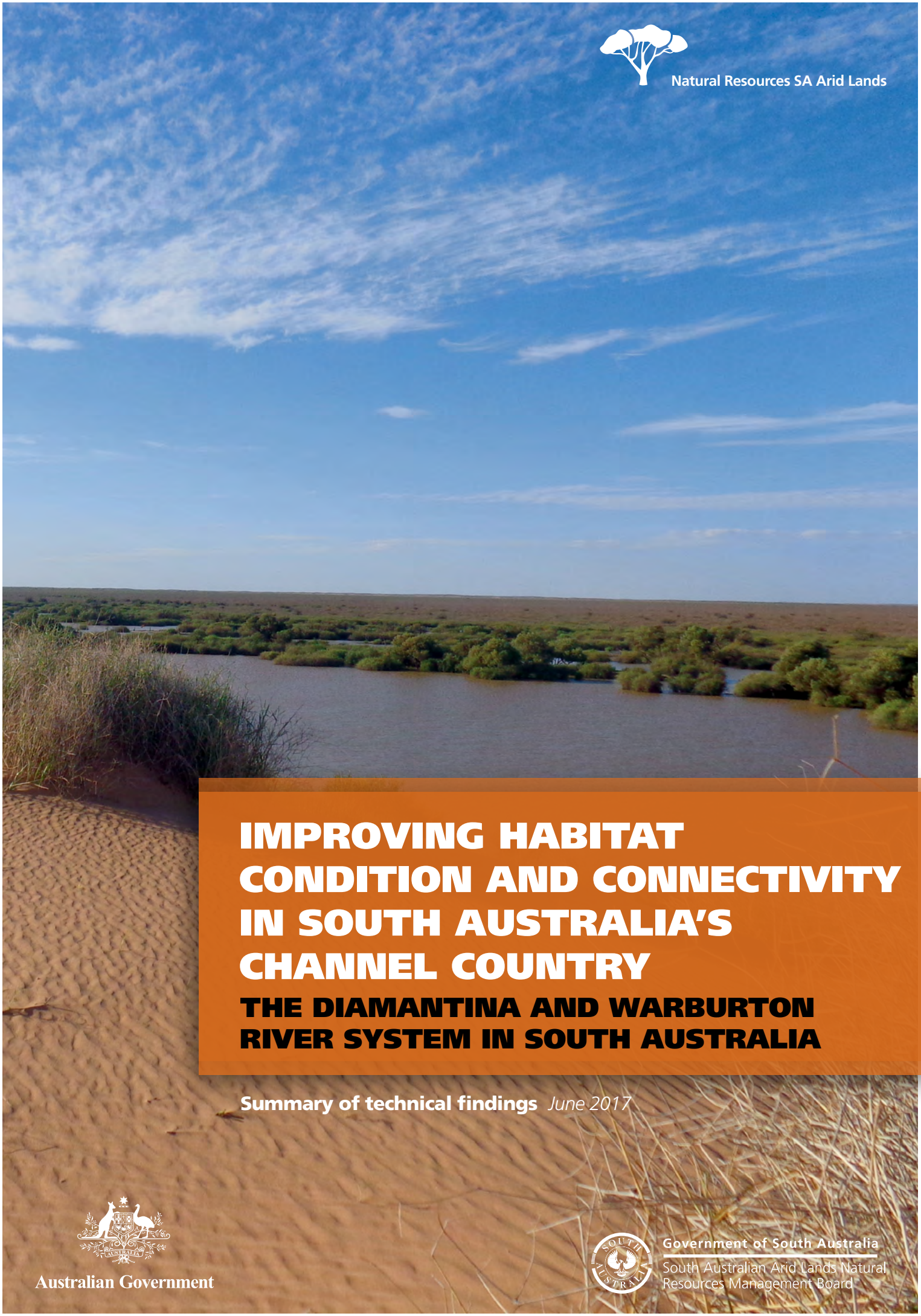

Natural Resources SA Arid Lands

IMPROVING HABITAT CONDITION AND CONNECTIVITY IN SOUTH AUSTRALIA'S CHANNEL COUNTRY

THE DIAMANTINA AND WARBURTON RIVER SYSTEM IN SOUTH AUSTRALIA

Summary of technical findings *June 2017*

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 2017

Cover photograph:
Koonchera Waterhole, 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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Government of South Australia
South Australian Arid Lands Natural Resources Management Board

Diamantina River

CONTENTS

The Lake Eyre Basin contains some of the few remaining naturally functioning, unregulated dryland river systems on earth.

The biodiversity values of the Diamantina River critically depend on maintaining this natural hydrological regime.

