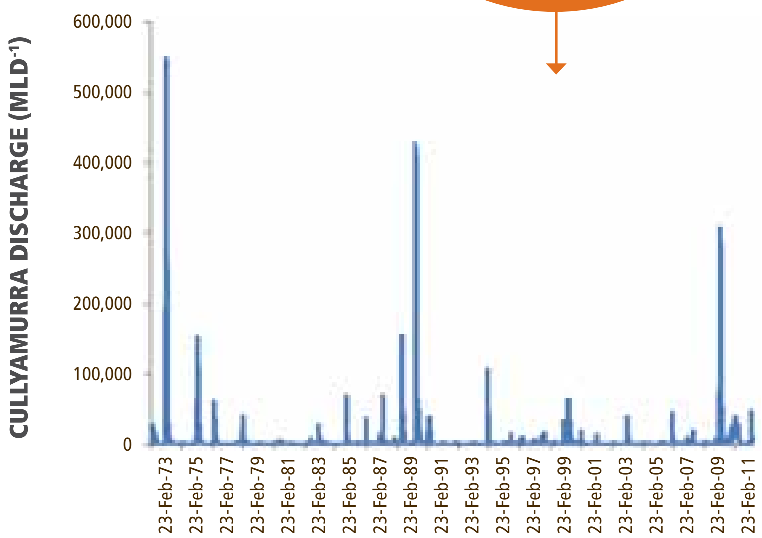
Improved understanding of flow patterns and distribution of aquatic fauna is integral to managing and protecting this unique system.

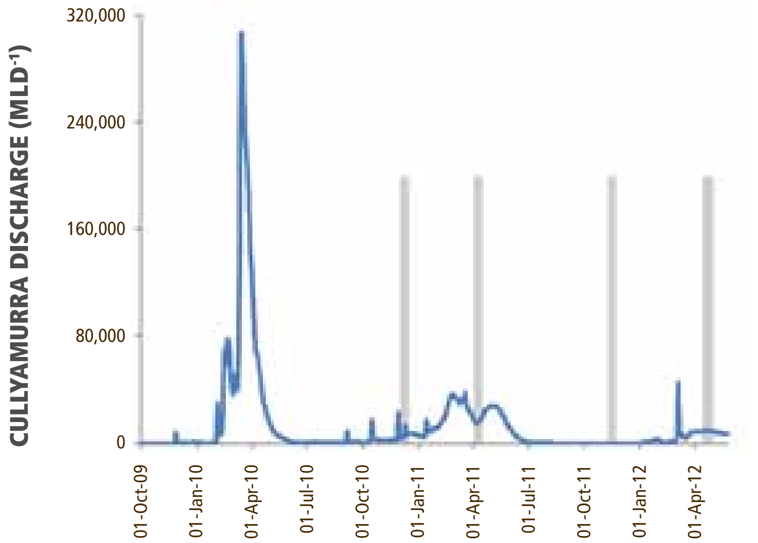
This study draws upon hydrologic and geomorphic monitoring data collected over four periods.

- The first phase of data collection occurred from April 2000 to February 2003 as part of the ARIDFLO project – when five water-level loggers were installed around Coongie Lakes.
- The second phase occurred during the period 2004-2006 as part of a University of Melbourne research project that examined salinity processes in the Coongie Lakes.
- The third phase occurred over 2007-2008 and involved maintenance of the water level logger network installed as part of the ARIDFLO project.
- The fourth phase occurred from April 2011 to April 2012 (Fig. 1) as part of this Cooper Creek project and included the following components:
  - ➔ Several low cost water level loggers were installed in key distributaries, and in the lower Cooper. These loggers were placed in positions that filled gaps in the existing ARIDFLO and SANTOS monitoring networks.
  - ➔ Key water-bodies were identified and their dimensions were measured (bathymetric surveys).
  - ➔ Water quality, particularly salinity, was measured to identify waterholes that may be subject to groundwater inflow.
  - ➔ Sampling of algae (phytoplankton) was undertaken.

Figure 1.

Hydrograph of Cullyamurra gauging station record for Cooper Creek for the period 1973-2012 (top panel). The lower panel shows the Cullyamurra hydrograph for the flood years of 2010 – 2012. The periods of Cooper Creek fieldwork are shown by the grey columns.





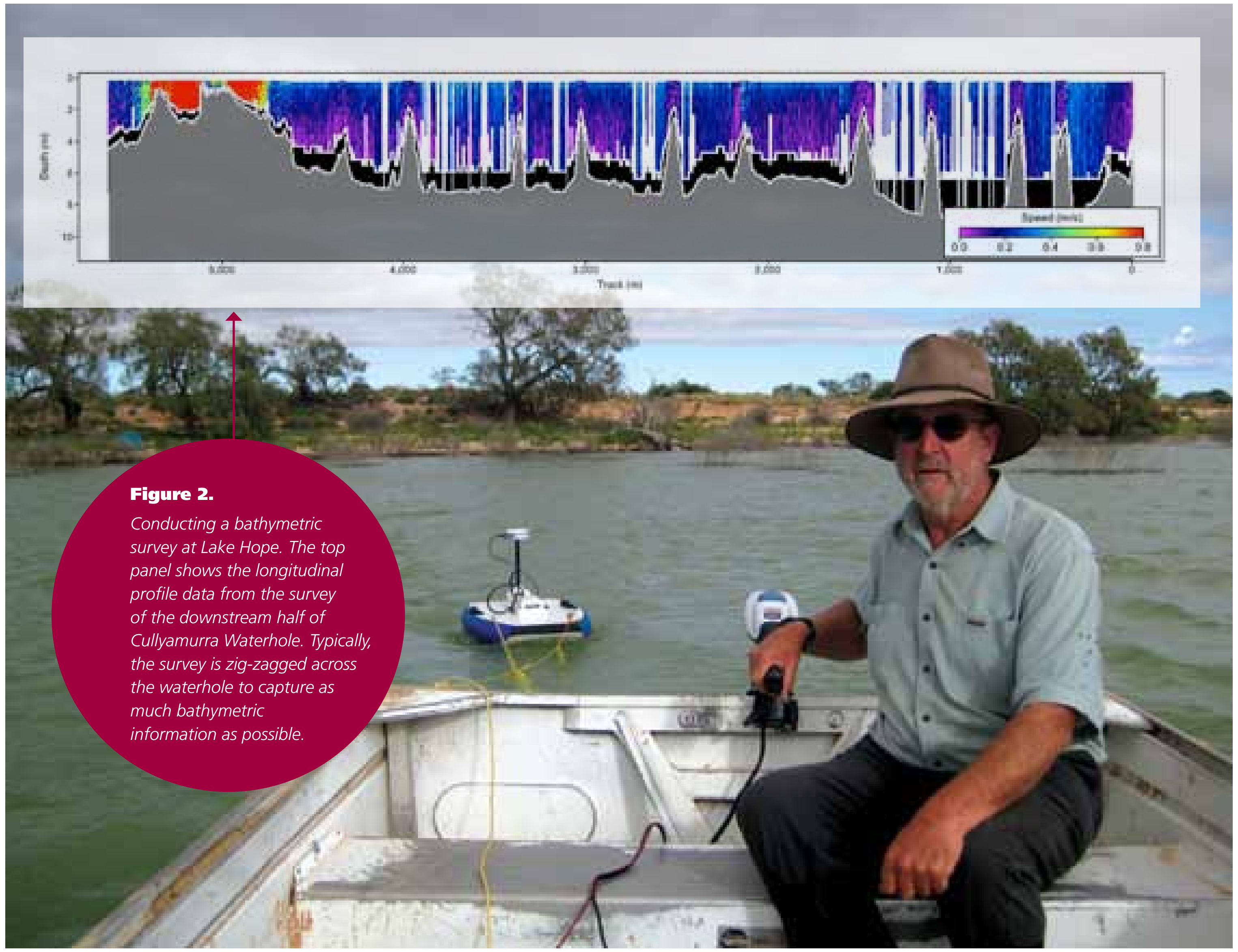
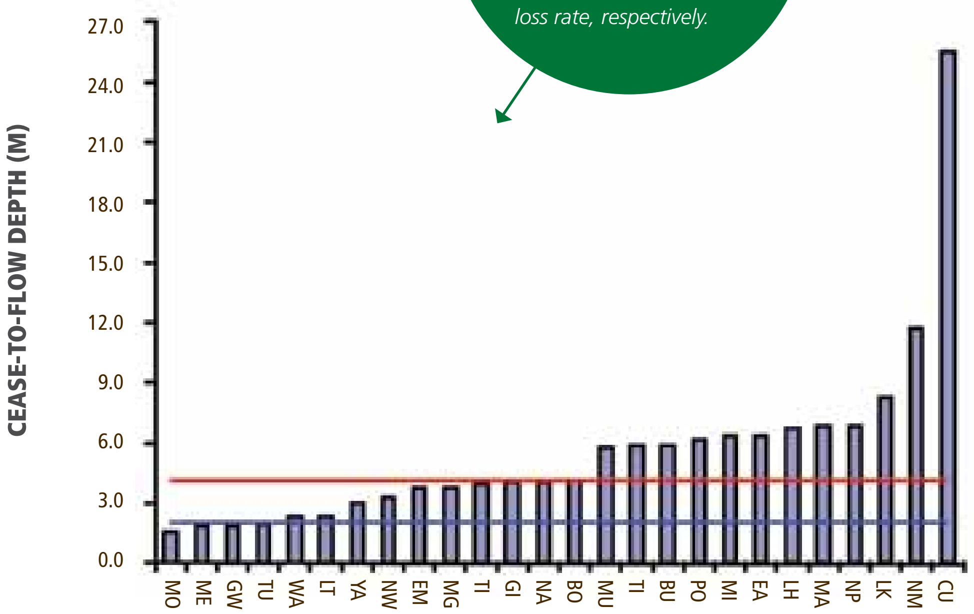


Figure 2.
Conducting a bathymetric survey at Lake Hope. The top panel shows the longitudinal profile data from the survey of the downstream half of Cullyamurra Waterhole. Typically, the survey is zig-zagged across the waterhole to capture as much bathymetric information as possible.

Figure 3.
Maximum Cease-to-Flow Depths measured for Cooper Creek water-bodies. The blue and red lines show the one-year and two-year open water loss rate, respectively.



Moorari	MO
Merimelia	ME
Gwydir's Crossing	GW
Turra	TU
Wattathoolendinie	WA
Lake Toontoowaranie	LT
Yaningurie	YA
Northwest Branch (Coongie)	NW
Embarka	EM
Munga Munga	MG
Tirrawarra	TI
Gidgealpa	GI
Narie	NA
Booloo Booloo (Dig Tree)	BO
Mulkonbar	MU
Tilcha	TI
Burke's	BU
Policeman's	PO
Minkie	MI
Eaglehawk	EA
Lake Hope	LH
Nappapethera	NP
Marpoo	MA
Lake Killalpaninna	LK
Nappa Merrie	NM
Cullyamurra	CU

WET CONDITIONS

In 2010-2011 the Cooper flowed for 598 days through Cullyamurra and this was the first (recorded) time flow has extended continuously over two flood years. This did not even occur following the massive 1974 flood which is the largest on record. Therefore, conditions during this Cooper study were wetter than average and with highly unusual durations of connectivity. Another feature of the study period was that significant local rainfall and runoff events also occurred.

BATHYMETRIC SURVEYS HIGHLIGHT CRITICAL REFUGIA

Bathymetric surveys (i.e. surveys of underwater depth) of 40 waterbodies were conducted to identify their refugia potential (Fig. 2). The survey of Cullyamurra recorded a maximum depth of 26.0 m (flowing), more than twice the depth of the second deepest waterhole measured: the Nappa Merrie homestead waterhole (11.7 m deep, not flowing).

The results (Fig. 3) indicate that the cease-to-flow depths of waterholes in the Cooper Creek upstream of the Main Branch – Northwest Branch junction are typically around 5.5 – 6.5 m while the Northwest Branch and Main Branch are mostly less than 5.5 m. In addition to its depth, the sheer size of Cullyamurra Waterhole enhances its value as a fluvial 'super refuge', the 'Noah's Ark' of the ark refugia. The reach around Cullyamurra also gets a significant amount of streamflow generated from local runoff from the Innamincka Dome and this may result in generally shorter periods of no-flow than experienced by the middle reaches of the Cooper in Queensland.

IMPROVED HYDROLOGICAL MODELS AND MONITORING CAPACITY

This study improves data availability for hydrological modelling of the Cooper. In particular, information from water level loggers improves our understanding of flow patterns and timing at the key distributary and flow constriction points.