Lower Warburton River

Lower Warburton River

A vital component of the Diamantina catchment is its people, Aboriginal Traditional Owners, pastoralists, conservationists, industry and business operators and the array of people that visit the region.

There is a long and continuous Aboriginal history in the Diamantina catchment and a rich and complex culture that reflects connection with Country. Dreaming stories, traditional knowledge and language are alive and relevant today.

There is also a long history of pastoral enterprise that has contributed to the social fabric and unique nature of this region. Pastoralism and other industries bring together a community that is eager to work towards protecting the unique values of this country.

People living in the Diamantina River catchment know it is unique globally, it is presently unregulated and they want to keep it that way.

A community initiative that will drive long-term stewardship is succession planning involving the Birdsville Track community. This involves Traditional Owners, pastoralists and business owners working together to promote intergenerational participation in research and land management. Involvement in collecting data on fish, birds, and plants will encourage interest and lead to greater understanding and knowledge of system function to identify priorities for sustainable land management actions. This will promote continued management of this landscape to pass on to future generations.

Sharing and learning about our Country – bringing us all together

– *Mungerannie Community Workshop 10 May 2017*

This document summarises the activities and findings of the Australian Government funded project titled: "Improving habitat condition and connectivity in South Australia's Channel Country" 2013–2017. Referred to as the "Channel Country Project". The South Australian

STATEMENTS OF SIGNIFICANCE

reaches of the Georgina–Diamantina River catchment are characterised by iconic waterbodies and wetlands, such as Goyder Lagoon, Diamantina and Warburton Rivers, Eyre Creek and Kallakoopah Creek. The catchment has an unregulated flow regime with low water extraction and is a significant example, at a global scale, of a low gradient, intermittent, dryland river characterised by the 'boom and bust' dynamics that are characteristic of Australian arid and semi-arid environments. The boom-bust sequence is driven by the inter-annual variability in flow, with the Diamantina River having one of the most variable flow regimes in the world.

The Channel Country project aimed to gain a greater understanding of the interrelationships between landuse practice, such as pastoralism, mining, conservation, tourism and cultural heritage management, and the biophysical attributes and ecological processes that underpin a healthy functioning landscape. The project applied a multi-disciplinary based approach across a range of sciences to improve knowledge at the landscape scale.

Assessments were undertaken at 23 sites at permanent and semi-permanent waterholes; saline pools; and associated floodplain ecosystems of the lower Diamantina River and Warburton–Kallakoopah Creek system in SA. The identification of distinct zones based on distribution of flow and location of aquatic refugia provides a framework for dividing the Diamantina–Warburton system in South Australia into four management zones to facilitate a coordinated approach to management decisions.

The SA reaches of the Diamantina River have very high environmental value, with the Goyder Lagoon area often supporting large waterbird populations. The SA reaches of the Diamantina River are the centre of an extensive cattle grazing industry, with a number of Stations being run as organic beef properties and one property operating as a wildlife conservancy. The Birdsville Track is a focus for outback tourism but there is relatively little tourism interaction with the Diamantina and Warburton Rivers due to few access points from the Birdsville Track. Extractive oil and gas and exploration activities are currently operating at low levels compared to the Cooper Creek catchment.

The Diamantina catchment has received much less research activity in comparison to other catchments in the LEB. This limits the capacity of communities to work with government authorities to identify and manage key aquatic refugia in the catchment and to monitor hydrological change affecting flooding patterns that could occur from predicted climate change scenarios; and upstream landuse activities involving water extraction and infrastructure development.

This was emphasised at the community workshop:

> **"a considered, truly regional approach is needed to determine the most efficient and effective cross-jurisdictional policy settings that involve local community, State, cross-border and Federal authorities"**
>
> – *Community Workshop 10 May 2017, Mungerannie Hotel*