A major constraint on the management of the Cooper Creek and our capacity to detect adverse change is our limited capacity to model the system. This means that the effects of changes in the flow regime at key environmental assets like the Coongie Lakes, either due to climate change, water extraction, or changes in flow paths, are difficult to monitor or predict. More accurate understanding of the ecological implications of changes in flow regime can assist future management decisions.

COOPER CREEK NEEDS TO RUN FREE

The hydrology of the South Australian reaches of the Cooper Creek remains unregulated and generally unimpeded. Changes in the flow regime of a particular reach or wetland are likely to have significant long-term consequences. The cause of changes, particularly the reduction in flow to a given reach, could be the result of anthropogenic changes (upstream water extraction, land use changes, infrastructure affecting flooding patterns) or climate change. Reductions in the long-term frequency of inundation of wetlands and reaches could:

- result in a decrease in native fish diversity
- result in increases in wetland soil salinity due to decreased flushing by flood events.

There are increasing amounts of infrastructure assets being built along the Main Branch and Lower Cooper, including roads, culverts, bridges, drill pads and bund walls. Appropriate analysis and supervision is required to ensure that infrastructure does not affect flood patterns, storage capacity or retention time of floodwaters, as these changes could adversely affect the ecosystems of Cooper Creek.

GROUNDWATER INTERACTIONS

The extent of groundwater – surface water interactions in the SA reaches of Cooper Creek is not well understood. Data collected in the Coongie Lakes wetlands show that the unconfined groundwater occurs at shallow depths and is typically highly saline, except under the more frequently inundated lakes. Much of the Cooper in South Australia is likely to be characterised by shallow groundwater, although monitoring data is scarce.

In the Coongie Lakes, as a result of the shallow groundwater depths, the soil water of the sediments of the more ephemeral lakes (e.g. Goyder and Apanburra) and surrounding some of the lakes (e.g. Toontoowaranie) is saline due to evaporation from the shallow water table. While unproven, it is suspected that the distribution of red gums on Cooper Creek is related as much to the groundwater salinity as it is to the surface water regime at a site (e.g. frequency of flooding and drying). The dynamics of groundwater levels in response to recharge during flood events may also contribute to mass mortality events for riparian trees. Groundwater data from the Coongie Lakes show that significant rises in highly saline water can occur in response to flood events and this may place considerable osmotic stress on the ability of the riparian Eucalypt species to extract soil water for transpiration.

The logger position at the mouth of Ellar Creek and Lake Goyder

BREAKING THE COOPER CREEK INTO REACHES

The distribution of flow and aquatic refugia in the South Australian reaches of the Cooper Creek provide a framework for dividing it longitudinally into management reaches.

COOPER CREEK MAIN CHANNEL: Nappa Merrie to Northwest Branch – Main Branch junction.

This reach contains the most important fluvial refuge in the Lake Eyre Basin; Cullyamurra Waterhole. This waterhole was found to have a maximum depth exceeding 25 m and would retain water over several kilometres of river length under even severe drought conditions. The reach also contains the greatest concentration of ark refugia (waterholes greater than 5 m depth) in the Channel Country. The constriction of flow through this reach means it has excellent connectivity with upstream and downstream parts of the catchment and receives flow every year. This reach will provide the initial pathway for alien species (e.g. cane toads) into South Australia and also has the highest concentration of residents and tourists of the Cooper reaches.

NORTHWEST BRANCH: Junction with Main Branch to the Coongie Lakes.

This reach receives initial flows from the Cooper main channel and also contains the high environmental value Coongie Lakes wetlands at the effective terminus of flow along this distributary system. It is the occurrence of these relatively rare, open lake habitats rather than ark refugia which provide the greatest value hydro-ecological environments in the Northwest Branch, SA.

MAIN BRANCH: Junction with Northwest Branch to the junction with the Northern Overflow at Deparanie Waterhole.

This reach requires a modest discharge threshold of approximately 1200 MLd-¹ before flow occurs into the Main Branch. This flow path is not characterised by open lake environments or significant ark refugia and so has received less hydro-ecological attention. There are substantial amounts of oil-gas production infrastructure on the Main Branch and it is important that these do not alter the flow patterns or holding capacity of areas within the Main Branch, particularly the Embarka Swamp area. The areas downstream of Embarka Swamp do not receive flow annually and so any further decreases in their frequencies of inundation could have deleterious effects on these downstream ecosystems. The Embarka Swamp area is probably the most sensitive part of the South Australian reaches of Cooper Creek to changes in flow patterns from anthropogenic causes.

LOWER COOPER: Main Branch – Northern Overflow junction to Lake Eyre North.

This reach does not contain any significant ark refugia and receives flow approximately every 3-4 years. This reach does contain an opportunistic commercial fishery at Lake Hope that can operate following large flood (approximately 1:10 year) events.

UNDERSTANDING FLOW PATTERNS

Loggers and flow measurements give better understanding of flow thresholds and distribution in the distributaries of the Cooper Creek.

The split in flow between the Northwest Branch and the Main Branch is probably the most important distributary split in the lower Cooper. Flow measurements during 2012 found that at discharges of around 8000 MLd-¹ in Cooper Creek, approximately half the flow went into the Northwest Branch and half into the Main Branch. However, at higher flow levels in 2011 (16,000 MLd-¹) the proportion of flow going into the Main Branch had increased at the expense of flow going into the Northwest Branch. These flow measurements at different flow levels are extremely important for being able to improve our capability of determining how much flow should reach important ecological assets, such as the Coongie Lakes.

Loggers improving our knowledge of flows in Coongie Lakes

Flow gauging at the Coongie Lakes in November 2011 and April 2012 also gives some insights to the complexities of the 'fill and spill' mechanism at work in these lakes. In November 2011, the level in the Northwest Branch was falling and no flow was occurring. Modest flow into Lake Toontoowaranie was occurring, Ellar Creek was back-flowing (into Toontoowaranie) and flow into Apanburra Channel was a trickle. The backflow along Ellar Creek illustrates the complexities involved in trying to model flow in this important wetland system.

During April 2012, the rising flood was entering Coongie Lake and also generating flow into the Lake Apachirie – Lake Dare – Lake Massacre flow path and moderate flow out of Lake Toontoowaranie and into Lake Goyder and the Apanburra Channel. This data shows that Ellar Creek is the preferential pathway out of Lake Toontoowaranie during the filling phase but that flow relations can be complex during the falling phase.

The extent of flooding during the smallest annual flows seems to be an important parameter in the ecology of Cooper Creek. For instance, Coongie Lake receives inflow on an annual basis and has not been known to miss out on inflow in any year of the Cullyamurra gauging record. This important waterbody is also the most downstream extent of red gums on the Northwest Branch and has the highest reported fish diversity of the Coongie Lakes wetlands. The lakes and channels downstream of this point receive flow less frequently and dry out more frequently. Coongie Lake, as the terminus of the smallest annual flows, is an important monitoring point for identifying any change in the Cooper Creek flow regime.

PRIORITIES FOR FUTURE MANAGEMENT

Maintaining natural hydrological patterns

The health of the Cooper, and the environmental, social and economic benefits that flow on from good river health, are heavily dependent upon natural flow regimes being maintained. This includes careful management and supervision of new infrastructure being installed, such as roads, bridges, culverts and other structures. All have the capacity to interfere with natural flows, with significant negative consequences.

Cullyamurra Waterhole and other refuges

The Cullyamurra Waterhole is the principal refuge of Cooper Creek and the entire Lake Eyre Basin, and this underlines its ecological importance and requirement for management. Important management actions for the protection of Cullyamurra Waterhole are:

- ➔ No water extraction during periods of no flow
- ➔ Monitor that drop toilets aren't leaking into the groundwater and then into the waterhole.
- ➔ Improve tourist education on the need for low impact camping, particularly in protecting the riparian vegetation and limiting erosion.

The Nappa Merrie Waterhole was also identified as the second deepest refuge waterhole on Cooper Creek and some consideration should be given to its management (i.e. minimising water extraction beyond domestic use during long drought periods).

The refuge waterholes of the Northwest Branch (particularly Scrubby Camp and Kudriemitchie) and Main Branch (particularly Embarka and Narie) are less critical to the environmental health of the system but management plans should also be considered for these waterholes.

Hydrological monitoring

The level of hydrological monitoring (installed and planned) in the South Australian reaches of Cooper Creek is adequate for a remote, arid region catchment but could be better coordinated. At present, the monitoring has the capacity for volumetric assessment of Cooper flow coming into the State and of monitoring flows reaching the terminal areas for smaller annual flows. There is also some capacity for monitoring flows in the lower Cooper that support a commercial fishery.

On-going management of the Cooper Creek in South Australia would be greatly strengthened by the development of a new generation hydrological model that is capable of simulating the complex flow paths of this river system.

Monitoring Flood Patterns

A library of flood pattern data is required to ensure infrastructure assets are not resulting in any significant changes in flow patterns.

Mapping Plant Recruitment

Mapping the distribution of areas of successful recruitment and linking these to flooding patterns, soil salinity variations and grazing pressures would greatly add to our knowledge of the eco-hydrology of the Cooper Creek and assist in the sustainable management of the area (e.g. protecting key regeneration – recruitment locations from grazing or clearing).

Groundwater Monitoring

Further research into the links between groundwater depth and salinity, soil salinity and vegetation patterns would provide improved understanding of causes of vegetation changes and the most appropriate management actions to protect key vegetation communities.

FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Costelloe, J.F., 2013, Hydrological assessment and analysis of the Cooper Creek catchment, South Australia, Report by the University of Melbourne to the South Australian Arid Lands Natural Resources Management Board, Port Augusta*

VEGETATION AND SOIL INTERACTIONS

KEY POINTS

- The more reliably watered parts of the Cooper Creek system have higher soil fertility which supports more structurally and floristically diverse vegetation.
- Temporal connectivity, longitudinal connectivity along the channel, and lateral connectivity of the river with its floodplain, are critical to the vegetation and soils of the Cooper Creek.
- Long lived trees and shrubs in arid environments typically have 'windows of opportunity' for recruitment of new cohorts.
- Large trees are important to provide shade and nutrients that underpin the refugial nature of riparian sites in arid ecosystems, and small trees also have an important role as a source of shelter and food resources.
- It is imperative that cattle grazing, feral animals and invasive weeds are actively managed – to reduce negative impacts they may have on the condition of Cooper Creek vegetation.

THE COOPER CREEK *is a naturally functioning, unregulated drainage system with highly variable flow regimes, in an arid landscape. Its ecosystems are attuned and responsive to, and dependent on, this natural variability. The composition and structure of vegetation communities along the Cooper Creek reflects changes in soil type and flow reliability.*

This 2012 survey provides a 'snap-shot view', at a time when the vegetation of the Cooper Creek was in very good condition following several years of extensive rainfall and flooding. The findings provide insights into biophysical processes influencing ecosystem health along the Cooper Creek.

At each of the 14 waterholes where vegetation was assessed, records were collected from three sub-sites along a 100m x 4m belt transect running parallel to the waterbody. Importantly, these 'point in time' findings are analysed in the context of the longer climatic cycle of north-eastern South Australia.

VEGETATION OBSERVATIONS

This study, conducted at a time when the Cooper Creek environment had experienced three years of La Nina influenced hydrological pulses and significant extensive local rain events, provides insights into factors that influence ecosystem resilience.

A total of 148 plant taxa were recorded, 146 of these identified to species level. The taxa represented 106 genera and 42 families with the most seven commonly encountered families accounting for 63% of all species recorded. Of these, most species were from the grasses *(Graminae)*, legumes *(Leguminosae)*, chenopods *(Chenopodiaceae)* and daisies *(Compositae)*.

Over all sites only 9% of species (13) were introduced or naturalised weeds. However additional weed species of concern were observed in the near vicinity of the waterhole sites. These included buffel grass *(Cenchrus ciliaris)*, feathertop rhodes grass *(Chloris virgate)*, and barnyard millet *(Echinochloa cru-galli)*. Buffel grass is an aggressive invasive species that poses significant threat to biodiversity values.

Of significant interest was the collection of tall fleabane *(Conyza sumatrensis)*, from the Innamincka Regional Reserve campsite at the Coongie Waterhole site. This species had not been recorded before during previously locally extensive and thorough surveys suggesting a relatively recent introduction associated with tourism access.

Left *Buffel grass infestation at Kudriemitchie Outstation*

VEGETATION COMPOSITION

In stark contrast with the sparsely vegetated expanse of arid floodplain landscape around the Cooper Creek channel, the vegetation on the banks of waterholes forms an almost closed canopy covering dense vegetation beneath. The upper stratum at a number of upstream waterholes comprises a mix of river red gum *(Eucalyptus camaldulensis var. obtusa)*, coolibah *(Eucalyptus coolabah)* and Queensland bean tree *(Bauhinia gilva)*. Broughton willow *(Acacia salicina)*, river cooba *(Acacia stenophylla)* and lignum *(Muehlenbeckia florulenta)* shrubs dominate the mid-level stratum, shielding a ground layer dominated by climbing saltbush *(Einadia nutans)* and ruby saltbush *(Enchylaena tomentosa)*.

Progressing downstream from Cullyamurra waterhole, along both the North-west and main branches of Cooper Creek to the waterholes of the lower reaches, there is a distinctive shift in vegetation structure and plant species composition. For example, upstream at Cullyamurra waterhole, river red gum, coolibah, river paper-bark *(Melaleuca trichostachya)* and Queensland bean tree, all occur. Downstream, initially tea-tree drops out, next river red gum, then Queensland bean tree, until coolibahs are the only perennial tree present (Fig. 1).

VEGETATION STRUCTURE

Large trees are of primary importance in providing the shading and input of nutrient that underpins the refugial nature of riparian sites in arid ecosystems. However, smaller trees also have an important role in the ecosystem, as they are a source of shelter and food resources for terrestrial fauna. The creek wilga *(Myoporaceae)*,sour plum *(Meliaceae)*, plum bush *(Santalaceae)*, native orange *(Pittosporaceae)*, wild orange *(Capparaceae)* and whitewood *(Sapindaceae)* as well as the acacia spp *(Leguminosae)* belong to diverse plant families and so provide different food sources at different times of the year and flood cycle, compared to the taller trees. A robust vegetation mid-storey provides structural complexity which promotes higher bird diversity.

HYDROLOGICAL INFLUENCE

Hydrology is the most significant environmental influencing factor on the vegetation of the Cooper Creek. Those sections and waterholes of the Cooper Creek that are capable of holding the more regular reliable flood pulses typically exhibit the greatest structural diversity and floristic richness. As reliability of flooding decreases downstream, soil variables such as salinity and alkalinity exert increasing influence inhibiting the presence of a range of species not able to tolerate more saline conditions – and the vegetation structure and diversity reduces (Fig. 2). The lower reaches exhibit greatly reduced structural and floristic diversity.

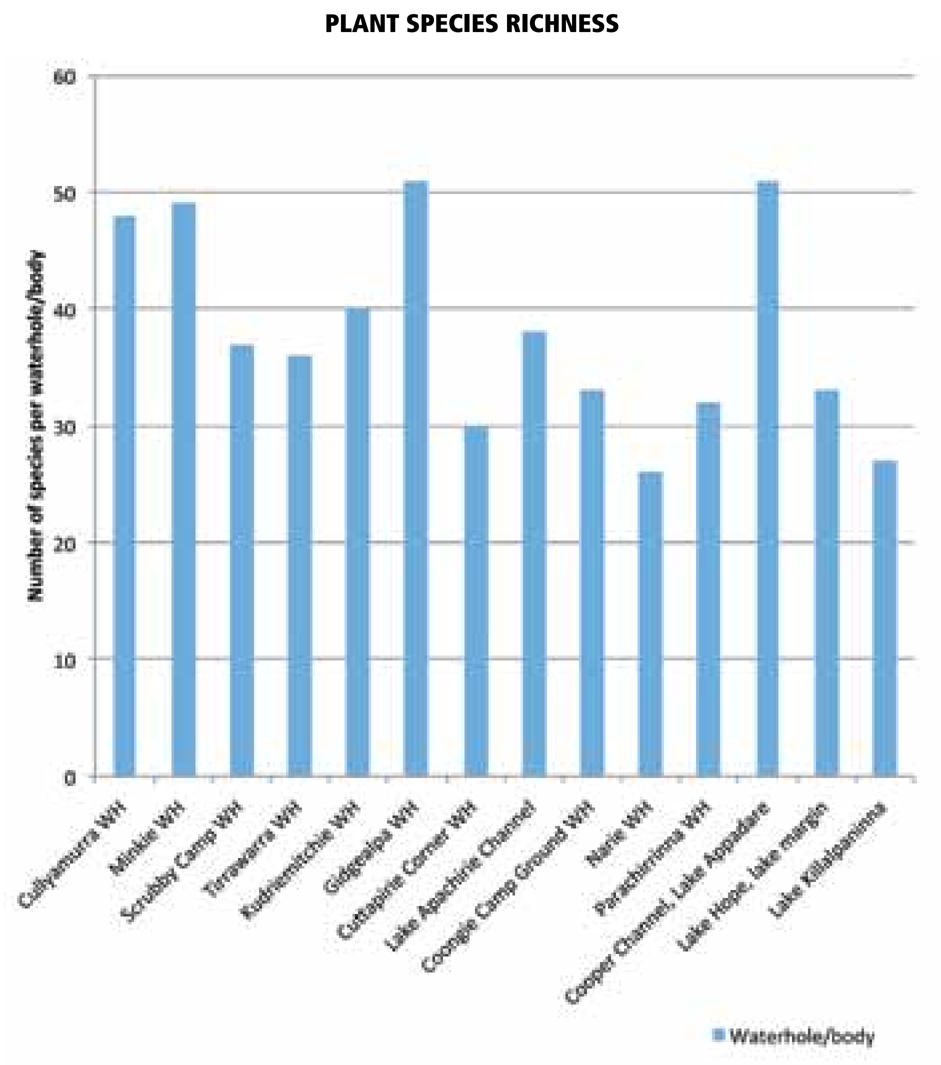


Figure 2. *Species richness at all sites*

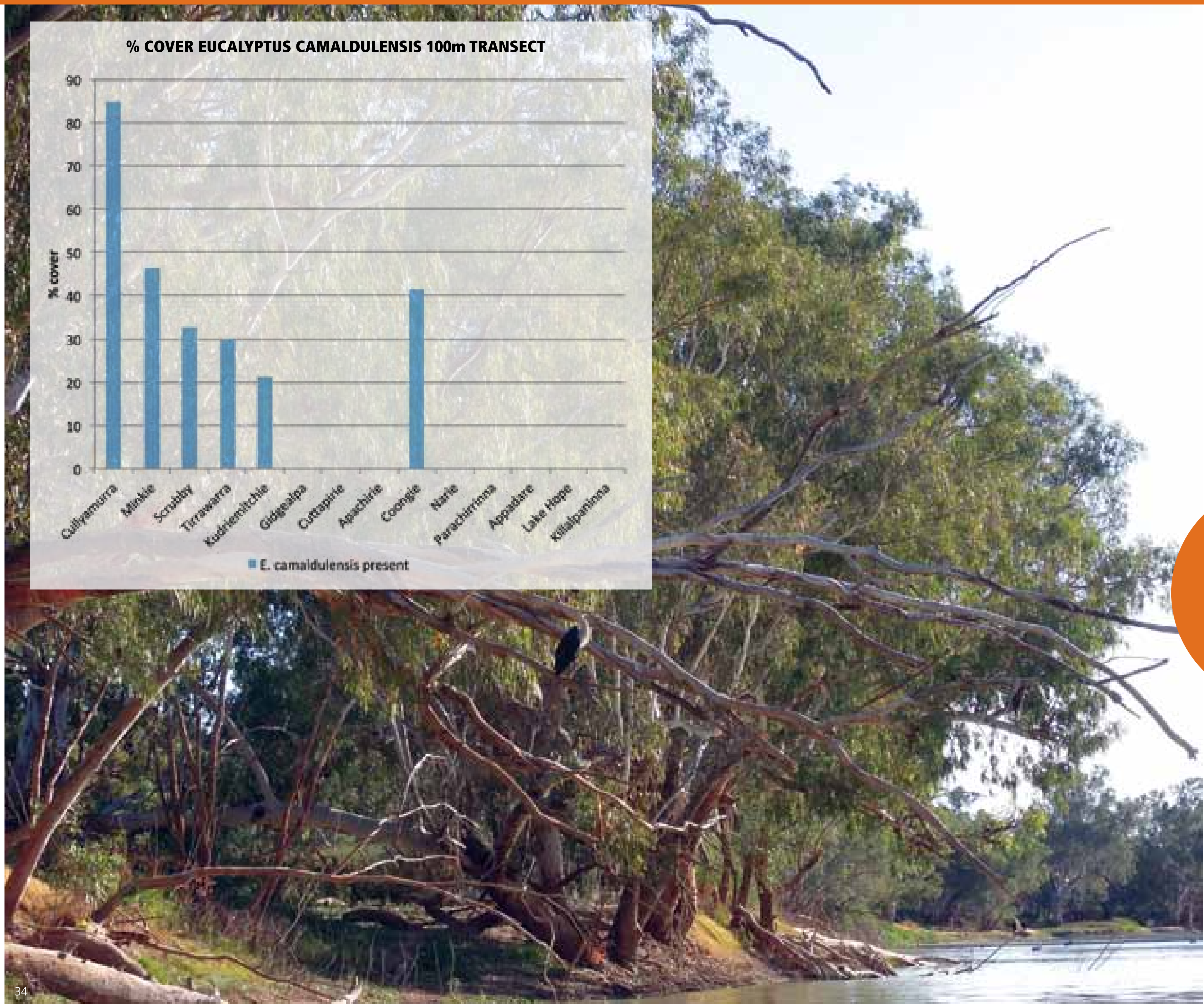
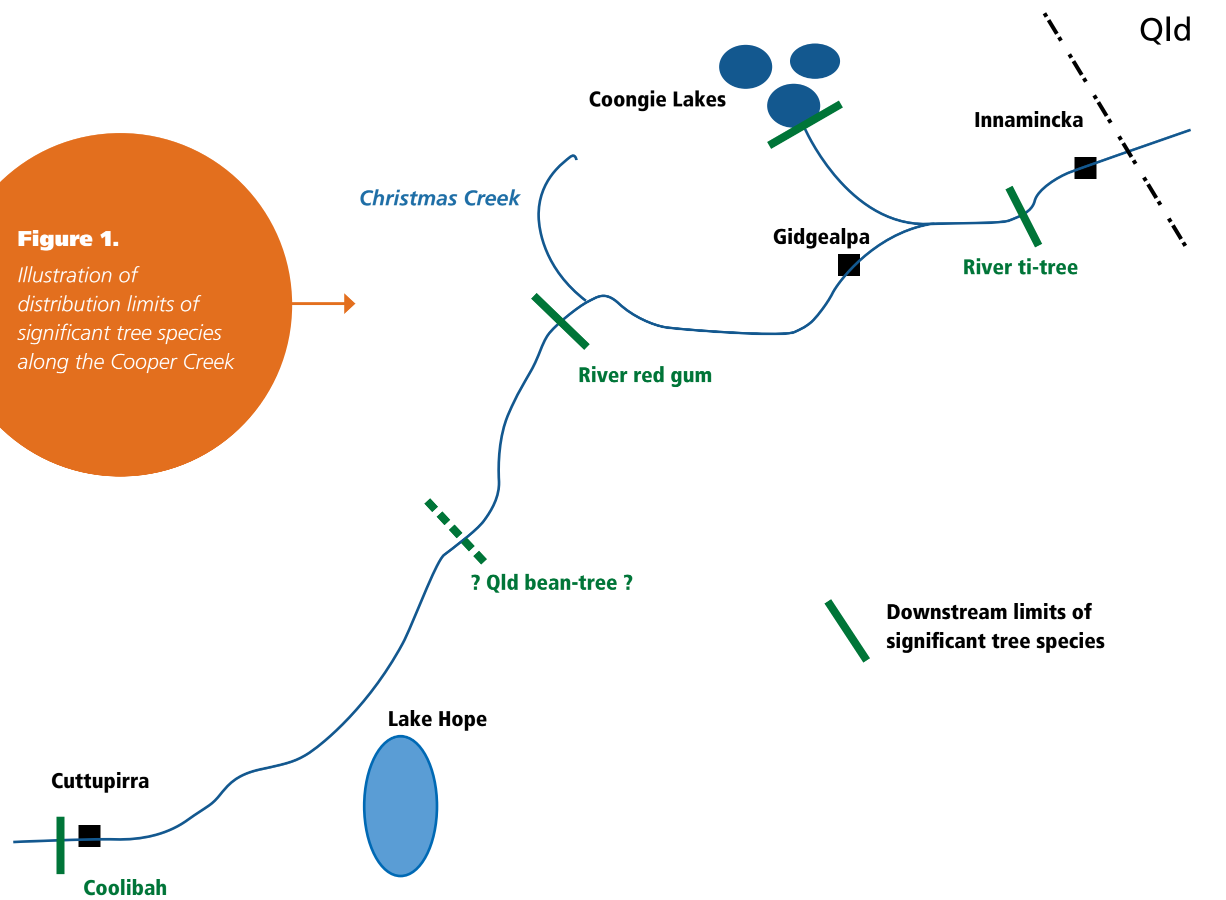


Figure 1. *Illustration of distribution limits of significant tree species along the Cooper Creek*



INTERPRETING PLANT SPECIES DIVERSITY

Where the dune fields are close to a waterbody, plant species typically found on dune sands were sampled in addition to those that are typically associated with the river corridor. The number of species surveyed at sites such as Lake Appadare is elevated as a result.