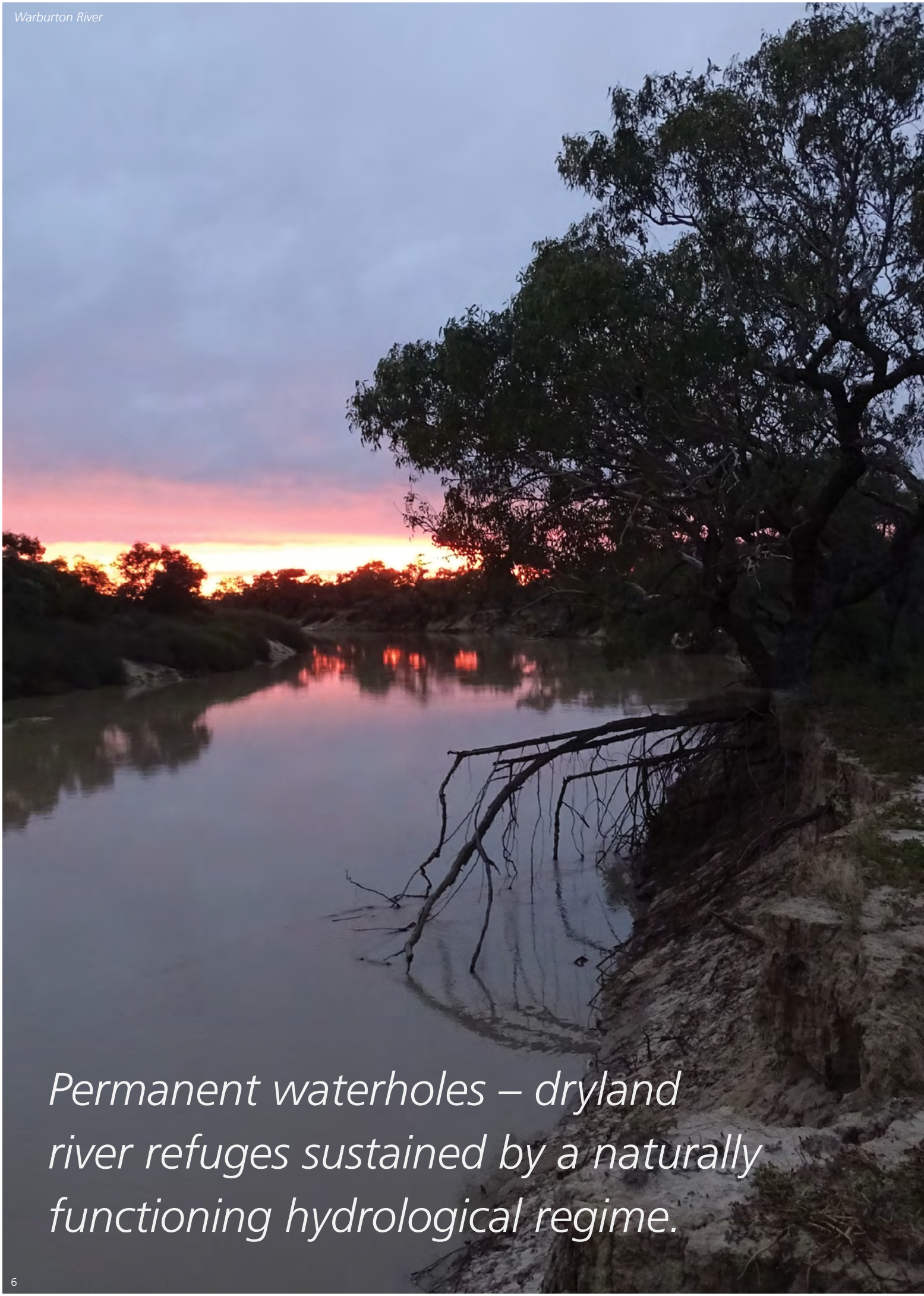
It is important the entire catchment is viewed holistically at the landscape system level. Hydrological function is the key driver of the system. This healthy ecosystem function is underpinned within this dryland river system through the natural variability and the unregulated nature of the hydrological regime.

It is important to note the system does not only comprise of waterholes and river channels but is an integrated hydrological system connected to adjacent floodplains and landscape features, including gibber plains and dunefields. Flooding events provide the mechanism to drive important nutrient cycling between the riparian channel and floodplain that sustains its high productivity for cattle grazing and biodiversity.

Identifying and mitigating against threats and pressures that have the capacity to disrupt the natural variability and functioning of the system are a basic requirement.

Any attempt to regulate the flow of the system or to extract water for mining or irrigation development will lead to a negative trajectory impacting the system's natural biophysical processes.

Maintaining the natural flow regime is essential.