At Cuttapirie Corner and at Narie waterholes the species richness is dramatically lower. The increased cover of introduced weeds and unpalatable natives is indicative of heavy cattle grazing pressure in the past and which continues to influence species diversity at these sites.

CATTLE IMPACTS

At waterholes where cattle had been recently present or in the past, the soil surface was pulverised and little surface plant litter was evident. Lignum cover that is typically extensive along the channel bank was sparse. Introduced weeds and unpalatable native species tend to be denser, excluding other native plants that are typically encountered in these environments.

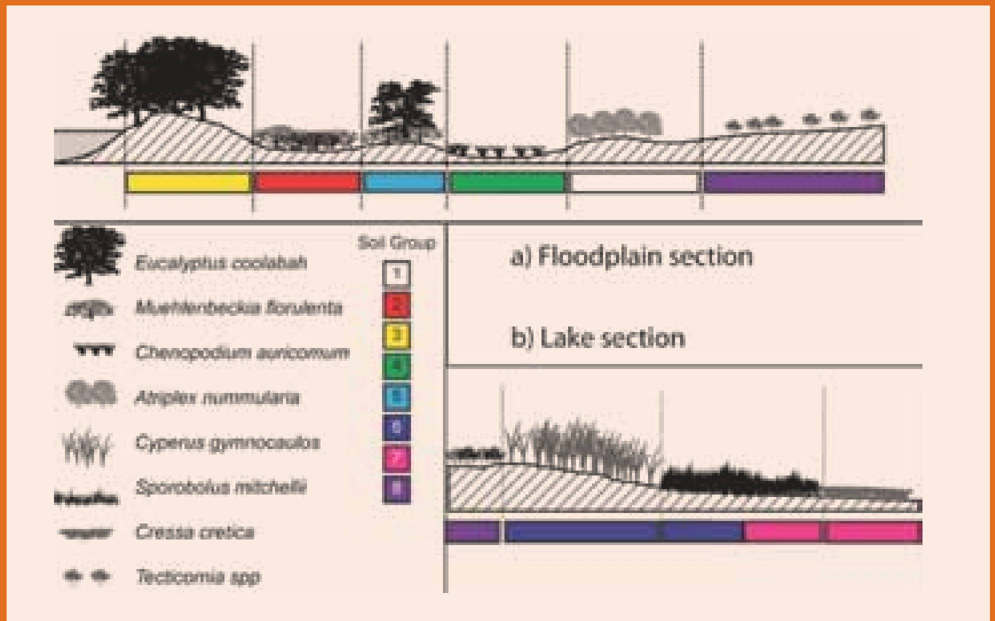


Figure 3. *Association of soil groups with vegetation*

SOIL CHARACTERISTICS

The various Cooper Creek vegetation communities are associated with different soil groups that change distinctly with progressive distance across the floodplain (Fig. 3).

Soils associated with the channel banks are predominantly lightly textured alluvial soils with mainly silty loams or silty clay loams in the upper profile and with increasing clay at depth. Significantly, these soils have the highest levels of total carbon in the surface layer– organic carbon is associated with biomass breakdown and raises soil capacity to retain nutrients and hold water in the profile. The complex vegetation structure and high species richness at persistent waterholes provides a constant source of organic material, raising soil carbon and hence fertility.

Soil type alters longitudinally down the creek. The soils of the lower reaches tended to be more saline and have higher alkalinity, reflecting reduced flows as the floodwaters penetrate these lake areas less reliably. The drier downstream areas with less complex vegetation structure tended to have lower carbon levels.

Waterholes which displayed past or recent signs of cattle impact possessed the highest levels of soil carbon, a reflection of the greater nutrient input. However when nutrient is imported by cattle into the shaded riparian environment, and combined with pulverization of the alluvial soils by cattle hooves, ideal conditions are created for weed invasion.

CONNECTIVITY

While significant local rainfall events are important spasmodic ecological drivers in arid environments, it is predominantly the major flood events derived from upper catchment monsoonal influence that drives the ecosystems processes of the Cooper Creek and its associated flood plain. The waterholes, creek channel and floodplain are an interconnected system. Temporal connectivity, longitudinal connectivity along the channel, and lateral connectivity of the river with its floodplain, are critical to the vegetation and soils of the Cooper Creek.

Connectivity through time is critical to boom and bust ecosystems such as those of the Cooper Creek. Long lived trees and shrubs in arid environments typically have 'windows of opportunity' for recruitment of new cohorts. Infrequent periods of extensive flooding and rainfall over several years lead to significant germination that may not reoccur for a long period. It is critical that these new cohorts persist through the post germination period, however their vulnerability to grazing pressure is very high during this life stage.

PRIORITIES FOR FUTURE MANAGEMENT

Ensure natural flow regimes:
Flood events are a crucial driving force, a natural disturbance factor, in the functioning of Cooper Creek ecosystems. Water extractive activities associated with agriculture and mining industries threaten the inextricably linked refugial role of waterholes.

Establish cattle watering points away from the creek channel:
Increased nutrient input from cattle dung, and soil pulverisation from cattle hooves, have immediate and long term impacts on vegetation cover and species diversity.

Manage cattle and feral animal impacts on post-boom recruitment:
The impacts of cattle grazing, and of rabbits and feral pigs is most severe during the post-boom phase when long lived tree and shrub recruitment is vulnerable. Active management to protect new cohorts is critical during this time.

Prevent invasive plants establishment:
Buffel grass *(Cenchrus ciliaris)* was observed in the early invasion stages near two waterholes. If permitted to spread, this plant has potential to severely alter ecosystems through displacing native species and altering fire regimes.

FURTHER INFORMATION

The information in this summary report is sourced from the technical report:
Gillen J.S., and Reid J.R.W., 2013, Vegetation and soil assessment of selected waterholes of the main and northwest channels of Cooper Creek, South Australia, April-May 2012, Report by the Australian National University to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

RIPARIAN BIRD ASSEMBLAGES

KEY POINTS

- Bird species richness was highest in the upper and middle reaches of the South Australian Cooper catchment, with upward of 40 bird species detected at some riparian sites.
- The highest landbird species richness at Tirrawarra and Kudriemitchie Waterholes on the North-west branch of the Cooper is comparable to the most diverse habitats Australia wide.
- Bird community abundance and assemblage composition were influenced by longitudinal position along the watercourse and lateral position across the riparian zone and floodplain.
- Tree cover of the region's three dominant riparian tree species; river red gum, coolibah and Queensland bean-tree, has a strong influence on bird community abundance, explaining 75% of the variation observed.
- The diversity in bird assemblages is directly related to vegetation structure and composition. Implications for management relate to maintenance of habitat, or vegetation type and condition, as the major biophysical influence on bird biodiversity.

BIRD SPECIES DIVERSITY *and abundance in the South Australian section of the Cooper Creek are recorded in this 'point in time' study which follows exceptional seasonal conditions.*

This study surveyed riparian bird assemblages (i.e. excluded water birds) from the Queensland border to the Cooper's mouth in Kati Thanda-Lake Eyre. A total of fourteen riparian and thirteen adjacent (paired) off-river bird assemblages were censused using a belt transect approach, at upstream, midstream and downstream locations during April-May 2012. However, it is noted that due to access limitations, a stretch of the Cooper Creek was not included in this survey; between Parachirrinna Waterhole and Lake Appadare - a straight-line distance of 95 km.

Bird observations were made over approximately 30 minutes, walking along a 500m x 100m belt transect. Bird densities were calculated as the sum of individuals of a species that were detected within the 100m belt (not flying over or through), expressed per hectare. Subsequent analysis was restricted to land-birds, excluding raptors, nocturnal species and quails as these groups could not be reliably counted using the methods above.

A floristic and structural description of the habitat was obtained for each transect from observations of wood plant species and two understorey components of the vegetation, namely grasses and other herbaceous plants.

RIPARIAN-FLOODPLAIN CONNECTIVITY

The floodplains of the Cooper Creek are significant wet-dry ecotones i.e. transition zones where different plant communities meet and integrate. The lateral connection between the creek and floodplain, where flows range from no-flow at all through to various sized inundating floods that connect a variety of extents of the plain, is fundamentally important ecologically. Downstream of Innamincka the Cooper spreads out (Cooper Creek Fan) in a broad arc between the Strzelecki Creek and the Coongie Lakes, creating a complex mosaic of distributary channels, riparian zones, ephemeral swamps and floodplains over a wide range of spatial scales, maximising the lateral connections which are thought to promote the high diversity of plant and bird species in this section of the river.

The riparian zone connects the river with the floodplain. This zone is important for filtering nutrients and sediment inputs into the channel, and for the direct contribution of organic matter (from log and litter fall). It also provides important habitat for terrestrial and aquatic species, as well shading and bank stability. The riparian zone provides a sheltered water source for landbirds that need to drink regularly, it is important breeding and foraging habitat for diverse and abundant raptor assemblages, and provides breeding, feeding and shelter habitat for a wide range of waterbirds.

FOCUSING ON SEDENTARY BIRDS

The composition of bird communities in arid lands of the world tend to be more dynamic than in other climatic zones where rainfall has more certainty and reliability, and nowhere is the between-year rainfall unpredictability and dynamism more pronounced than in inland Australian ecosystems. Mobile birds shift geographically and through time, in response to variation in habitat and food resources – in ways that are not predictable by date or location. In these circumstances, bird species that are sedentary and tied to defined habitats provide the best prospects for ecological monitoring. Australian studies have found that sedentary bird species dominate the assemblages of habitats in floodplain environments where soils are fertile and there is a preponderance of long-lived woody perennial tree and tall shrub species. This situation is exemplified in the Cooper Creek riparian zones.

For these reasons, the focus of this study was on sedentary land-birds (Table 1). Waterbirds and nomadic land-birds, given their non-sedentary nature, while recorded where they were observed were not the focus of further analysis.

COMMON NAME	SCIENTIFIC NAME
Australian Magpie	*Cracticus tibicen*
Australian Owlet-nightjar	*Aegotheles cristatus*
Australian Raven	*Corvus coronoides*
Australian Ringneck	*Barnardius zonarius*
Black Kite	*Milvus migrans*
Black-eared Cuckoo	*Chalcites osculans*
Black-faced Cuckoo-shrike	*Coracina novaehollandiae N*
Black-faced Woodswallow	*Artamus cinereus*
Blue Bonnet	*Northiella haematogaster*
Bourke's Parrot	*Neopsephotus bourkii*
Brown Songlark	*Cincloramphus cruralis N*
Brown Treecreeper	*Climacteris picumnus*
Budgerigar	*Melopsittacus undulates N*
Chestnut-crowned Babbler	*Pomatostomus ruficeps*
Chestnut-rumped Thornbill	*Acanthiza uropygialis*
Chirruping Wedgebill	*Psophodes cristatus*
Cockatiel	*Nymphicus hollandicus N*
Collared Sparrowhawk	*Accipiter cirrocephalus*
Common Bronzewing	*Phaps chalcoptera*
Crested Pigeon	*Ocyphaps lophotes*
Crimson Chat	*Epthianura tricolor N*
Diamond Dove	*Geopelia cuneata N*
Eastern Barn Owl	*Tyto javanica*
Eyrean Grasswren	*Amytornis goyderi*
Fairy Martin	*Petrochelidon ariel*
Galah	*Eolophus roseicapillus*
Grey Fantail	*Rhipidura albiscapa*
Grey Shrike-thrush	*Colluricincla harmonica*
Horsfield's Bronze-Cuckoo	*Chalcites basalis N*
House Sparrow	*Passer domesticus*
Jacky Winter	*Microeca fascinans*
Little Button-quail	*Turnix velox N*
Little Corella	*Cacatua sanguinea*
Little Crow	*Corvus bennetti N*
Little Eagle	*Hieraaetus morphnoides*
Little Grassbird	*Megalurus gramineus N*
Magpie-lark	*Grallina cyanoleuca*
Masked Woodswallow	*Artamus personatus N*
Mistletoebird	*Dicaeum hirundinaceum W*
Nankeen Kestrel	*Falco cenchroides*
Orange Chat	*Epthianura aurifrons N*
Pallid Cuckoo	*Cacomantis pallidus N*
Peaceful Dove	*Geopelia striata*
Pied Honeyeater	*Certhionyx variegates N*
Red-backed Kingfisher	*Todiramphus pyrrhopygius N*
Red-browed Pardalote	*Pardalotus rubricatus*
Red-capped Robin	*Petroica goodenovii W*
Red-rumped Parrot	*Psephotus haematonotus*
Restless Flycatcher	*Myiagra inquieta*
Rufous Songlark	*Cincloramphus mathewsi N*
Rufous Whistler	*Pachycephala rufiventris W*
Sacred Kingfisher	*Todiramphus sanctus S*
Singing Honeyeater	*Lichenostomus virescens*
Southern Whiteface	*Aphelocephala leucopsis*
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*
Spotted Harrier	*Circus assimilis*
Spotted Nightjar	*Eurostopodus argus ?N*
Stubble Quail	*Coturnix pectoralis N*
Tree Martin	*Petrochelidon nigricans*
Variegated Fairy-wren	*Malurus lamberti*
Whistling Kite	*Haliastur sphenurus*
White-backed Swallow	*Cheramoeca leucosterna*
White-breasted Woodswallow	*Artamus leucorynchus*
White-plumed Honeyeater	*Lichenostomus penicillatus*
White-winged Fairy-wren	*Malurus leucopterus*
White-winged Triller	*Lalage sueurii N*
Willie Wagtail	*Rhipidura leucophrys*
Yellow-throated Miner	*Manorina flavigula*
Zebra Finch	*Taeniopygia guttata*

Table 1. *Land-bird species observed across the 25 transects: N: nomadic; W: non-breeding winter visitor (mainly); S: summer breeding visitor.*

BIRD ABUNDANCE

Riparian bird abundance was very high in the upper parts of the study area (27-46 individuals/ha) and declined at the lower sites (18-22 individuals/ha) along the Cooper Creek.

There is a strong distinction between bird assemblages at the riparian sites and off-river sites. In nearly all cases bird abundance, and diversity, was greater at the riparian sites than the paired (adjacent) off-river sites (Table 2).

		Riparian		Off-river	
	Site	**Richness**	**Abundance**	**Richness**	**Abundance**
Decreasing Annual Discharge of water ↓	**Cullyamurra**	17	26.7	13	7.3
	Minkie	17	26.1	15	11.1
	Scrubby Camp	17	33.0	20	14.1
	Tirrawarra	24	40.3	14	11.8
	Kudriemitchie	22	27.0	4	1.6
	Embarka	20	30.0	11	8.2
	Narie	21	28.9	6	5.0
	Coongie	17	27.0	13	18.1
	DAER channel	18	16.3	6	5.4
	Parachirrinna	17	29.8	12	8.3
	Appadare	14	10.3	9	3.7
	Hope	10	8.3	9	8.9
	Muckeranna	17	13.8	-	-
	Killalpaninna	15	14.9	12	12.6

Table 2. *Summary of bird species richness and community abundance (number of individuals/ha) for resident only species at 14 locations on Cooper Creek. Sites are placed in rank decreasing order of estimated long-term annual discharge.*

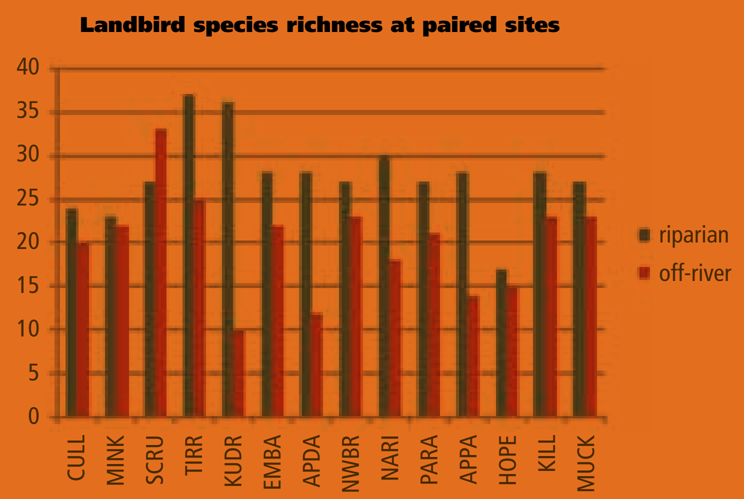


Figure 1a. *Histogram of landbird species richness (raptors and quails excluded) from single transect counts at 14 pairs of sites.*

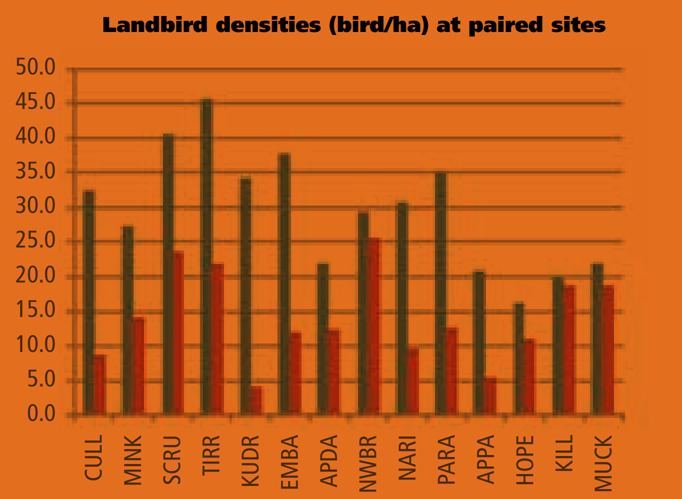


Figure 1b. *Histogram of assemblage abundance (birds ha-1; raptors and quails excluded) from single transect counts at 14 pairs of sites.*

Site Code	Waterbody Name
CULL	Cullyamurra Waterhole
MINK	Minkie Waterhole
SCRU	Scrubby Camp Waterhole
TIRR	Tirrawarra Waterhole
KUDR	Kudriemitchie Waterhole
EMBA	Embarka Waterhole ('Gidgealpa HS')
APDA	channel between Lakes Apachirie and 'DAER'
NWBR	'Coongie Waterhole' (North West Branch)
NARI	Narie Waterhole
PARA	Parachirrinna Waterhole
APPA	waterhole downstream of Lake Appadare
HOPE	Lake Hope
KILL	Lake Killalpaninna
MUCK	Muckeranna Waterhole

BIRD DIVERSITY

The survey found bird species richness was highest in the upper and middle sections of the Cooper Catchment, with upward of 40 landbird species detected at some riparian sites (Fig. 1a). Density declined rapidly in the middle portion of the study area – (Fig. 1b).

Landbird species richness at Tirrawarra and Kudriemitchie Waterholes on the North-west branch is comparable to the most diverse habitats Australia wide.

A surprising result was that bird diversity was greater in the middle sections (the swamp-dominated area between the disjunction of the Cooper into its two main distributaries than the higher volume environments around Innamincka. This result suggests the highest riparian bird diversity may occur where there is a landscape level mass of well-watered swampy and riparian habitat; in the flatter great expanse of floodplain crossed with distributary channels and swamps in the lower half of the North-west branch and adjacent section of the main branch. However this is a cautious finding because it was expected that greater bird diversity would be found where flow volumes are greatest and water is more reliable – in the upper reaches. Further investigation is recommended.

EXPLAINING BIRD DIVERSITY AND ABUNDANCE

Variance in bird species richness and community abundance was found to be directly related to differences in vegetation structure and floristic composition. The rank cover-abundance score of coolibah presence was highly correlated with bird species richness and abundance. Coolibah explained 79% of the variation in resident bird species richness across the 27 sites surveyed, and 70% of the variation in abundance of the resident bird communities. Furthermore, the combined rank cover-abundance score of the region's three dominant riparian tree species; river red gum, coolibah and Queensland bean tree, explained 75% of the variation in bird community abundance – with coolibah being the most influential of these tree species.

In addition to coolibah cover, differentiation in bird community composition separating the 10 upstream riparian bird communities from the other 17 sites is also influenced by the cover of small trees (e.g. plumbush, Broughton willow,river cooba and native orange). These small to medium-sized trees add much structural complexity to the riparian vegetation in upper and middle portions of the study area, but are generally absent from the channel margins in downstream sections.

Left *Zebra Finch*
Photo credit; Lynn Pedler

While coolibah is the most influential plant species in the region in terms of controlling most of the variation in bird species richness and compositional turnover, the restricted distribution of river red gums is also highly significant as the distribution of six bird species, including the barking owl *(Ninox connivens)*, a nationally threatened species, is largely confined to areas where the red gum occurs.

LOCATION AND SPECIES COMPOSITION

Compositional turnover in bird communities, a secondary aspect of diversity, varied laterally away from the river channels and longitudinally in the Cooper Creek region.

A dramatic shift in the composition of riparian bird assemblages occurred between Parachirrinna Waterhole and the lakes Appadare-Hope area, coincident with the marked reduction in species richness. Several species, more characteristic of open-structured floodplain environments in upper parts of the study area, e.g. blue bonnet, yellow-throated miner, singing honeyeater, black-faced woodswallow and Australian magpie, were found to be prominent members of the downstream riparian communities. Riparian bird species absent from the four most downstream sites included peaceful dove, Australian ringneck, brown treecreeper, jacky winter and grey shrike-thrush, while others were much less abundant than in upstream areas, e.g. little corella, red-rumped parrot and spiny-cheeked and white-plumed honeyeaters.

MATTERS OF PARTICULAR CONSERVATION SIGNIFICANCE

The riparian vegetation along the Cooper Creek provides important breeding habitat for the Nationally Vulnerable grey falcon *(Falco hypoleucos)*. Also, the Cooper Creek floodplain vegetation is important habitat for the Endangered and little known night parrot *(Pezoporus occidentalis)*.

During the study, species of conservation significance were observed or heard including a small flock of black-tailed Godwits *(Limosa limosa)*, which are classified as 'Near Threatened', and two white-winged black terns *(Chlidonias leucopterus)*. These species are protected under international bird treaties (EPBC Act, 1999).

OBSERVATIONS OF INTEREST

A number of observations were made in addition to the transect counts that are important to note:

- Barking owls *(Ninox connivens)* were heard at all sites between Cullyamurra Waterhole and Coongie Lake.
- Eastern barn owls *(Tyto javanica)* were present at most sites (indicative of high rodent numbers)
- Brown quail *(Coturnix ypsilophora)* were seen at Cullyamurra, Scrubby Camp, and Narie waterholes, – a native species, it has colonised much of arid Australia only since 2000.
- Plum-headed finches *(Neochmia modesta)* had recently been found at Cullyamurra Waterhole prior to this survey, being the first record of this species in South Australia.
- Small numbers of flock bronzewing *(Phaps histrionica)* were seen on the floodplain south of Gidgealpa homestead, at Lake Hope and at the Cooper Crossing near Etadunna.
- Three yellow chats *(Epthianura crocea)*, a species with very restricted (known) distribution within far north-east South Australia, were seen in floodplain south of Gidgealpa homestead.
- Banded lapwing *(Vanellus tricolor)* was locally common in the Embarka Swamp and at a few other locations.
- Australian bustards *(Ardeotis australis)* and emus *(Dromaius novaehollandiae)* were scattered across the survey area, and Australian spotted crakes *(Porzana fluminea)*
- Black-tailed native-hen *(Tribonyx ventralis)*, spotted harriers *(Circus assimiilis)* were common in some areas.
- Other species seen included; one black-breasted buzzard *(Hamirostra melanosternon)*, one white-bellied sea-eagle *(Haliaeetus leucogaster)*, a grey falcon *(Falco hypoleucos)*, two black falcons *(Falco subniger)*, two letter-winged kites *(Elanus scriptus)*, one party of ground cuckoo-shrikes *(Coracina maxima)* and several swamp harriers *(Circus approximans)*.

BIRDS MAY BE PALER IN THE ARID AREAS

Several bird species in the arid study area have evolved paler colouring than subspecies and populations in wetter parts of Australia. Examples include the red-rumped parrot and blue bonnet. Cooper Creek populations of jacky winter and grey shrike-thrush are also distinctly more pallid than their south-eastern Australian counterparts. The evolution of pale, 'washed-out' plumage, being common to several species, is thought to represent ecophenotypic, genetically-based, adaptation to the high levels of sunlight, bleached soils and openness of the vegetation and terrain in the Lake Eyre Basin, and only occurs in sedentary species.