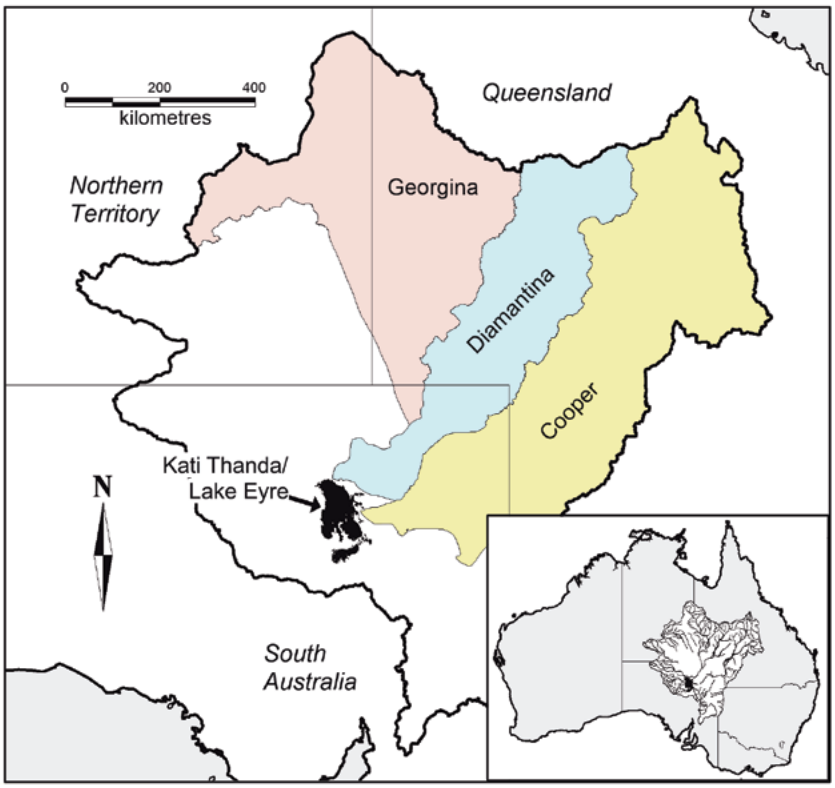
Warburton River

Permanent waterholes – dryland river refuges sustained by a naturally functioning hydrological regime.

SETTING THE SCENE: SOUTH AUSTRALIA'S CHANNEL COUNTRY

A SNAPSHOT

The South Australian Channel Country occupies an area of 56,000 square kilometres (sq. km) in the far north-eastern corner of South Australia. The Cooper Creek, Diamantina River, and to a lesser extent the Georgina River, are its iconic desert channels. They support an internationally exceptional suite of ephemeral and semi-permanent wetlands that vary in their size and response to climate and variable flooding frequencies. These systems are recognised nationally and internationally as unique and unregulated water resources which support systems of unique biodiversity.



Lake Eyre Basin, showing Diamantina River Catchment (Map source: Wakelin Associates: Rivers Assessment (DEWHA))

The Channel Country derives its name from the multi-channelled nature of the rivers, that in their entirety spreads across parts of two states and one territory: Queensland, South Australia and the Northern Territory. The Channel Country rivers are ranked as the most highly variable in the world, and flood and flow toward (but only periodically reaching) Kati Thanda–Lake Eyre, the terminal point in this inwardly draining system. Flows from the Diamantina reach Lake Eyre approximately every second year.

Kati Thanda–Lake Eyre, which contains the lowest natural point in Australia (15 m below sea level), is in Australia's largest inland draining system, the Lake Eyre Basin (LEB). The basin occupies about one-seventh of the Australian continent (1.14 million sq. km).

The basin is located in one of the most extreme climatic regions of Australia. Very dry hot summers are contrasted only briefly by short dry winters. Summer temperatures can exceed 50 degrees Celsius and annual rainfall is less than 250 mm in the central part of the Basin. Highly unpredictable and variable rainfall events can stimulate widespread annual and ephemeral plant responses – a carpet of wildflowers.

The Channel Country river system has a more reliable moisture regime supporting long-lived perennial vegetation communities. The reliability of parts of the system is driven by regular flooding resulting from the annual incursion of monsoonal rain events in the upper Queensland catchment. In most years, Channel Country rivers stop flowing completely for at least a few months.

The aquatic organisms of the Channel Country have life histories that reflect the highly variable 'boom' and 'bust' ecology of these ecosystems. The cycle of drought and flooding influences a range of plant adaptations. Ephemeral plants exhibit a short life-cycle in response to ephemeral rainfall events. Perennial plants such as the Coolibah (*Eucalyptus coolabah*) associated with more reliably watered river systems are long-lived with extensive root systems to cope with periods of drought.

Reliable sources of water are also at the core of traditional, historic and contemporary human activity in the area. Archaeological fieldwork places Aboriginal occupation in this landscape at around 40,000 years before present (BP). Times of periodic flood and then times of plenty determined periods of intense socialisation, occupation, movement and trade.

A large part of land in the Basin is used for grazing cattle and sheep, though numbers fluctuate greatly and considerable skill is required on the part of graziers.