PRIORITIES FOR FUTURE MANAGEMENT

- Further research is required to determine whether riparian bird communities are actually more diverse in the swamp-dominated mid sections of the study area than the more reliably watered environments around Innamincka, as single bird censuses at a limited number of sites could generate misleading results.
- Research is required into the factors that affect the distribution, recruitment and mortality of coolabah and river red gum, and also into the ecological links between them and the associated bird species.
- Bird assemblages along the Cooper Creek seemed to be within the expected bounds of variability, although low abundance of variegated fairy wren was observed in lignum dominated riparian vegetation. Reassuringly, no imminent threatening processes were detected. However, in the long term it is essential to ensure:

➜ security of water, meaning ensuring the hydrology of the Cooper Creek remains natural by preventing major water diversions and/or dam building upstream, and

➜ protection of the riparian vegetation from physical clearance or other processes that might prevent regeneration of the key species.

FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Reid, J.R.W., and Gillen, J. S., 2013, Riparian bird assemblages of Cooper Creek, South Australia April-May 2012, Report by the Australian National University to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.*

FISHING FOR ANSWERS

KEY POINTS

- The waterholes of the Cooper Creek system in South Australia provide vital habitat for a range of fish and other native species.
- Permanent waterholes such as Cullyamurra are particularly important as refuges for fauna in times of drought, providing the only habitat to sustain aquatic species through extended dry periods.
- Maintenance of natural flow regimes is critical for conservation of aquatic ecosystems.
- Main threats include exotic animals such as Gambusia, goldfish, pigs, and potentially cane toads; and impacts from stock grazing, and structures such as bridges associated with mining and industry.

THIS STUDY *focuses on the fish species of the Cooper Creek system in South Australia, and also reviews the status of other aquatic species such as crustaceans, mussels and turtles. It assesses the distribution and habitat use of native and introduced fish species, the ecological function and importance of key refuge habitats for aquatic fauna, and key threatening processes affecting the Cooper Creek aquatic biota.*

This study was undertaken during 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.

KEY SITES

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. Along with other permanent waterholes, it provides critical refuge for native fish and other aquatic species during extended dry periods.

Lake Hope is a large, ephemeral, off-channel lake which hosts the Lake Eyre Basin's only commercial fishery.

WATER QUALITY

Water quality parameters were complex and variable with booms and declines in turbidity and dissolved oxygen suggestive of dynamic variability in microalgal communities. Despite intrinsic variability in water quality, the larger waterbodies, such as Cullyamurra, display marked resilience with values varying dynamically but remaining within a spectrum of values that is habitable to fish.

Further downstream at Lake Hope, salinity values were higher than those observed upstream reflecting an accumulation of salts in influent waters. Further increases in salinity observed in autumn 2012 were attributable to in situ evaporation.

SAMPLING

Sites were initially chosen to cover a broad geographic spread and encompass the range of waterhole typologies as described above. However, due to the exceptionally wet climatic period with high rainfall and inundation patterns, final site selection became more opportunistic.

At each site: substrate type, in-stream structure, maximum depth, rate of flow and connectivity to the main channel were assessed and recorded. Aquatic vegetation was also assessed, along with a number of water quality parameters - dissolved oxygen, water temperature, pH and salinity.

Fish were sampled using a standard set of fyke nets. A netting efficacy study was undertaken at Cullyamurra Waterhole and a pilot survey of recreational fishing activities was undertaken in Innamincka Regional Reserve.

FISH MONITORING

Sampling over four seasons identified fifteen species of fish with thirteen native and two exotic species captured. A total of 140,851 fish were caught at 28 sites.

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 over winter. 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 like Cullyamurra, Burke's and Minkie waterholes 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. Table 1 summarises the native fish sampled during this study.

A key finding of this study is that the upper and lower reaches of the Cooper appear to be spatially divergent. Whilst flows connected the entire catchment several times during the study period, the species assemblages maintained a high degree of spatial integrity. Resilient species such as bony herring, spangled perch and rainbow fish occupied and dominated ephemeral sites in the lower catchment. Resistant species such as Lake Eyre hardyhead took advantage of declining water quality in the lowest reaches of the catchment. All species maintained populations in the permanent or near-permanent waterholes of the upper catchment.


Yellow Belly

Common Name	Scientific Name	Distribution	Comments
Australian Smelt	*Retropinna semoni*	Observed from the upper reaches at Minkie Waterhole to the lowest site at Cuttapirra Waterhole	There was no pattern to their distribution but abundance was always low
Barcoo Grunter	*Scortum barcoo*	Patchy distribution from Cullyamurra to Cuttapirra Waterhole	Low in abundance
Bony Herring	*Nematolosa erebi*	An early migrant that moved into every site with floodwaters	Numbers then decreased over time, possibly associated with interspecific competition
Carp Gudgeon	*Hypseleotris spp*	Species expanded from two recordings in 2010 to become one of the ubiquitous species in following seasons	Appears to be a mid-late successional species
Cooper Creek Catfish	*Neosiluroides cooperensis*	Mid to upper Cooper in SA	Only four individuals caught during study
Desert Glassfish	*Ambassis mulleri*	Initially patchy and as far downstream as Lake Hope; much more widespread as flooding continued	Appears to be a late-mid successional species that is intolerant of declining water quality
Desert Rainbow Fish	*Melanotaenia splendida tatei*	Ubiquitous throughout the study area	The only native to persist in the highly degraded Yaningurie site during autumn 2012
Golden Perch	*Macquaria ambigua*	Widespread distribution	Appears to be the top fish predator in the system
Hyrtl's Tandan	*Neosilurus hyrtlii*	Patchy distribution at only a few sites	Does not appear to be an effective disperser in flood times
Lake Eyre Hardyhead	*Craterocephalus eyresii*	Initially at lowest, most saline site; moved upstream to seven other sites during floods	Specialised to highly saline environments
Silver Tandan	*Porochilus argenteus*	Restricted to upper and mid sections of Cooper	Highest numbers at Cullyamurra and Minkie Waterholes
Spangled Perch	*Leiopotherapon unicolor*	A rapid coloniser, found throughout study area	Numbers plummeted towards end of survey, possibly linked with water quality decline
Welch's Grunter	*Bidyanus welchii*	Well distributed in all areas except lower Cooper	The most variably distributed species (from one sampling round to the next)

Table 1. *Native fish species sampled*

FYKE NETS

Fyke nets are available in a range of shapes and sizes, each type being suitable for capture of different species of fish. For example, the small fyke net is suitable for catching small-bodied fish in shallow water habitats, while a double-wing large fyke net is suitable for catching larger fish in deeper waters. Four types of fyke net were used in this survey.

WATER-HOLES VITAL REFUGES

Deep permanent waterholes in the arid zone provide vital refuges for aquatic animals and plants in dry times they may be the only habitat left in times of drought.

Other waterholes may persist for some time after good rains but dry up in drought. These can provide very important habitat for aquatic species to spread out to in good seasons.

Other waterholes are permanent but become extremely saline in drought. Only the hardiest of fish, such as the Lake Eyre hardyhead, can survive these conditions.

OTHER NATIVE FAUNA

Cooper Creek turtles *(Emydura sp.)* were caught at 12 sites in the South Australian stretch of the Cooper Creek. Cooper Creek turtles have slow generation times and have been shown to suffer from illegal fishing activities. However, with longevity of up to 80 years, 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.

Freshwater shrimps (*Macrobrachium, Paratya* and *Caradina* species) were recorded at every location sampled throughout this study. The relatively short life cycles of shrimp and their 'boom and bust' population dynamics allow for wide distribution and rapid colonisation of wetland areas in favourable conditions.

Yabbies *(Cherax destructor)* were recorded across most reaches and appear to be capable of moving long distances. The upstream reaches of the Cooper, particularly Cullyamurra Waterhole, had the highest richness of crustacean species.

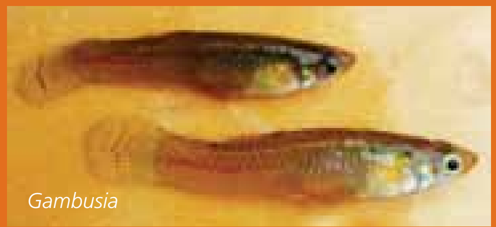
Freshwater mussels *(Velesunio spp)* were only located in the uppermost sites in the studies in deep, permanent waterholes.

INVASIVE SPECIES

Two introduced fish, Gambusia *(Gambusia holbrooki)* and goldfish *(Carassius auratus)*, occur in the catchment, with both changing in distribution and abundance according to the seasons.

Gambusia prey on native fish larvae and are aggressive to adult native fish, while goldfish increase water turbidity thus affecting aquatic vegetation and can be a vector for disease. While these exotic fish are a concern, their impact appears to be mitigated by the fact that the Cooper system is essentially unregulated and this seems to work in favour of the native species. Similarly, disease rates are relatively low in the native fish and this seems to reflect a natural level in an unregulated environment.

Feral pigs occur in the area and predate on turtles and freshwater mussels. Predation of long lived turtles and mussels from the upper Cooper waterholes is anticipated to be most damaging during periods of drought when populations are concentrated into increasingly smaller aquatic environments. Cane toads were not observed at any sites in this study, but remain an ever present threat to this system.



Gambusia

Feral Pig

ACTIVITIES AFFECTING AQUATIC ECOSYSTEMS

Mining

Rich petroleum and natural gas deposits in the north of South Australia have attracted significant operations in the Cooper Basin. While direct, observable impacts to aquatic fauna 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 Kudnarri Bridges. Both bridges have been observed to bottleneck flow with significant backing up of flood waters above the bridge.

It is anticipated that hydrological and bathymetric effects from these infrastructures will be localised. Perhaps of more concern is the potential for bridges to create an impassable velocity barrier to upstream movement under most flow conditions.

Grazing

Grazing is widespread throughout South Australia's Cooper Creek landscape 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. Gwydir's Crossing site is an example of a heavily impacted waterhole.

Grazing impacts and potential remedial measures should be assessed on a site by site basis. Off-channel watering points coupled with exclusion fencing can constitute an effective approach.

Recreational Fishing

Recreational fishing is a significant activity in the system. Increased signage at key visitation sites is recommended to increase awareness about potential impacts and appropriate fishing practices.

PRIORITIES FOR FUTURE MANAGEMENT

- Maintaining natural flow regimes in Cooper Creek should remain a priority. Natural flows are essential to sustain fish and other aquatic species and to facilitate widespread recolonisation across the system during flood events. Activities that threaten natural flow regimes should be avoided or thoroughly assessed before implementation.
- 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.
- Ongoing fish monitoring in the Innamincka area should be undertaken. While native fish populations appear to be in good shape at the moment, a number of pressures and threats are present and it is important to monitor any changes over time.
- An expanded recreational fishing survey should be conducted in the Innamincka Regional Reserve and interpretive signage relating to fishing should be installed. Recreational fishing can have significant impact and in this remote area where surveillance is difficult, it is important that fishers should be well-informed.
- The impact of activities such as road and bridge building on fish passage and floodplain function warrants further investigation.
- Research funding should be sought to collect comprehensive fisheries data for the Lake Hope fishery.
- Potential implications of cane toad incursion into the SA Cooper system need further investigation.

FURTHER INFORMATION

The information in this summary report is sourced from the technical report:

Schmarr, D.W., Mathwin, R., Cheshire, D.L. and McNeil, D.G. 2012, Aquatic ecology assessment and analysis of the Cooper Creek: Lake Eyre Basin, South Australia. Report by South Australian Research and Development Institute (Aquatic Sciences) to the South Australian Arid Lands NRM Board, Port Augusta.

WATERHOLES AND WETLANDS

KEY POINTS

- Maintenance of riparian vegetation and hydrological connectivity is critical for conservation of waterhole and wetland ecosystems.
- The control of pest plant and animal species, coupled with appropriate stock grazing regimes, is critical to wetland ecosystem conservation and soil (e.g. stream-bank) stability.
- Cumulative visitor impacts are affecting native vegetation and soil stability and need to be managed carefully.
- Permanent waterholes, such as Minkie and particularly Cullyamurra, are vital refuges supporting native fish and other species in the driest of times – thus maintaining species in the system so that recolonisation can occur through the system when wetter times return.

THIS STUDY *aimed to assess the ecological condition, integrity and importance of representative water-bodies and to identify significant threats to those water-bodies.*

The main focus of this report is assessment of the ecological character and condition of aquatic ecosystems with high ecological value.