PROJECT OBJECTIVES

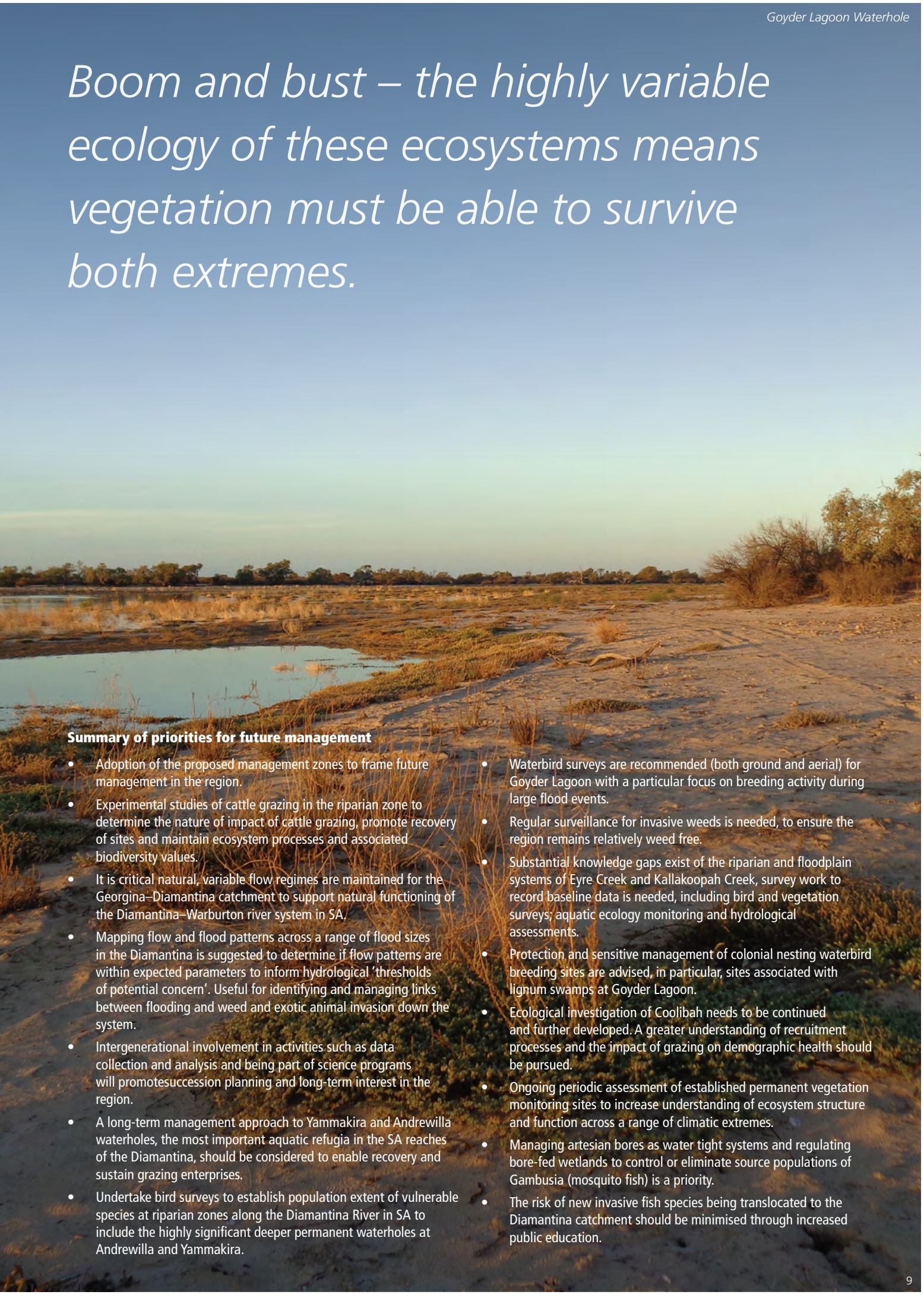
The Channel Country Project investigated the ecological, cultural, economic and biophysical values of the South Australian section of the Diamantina catchment. It also identified and assessed a range of threats and impacts upon these ecosystems, thus providing a basis to identify ecological importance, and investment and management priorities through a greater understanding of the present and potential impacts facing these important natural assets.

PROJECT APPROACH

The Channel Country Project adopted a holistic, multi-disciplinary approach to data gathering and analysis, which included investigations in geomorphology, hydrological monitoring and assessment, aquatic ecology (fish monitoring), ecological condition assessment and terrestrial ecology assessments of plants, soils, and birds.

The landscape scale approach adopted for the project provided a means of assessing a broad range of habitats and aimed to not only assess biodiversity issues but to also address issues relating to local business enterprises (pastoralism; tourism; mining and exploration); the challenges of climate change; and the health and social benefits of the environment.