WATER HOLE ASSESSMENT

The Cooper system in South Australia comprises four distinct aquatic management units and representative water-bodies within each management unit were selected for investigation as follows:

- ➔ Innamincka complex with deep, permanent waterholes, e.g. Cullyamurra Waterhole (WH) and Minkie WH;
- ➔ Coongie Lakes system and North-West Branch, e.g. permanent and semi permanent lakes and waterholes and floodplains, e.g. Scrubby Camp WH, Tirrawarra WH; Kudriemitchie WH, Coongie Lake outflow channel;
- ➔ Central waterholes and Lakes, e.g. Embarka WH, Narie WH, Cuttapirie Cnr WH, Deparanie WH [not assessed due to flooding]
- ➔ Lower catchment waterholes and lakes, e.g. Kudnarri Bridge (not assessed due to access issues), Lake Hope, Lake Killalpaninna and Cuttupirra WH.

A standard rapid assessment methodology has been used in this study which involves assessment of:

- ➔ ecosystem values (plant and habitat diversity, hydrological value, salinity, uniqueness and value as a key aquatic refuge; and cultural heritage value)
- ➔ ecological threats (weeds, exotic animals, surface and groundwater extraction, nutrients)
- ➔ ecosystem pressures (infrastructure development, tourism and recreational activity, soil disturbance, grazing)
- ➔ condition (factors such as spatial and structural integrity given a rating from largely unmodified to severely modified)

Combined assessment of these parameters enables an overall rating (low / medium / high) to be placed against ecological importance, restoration potential and investment priority.

TABLE 1. WETLAND SITE CONDITION SUMMARY

(colours reflect investment priority)

Waterhole	Catchment Section	Catchment Section Investment Priority	Key Aquatic Refuge – Ecological Priority	Threats	Pressures	Site Condition	Connectivity Value
Cullyamurra Waterhole	Upper Cooper main channel	High	High – permanent upper refuge	Exotic plants and feral pigs but minor impacts. Minor water extraction	Visitor impacts: e.g. walking and vehicle tracks	Good	High
Minkie Waterhole	Upper Cooper main channel	High	High – permanent upper refuge	Exotic plants; goldfish and Gambusia present	Visitor impacts: e.g. erosion gullies	Good	High
Scrubby Camp Waterhole	North-west Branch	High	High – permanent upper refuge	Exotic plants; rabbit and grazing impacts	Major erosion channels from access track	Good	High
Tirrawarra Waterhole	North-west Branch	High	High – permanent North-west Branch refuge	Exotic plants and feral pigs but minor impacts. Grazing impacts	Vegetation and soil damage from grazing	Moderate	High
Kudriemitchie Waterhole	North-west Branch	High	Moderate – permanent North-west Branch refuge	Exotic plants including major Buffel Grass infestation; rabbit and historic grazing impacts	Visitor impacts and soil disturbance from rabbits	Moderate	Moderate
Coongie Lake Inflow Channel	North-west Branch	High	Moderate	Exotic plants; rabbits affecting natural regeneration	Visitor access but impacts minor	Moderate	Moderate
Embarka Waterhole	Main Branch	High	High – permanent Main Branch refuge	Exotic plants; minor rabbit impacts and minor water extraction	Grazing impacts; pressures due to proximity to homestead	Good	High
Cuttapirie Corner Waterhole	Main Branch	Moderate	Moderate – semi permanent refuge	Exotic plants and feral pigs but minor impacts	Historic grazing and visitor impacts but none current	Moderate	Moderate
Narie Waterhole	Main Branch	Moderate	Moderate to High – semi-permanent refuge	Exotic plants; high rabbit numbers; stock grazing	Soil and vegetation impacts from stock and rabbits	Moderate	Moderate
Lake Hope shoreline	Lower Cooper Creek	Moderate	Moderate to High – non permanent Lower Cooper lake	Exotic plants; rabbit and camel activity	Soil disturbance from rabbits	Moderate	Moderate
Lake Killalpaninna	Lower Cooper Creek	High	Moderate to High – non permanent Lower Cooper lake	Exotic plants; minor rabbit impacts. Light grazing	Low level soil disturbance from grazing and visitor access	Moderate	Moderate
Cuttupirra Waterhole	Lower Cooper Creek	Low	Moderate – ephemeral Lower Cooper waterhole	Exotic plants; high rabbit numbers	Soil disturbance from rabbits	Moderate	Moderate

SUMMARY OF SURVEY RESULTS

Generally vegetation condition was rated as 'good' (Table 1). There was impact (moderate stream-bank damage) from tourism activity and grazing pressure at some waterholes and an increase in mining activity and infrastructure development affecting floodplain environments. Recreation and tourist visitation at sites had an impact on the landscape through compaction and soil erosion from vehicles and human use and firewood collection. Feral animal grazing from rabbits was a major threat with impacts likely to increase. Vegetation responses such as extensive regeneration of coolibah seedlings and prolific seed production particularly for native grasses were observed due to the favorable conditions. Presently the system is not greatly impacted by any serious weed infestations. However, buffel grass *(Cenchrus ciliaris)* poses a serious future threat and requires management to contain isolated populations at priority sites (e.g. Kudriemitchie Outstation and Minkie Waterhole).

RIPARIAN VEGETATION A KEY COMPONENT

Riparian vegetation is a key component of the Cooper Creek condition, particularly perennial, long-lived structural canopy species such as coolibah *(Eucalyptus coolabah)* and river red gum *(Eucalyptus camaldulensis)*. The episodic establishment of these species after the recession of large floods is an important process.

Good seasons provide opportunities for widespread recruitment through seed germination. Without this recruitment, albeit at infrequent intervals, there will be no replacement for mature trees and shrubs as they mature and die and the whole vegetation structure and its associated ecosystems will change significantly.

THE MAIN THREATS

The Cooper Creek in SA is an unregulated system and an important biodiversity corridor. It is critical periodic flow, connectivity and environmental flow requirements are maintained to ensure healthy ecosystem function. Sedimentation through lack of major hydrologic flushing processes can further reduce the capacity of the channel to hold water so that persistent pools are reduced in number and temporal quality. Development of artificial barriers (culverts, flood mitigation barriers, crossings etc) has the potential to reduce connectivity between refuge areas and other parts of the system (e.g. floodplains).

Major threats and pressures include:

- Aquatic feral species (e.g. Gambusia and goldfish and potential cane toad infestation) modifying the natural biotic systems. Feral aquatic species have the potential to displace native species and substantially disrupt natural ecosystems. They can also disrupt commercial and recreational fisheries. This effect is likely to be exacerbated if natural flow regimes are also impacted.
- Recreation and tourism impacts (eg compaction, trampling and removal of firewood). Soil disturbance may lead to siltation of waterholes, while firewood removal takes away habitat and reduces the potential for tree hollows to develop, as needed by a range of native fauna.
- Overgrazing causes loss of vegetation cover and habitat diversity and increased erosion in turn adding to siltation of waterholes. Grazing of young seedlings can destroy a generation of new plants, substantially damaging vegetation structure.
- Water resource development (irrigation, flow diversions, infrastructure development and dams) disrupting natural flow regimes. Significant changes to flow regimes would have enormous implications for survival and recolonisation of a range of animal and plant species that underpin the ecology of the system.
- Climate change impacts including predicted increases in temperature would lead to increased evaporation, longer drought conditions and reduced periods of inundation and waterhole permanency.
- Contamination and aquatic pollutants have the potential to greatly disrupt the local wetland ecology. For example, high nutrient levels cause excessive algal growth, in turn depleting oxygen levels to the detriment of aquatic fauna.
- Unsustainable resource use such as illegal fishing or over-fishing has the potential to deplete native fish populations to the point that they are not sustainable in the longer term.
- Weed invasions from upper reaches in Queensland establishing permanent terrestrial and aquatic weed populations have the potential to displace native species, with flow-on effects that can affect the ecology of the whole system.


Localised livestock impacts


Soil compaction and erosion gully


Firewood removal


Floodplain incision

WATERHOLES

Waterholes can be classified as permanent if they have a cease to flow depth of greater than 4 m. This depth exceeds the evaporative demand estimated at approximately two metres per annum for the South Australian Arid Lands region and before the next flow occurs. These refuge water bodies are those that persist for at least 18-24 months without receiving inflow. Deep, permanent waterholes, such as Cullyamurra and Minkie, are critical refugia in providing habitats for fish and other aquatic species when other wetlands have dried up. This provides a pool of species able to recolonise the system when further flooding occurs.

PRIORITIES FOR FUTURE MANAGEMENT

Management

- Maintain environmental flow regimes throughout the Cooper Catchment particularly at upstream reaches in Queensland. As noted, disrupted flow regimes would affect the ecological sustainability of the whole system. This is not just an issue for nature conservation. Natural flooding regimes are essential for maintaining nutrient levels on floodplains, thus maintaining a grazing resource for both native animals and pastoral livestock. Natural flow regimes support fish stocks and maintain a healthy system that is a focus for tourism.
- Build knowledge and understanding of best practice grazing management strategies at key waterholes and trial grazing management strategies at high ecological value aquatic ecosystems.
- Promote best practice tourism management at key tourist sites associated with priority waterholes. Encouragement of best practice will not only help conserve natural ecosystems – it will also help to maintain the tourism industry by keeping prime attractions in good condition.
- Monitor and control weed and feral animal infestations particularly buffel grass, cane toads and rabbits. Pest species are in nobody's interests: they damage natural ecological processes, disrupt primary production and disturb amenity values with flow-on effects for tourism.

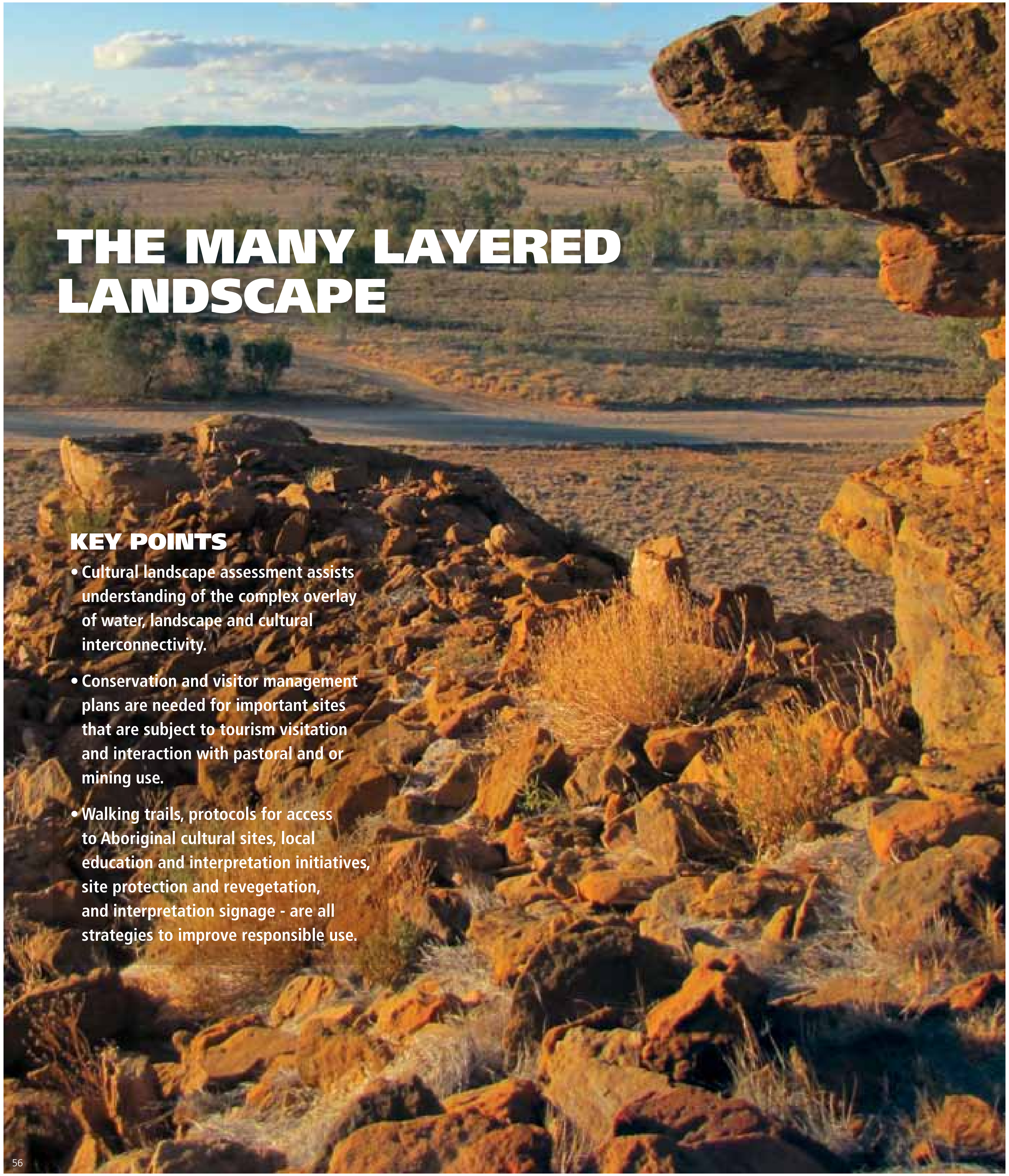
Research and Monitoring

- Assess further sites to improve understanding of riparian and floodplain vegetation dynamics. While this project has provided a good overview of key representative sites there are many other important sites that have not yet been assessed in detail.
- Investigate recruitment triggers and success of key perennial species such as coolibah and river red gum. Our knowledge of regeneration processes for species such as these in the arid zone is incomplete and, particularly with climate change effects looming, more information is needed to assist management of these processes.
- Address knowledge gaps relating to floodplain ecology and nutrient and energy cycling. Again, we have limited knowledge about nutrient and energy cycling on floodplains.
- Improve understanding of climate change scenarios and their likely effects. On the basis of current knowledge, the Cooper system will change as a result of climate change – irrespective of any other human-induced changes.
- Undertake monitoring to track changes in condition at high priority waterholes and test management interventions through appropriate monitoring and evaluation processes.