A major component of the study was the state and recruitment of the keystone species, *Eucalyptus coolabah*. Alongside these studies the human imprint on the landscape formed an important aspect and the study sought to identify the cultural and social values, attitudes and management implications relating to tourism, visitor management, and Aboriginal cultural site management options. The outcomes provide the basis of a management strategy for this region.

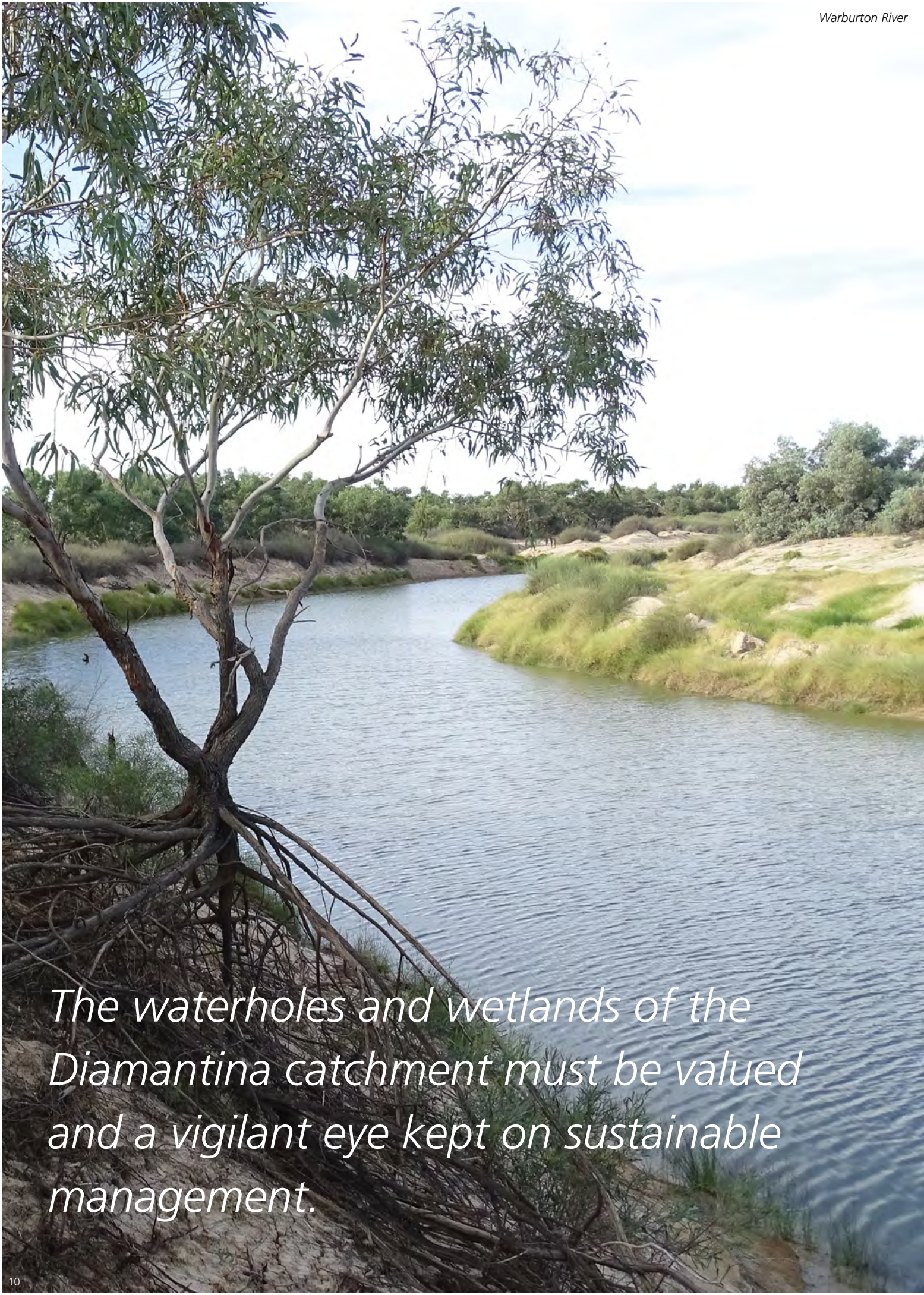


Goyder Lagoon Waterhole

Boom and bust – the highly variable ecology of these ecosystems means vegetation must be able to survive both extremes.

Summary of priorities for future management

- Adoption of the proposed management zones to frame future management in the region.
- Experimental studies of cattle grazing in the riparian zone to determine the nature of impact of cattle grazing, promote recovery of sites and maintain ecosystem processes and associated biodiversity values.
- It is critical natural, variable flow regimes are maintained for the Georgina–Diamantina catchment to support natural functioning of the Diamantina–Warburton river system in SA.
- Mapping flow and flood patterns across a range of flood sizes in the Diamantina is suggested to determine if flow patterns are within expected parameters to inform hydrological 'thresholds of potential concern'. Useful for identifying and managing links between flooding and weed and exotic animal invasion down the system.
- Intergenerational involvement in activities such as data collection and analysis and being part of science programs will promotesuccession planning and long-term interest in the region.
- A long-term management approach to Yammakira and Andrewilla waterholes, the most important aquatic refugia in the SA reaches of the Diamantina, should be considered to enable recovery and sustain grazing enterprises.
- Undertake bird surveys to establish population extent of vulnerable species at riparian zones along the Diamantina River in SA to include the highly significant deeper permanent waterholes at Andrewilla and Yammakira.
- Waterbird surveys are recommended (both ground and aerial) for Goyder Lagoon with a particular focus on breeding activity during large flood events.
- Regular surveillance for invasive weeds is needed, to ensure the region remains relatively weed free.
- Substantial knowledge gaps exist of the riparian and floodplain systems of Eyre Creek and Kallakoopah Creek, survey work to record baseline data is needed, including bird and vegetation surveys; aquatic ecology monitoring and hydrological assessments.
- Protection and sensitive management of colonial nesting waterbird breeding sites are advised, in particular, sites associated with lignum swamps at Goyder Lagoon.
- Ecological investigation of Coolibah needs to be continued and further developed. A greater understanding of recruitment processes and the impact of grazing on demographic health should be pursued.
- Ongoing periodic assessment of established permanent vegetation monitoring sites to increase understanding of ecosystem structure and function across a range of climatic extremes.
- Managing artesian bores as water tight systems and regulating bore-fed wetlands to control or eliminate source populations of Gambusia (mosquito fish) is a priority.
- The risk of new invasive fish species being translocated to the Diamantina catchment should be minimised through increased public education.


Warburton River
The waterholes and wetlands of the Diamantina catchment must be valued and a vigilant eye kept on sustainable management.

MAIN FINDINGS

The Diamantina River system is an internationally rare example of a naturally functioning dryland river system. The naturally functioning hydrological regime operating at the catchment level has not been significantly disrupted by human induced regulation. As such the whole system provides a valuable reference system.

As important as the rufugial waterholes undoubtedly are, the enormous biological productivity of the aquatic system – from aquatic plankton to the macroinvertebrates, fish and waterbirds – lies in the major floodplain wetlands, particularly Goyder Lagoon. For instance, at times these wetlands support more than half a million waterbirds