FURTHER INFORMATION

The information in this summary report is sourced from the technical report:

Mancini, H. (2012) Ecological condition assessments of Cooper Creek (SA) wetlands. South Australian Arid Lands NRM Board, Pt Augusta.



THE MANY LAYERED LANDSCAPE

KEY POINTS

- Cultural landscape assessment assists understanding of the complex overlay of water, landscape and cultural interconnectivity.
- Conservation and visitor management plans are needed for important sites that are subject to tourism visitation and interaction with pastoral and or mining use.
- Walking trails, protocols for access to Aboriginal cultural sites, local education and interpretation initiatives, site protection and revegetation, and interpretation signage - are all strategies to improve responsible use.

THIS STUDY *describes important cultural aspects of the Cooper Creek's landscape. Four broad themes are identified – the Conservation Landscape, Industrial Landscape, Productive Landscape and Storied Landscape.*

The physical features of natural ecosystems of particular cultural significance, and the human influences that may be impacting on their condition, are investigated. Environmental, economic, cultural and social values associated with landscape features such as watercourses and their riparian and flood zones, are identified using a landscape design approach.

PLANS AND PLANNING

Underpinning direction is provided by a range of existing plans and strategies. These include;

The South Australian Arid Lands Regional Natural Resources Management Plan 2010; nominates key conservation issues such as excessive grazing, pest plants and animals, soil erosion, disruption of natural flows, decline in water quality, inappropriate vehicle access, poorly maintained infrastructure and inadequate response to climate change events.

The Biodiversity Strategy for the South Australian Arid Lands 2009; nominates priority actions that include improving ecological knowledge, decision making and capacity, reducing the impact of climate change, invasive species, total grazing pressure, and land use pressure on biodiversity.

The South Australian Government, through Planning SA, 2008; identifies priority issues relating to expanded mining activity, changing employment opportunities, retention of character, and workforce planning.

The South Australian Pastoral Board; facilitates public access via public access routes (PARs) which are an ongoing source of management concern due to remoteness and need for maintenance and appropriate signage.

The South Australian Tourism Plan 2009-2014; provides limited direction for the Cooper Creek region, however principles include community and visitor held landscape values combined with conservation of natural and historic features.

Outback Communities Authority Strategic Management Plan 2011 – 2015; identifies issues including: increased mining and tourism activity, planning and policy development and standards of infrastructure provision, availability and capacity of community volunteers, and fundraising capacity.

The Lake Eyre Basin Intergovernmental Agreement; focuses on sustainable management of the water and related natural resources associated with cross-border river systems in the Lake Eyre Basin to avoid downstream impacts on associated environmental, economic and social values.

UNDERSTANDING LANDSCAPE FEATURES

The geology of the Cooper Creek and the 35,000 square kilometre Cooper Basin region is diverse (Fig. 1). The landforms of the Channel Country river systems, swamps and wetlands in the north-east, merge into the dune-fields, playa lakes, dry creeks and floodplains to the west. Along the Cooper Creek the gibber plains and the stony plateaux towards Kati Thanda-Lake Eyre further demonstrate the variation.

Over 500 million years the various layers set down during cold and dry periods were interspersed by warm and wet times with forest growth, lakes and swamps. The oil and gas seams and mudstones of the Cooper Basin resulted from the deposits of these warmer times. The sandy dune-fields developed during arid and windy drier times through lake evaporation that exposed significant limestone sheets.

Figure 1. *Cooper Creek Catchment (SA Section) stretching from beyond the Queensland border to North Lake Eyre indicating the Cooper Creek Channel, major geological and landscape features and named places.*

ABORIGINAL OCCUPATION

The Dieri and the Yandruwandha and Yawarrawarrka peoples, over thousands of years, introduced a range of fire and localised water resource management practices that have subtly modified the landscape. Traditional practices and layers of knowledge of land and aquatic systems have built up over time. The Cooper Creek landscape comprises multiple cultural sites, particularly associated with waterholes, lakes and wetlands and their nearby dunes. Water places are frequently named in both Aboriginal and non-Aboriginal language.

SETTLEMENT AND INDUSTRY

The only permanent settlements beyond Innamincka and Moomba on the Strzelecki Track are pastoral homesteads. A number of ruins of early settlements defeated by drought are marked and interpreted along the Tracks. Semi-permanent mobile mining camps now dot the designated mining areas to the east and west of Innamincka, linked by good quality unmade roads.

Although land use is predominantly designated as pastoral leasehold, with mainly cattle production on the floodplains, the study area is also characterised by extensive mining through gas or oil exploration and extraction operations in the Cooper Basin.

Once extensive pastoral leases, the Innamincka Regional Reserve, Coongie Lakes National Park and the Strzelecki Regional Reserve are now co-managed for conservation by the SA Government, yet also support a range of multiple-use activities including pastoralism, mining and tourism.

ENVIRONMENTAL AND CULTURAL WATER

'Water for the environment', also referred to as 'environmental flows', includes both surface and groundwater systems. It refers to the amount and pattern of flow needed to provide sufficient water to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity.

In Indigenous terms, water in the living cultural landscape is inseparable from land, people, ancestors and social relations. The idea of 'cultural flows' - meaning the importance of sufficient quality waters legally available to support and improve traditional, healthy and economically beneficial lives – must be regarded as overlapping with environmental water. The conception and management of cultural flows needs ongoing input of Indigenous people on their country.

CRITICAL ISSUES

Key issues were raised by a range of stakeholders consulted in this study. These included; the dynamics of arid zone water regimes, access to water, flood, drought and recovery, changing resource use; mining, pastoral, tourism practices and community awareness of cultural values, involvement of Aboriginal stakeholders in expanded programs, impacts upon riparian zones adjacent to waterholes and water points, communication, information and access, and government programs and support.

Figure 2. *Three distinct water feature types; the typical inland river channel (main), the western lake white/grey shoreline adjacent the channel floodplain (top right), and the southern ochre/pink dunefield margins (bottom). Images; June 2013.*

CULTURAL LANDSCAPE MATRIX

A cultural landscape matrix is an organisational tool that includes freehand sketch mapping (not to scale), systematically recorded site notes, interpretation of aerial imagery, illustrative photographic imagery and collection of materials and vegetation that contribute to the character of a place. The resultant matrix forms a common language basis for ongoing communication. In this study a total of thirteen waterhole systems and four lakes are assessed in this way.

SITE REPORT – COONGIE LAKE*

*The Coongie Lake (summarised) site report is selected as an example of a site report.

The expansive Coongie Lake is a permanent feature of the important Coongie Lakes wetland landscape. The low gradient of the surrounding landscape forms the lake - which is at most less than 2 metres deep – and the adjacent lakes. Where the channel of the Cooper Creek's North-west Branch enters the lake it diverges into two channels that finally flow beyond the lake margins forming a small delta of deposited sediment and a constrained floodplain. A natural area for sheltered occupation and use is formed here.

Where the Creek channel enters the Lake, the low plain is typified by clay, sand and silty soils that provide rich habitat for aquatic fauna and vegetation. To the south, where the sandy dunes intersect the Lake, the trees thin out to line the shoreline margins with some zones of coolabah, grasses and rushes transitioning to whitewood, sandhill wattle and sandhill canegrass.

Three distinct water feature characters types provide diversity; the deeper Branch channel flows linearly, the shallow floodplain lake is affected by silting and flooding regimes, and the sandy lake is defined by intersecting dunes and dune plains (Fig. 2).

The area is designated a National Park and Ramsar Wetland and co-management regimes are applied. A small campground and ablution facilities is located at the confluence of the North-west Branch channel and Lake. Alternative southern campsites line the lakeside in a variety of low white sandy beach and swampy wetland sites (Fig. 3).

Evidence of long-term occupation of the area by the traditional owners, the Yandruwandha and Yawarrawarrka peoples, is found in the shell middens visible over great areas of the adjacent floodplains and dunes adjacent to the Lake.

Figure 3. *The Coonglie main eastern campsite area on the channel and lakeside 'wild' campsites. Image: Sep 2012.*

PRIORITIES FOR FUTURE MANAGEMENT

- Implementing sound management strategies for waterbodies in the Cooper Creek Catchment, in particular the Innamincka Complex of waterholes, Coongie Lakes, Lake Hope and Lakes Killalpaninna and Kopperamanna.
- Increased access to information websites where waterbodies can be located with GPS technologies, and a network of mining industry roads, means some sites have become more vulnerable to visitor impacts – management is required to ensure appropriate use.
- Educational programs – including community participation, illustrated print materials, web based materials, and published protocols for the mining industry – promotes responsible use.
- Graphically informative interpretation signs at key sites are needed to raise visitor awareness of culturally important sites, ecological and landscape systems and their fragility to human generated impacts, and pastoral and mining history and operations.
- A program to document and tell the Yandruwandha and Yawarrawarrka and Dieri communities' knowledge will assist in both future planning of sites for visitation, or for protection from visitation, and ensuring culturally important material about the landscape and its people is kept.

FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Lee, G. 2013. Landscape assessment and analysis of the Cooper Creek Catchment (SA Section). A report by the University of Melbourne to the South Australian Arid Lands Natural Resources Management Board. Port Augusta.*

Technical Reports

This report summarises information sourced from the Managing the High Ecological Value Aquatic Ecosystems of the Cooper Creek Catchment (SA section) technical reports:

Geomorphology

Wakelin-King, Gresley A., 2013. Geomorphological assessment and analysis of the Cooper Creek catchment (SA section) October 2012, Report by Wakelin Associates to the South Australian Arid Lands Natural Resources Management Board.

Wakelin-King, G.A., 2013, Cane Toads and South Australian Arid Lands Geomorphology. Report by Wakelin Associates to the South Australian Arid Lands Natural Resources Management Board, Port Augusta

Hydrology

Costelloe, J.F., 2013. Hydrological assessment and analysis of the Cooper Creek catchment, South Australia, Report by the University of Melbourne to the South Australian Arid Lands Natural Resources Management Board.

Vegetation and Soils

Gillen J.S., and Reid J.R.W., 2013. Vegetation and soil assessment of selected waterholes of the main and northwest channels of Cooper Creek, South Australia, April-May 2012, Report by the Australian National University to the South Australian Arid Lands Natural Resources Management Board.

Riparian Birds

Reid, J.R.W., and Gillen, J. S., 2013. Riparian bird assemblages of Cooper Creek, South Australia April-May 2012, Report by the Australian National University to the South Australian Arid Lands Natural Resources Management Board.

Ecological Assessment of Wetlands and Waterholes

Mancini, H., 2013. Ecological condition assessments of Cooper Creek (SA) wetlands. South Australian Arid Lands NRM Board

Aquatic Ecology

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 South Australian Research and Development Institute (Aquatic Sciences) to the South Australian Arid Lands NRM Board

Cultural Landscape Assessment

Lee, G. 2013. Landscape assessment and analysis of the Cooper Creek Catchment (SA Section). A report by the University of Melbourne to the South Australian Arid Lands Natural Resources Management Board. Port Augusta.

Additional information was sourced from:

Jeansch, R., 2009. Floodplain Wetlands of the Channel Country. South Australian Arid Lands Natural Resources Management Board.

Notes

Australian Government

Government of South Australia
South Australian Arid Lands Natural Resources Management Board