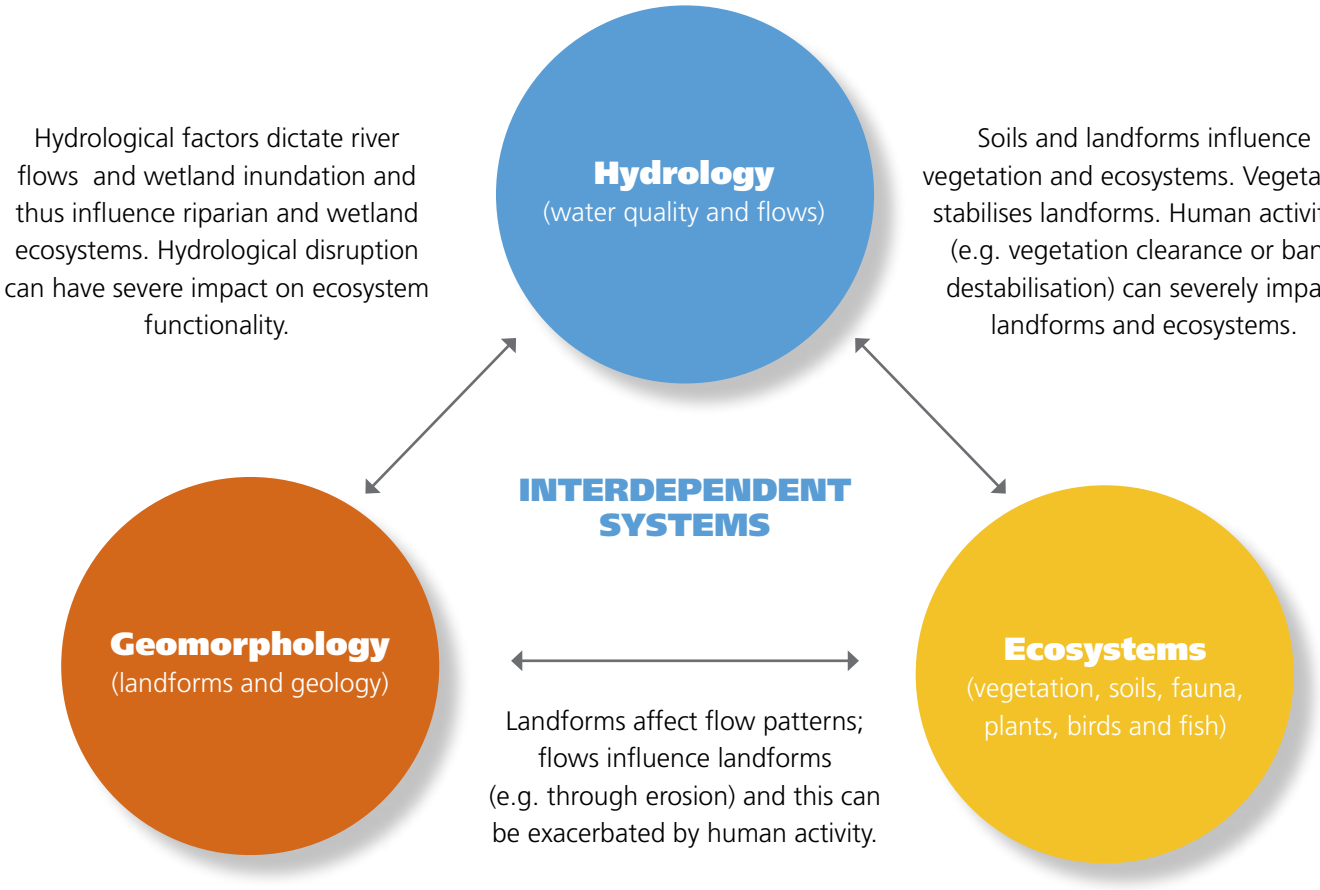
The waterholes, wetlands and floodplains of the Diamantina catchment must be valued. Sustainable management methods, ongoing research and community collaboration must work to mitigate threats and pressures, and continue to increase the understanding of its ecological functioning, ecosystem dynamics and cultural importance.

The multi-disciplinary approach emphasises these interconnections, the links between landforms, hydrology and ecosystem functionality, and the relationships between natural systems and human activity.

Key findings emphasise the importance, in particular, of the Diamantina Management Zone (shown in the map on pages 14 and 15), that includes Andrewilla and Yammakira waterholes, which provide high ecological value aquatic refuges within the SA section of the Diamantina catchment.

There is a moderate to high impact on vegetation structure from stock grazing and feral herbivore activity at some waterholes. Weed infestation is low and feral animal control is ongoing, maintaining relatively low numbers of invasive species. Coolibah (*Eucalyptus coolabah*), as the dominant perennial, is a vital component of the riparian vegetation of the Diamantina/Warburton River system; Coolibah has a major role in contributing to and supporting the biodiversity of the system and as such should be viewed as a keystone species influencing directly and indirectly biotic and abiotic processes supporting a broad range of associated taxa.

The cultural significance of the permanent waterholes also elevates their importance and forms the foundation of many Dreaming stories. It is hoped a combined approach to their management will be an ongoing priority enabling Traditional Owners to participate actively



Representation of interdependency between systems

in research, monitoring and management decisions and activities.

With no large-scale hydrological modifications, the wetlands of the Diamantina and Warburton river systems are resilient self-regulating systems that depend on the maintenance of natural flow regimes, the absence of flow modification and water abstraction, and variable flooding frequencies. Flooding is a major natural disturbance, providing the key driver for species dispersal, recruitment and nutrient exchange. If the landscape processes are working well, floods can repair and maintain the land's structure, reducing pressures on ecosystems.

Maintaining strategic weed and pest animal management programs, managing total grazing pressure, and managing recreational visitor impacts on accessible and well-used waterholes are key factors in maintaining the integrity of these waterholes and wetlands.

Grazing impacts (from stock and feral herbivore activity) have occurred in the vicinity of the more permanent water sources on the Diamantina and Warburton Rivers, with moderate to high impact on vegetation structure.

Slightly over half (13) of the 22 assessed riparian sites had low to moderate degrees of impact, and the other nine sites were rated as moderate to high total grazing pressure. At locations like Andrewilla waterhole, where the topography and the sandy clay soils make landforms susceptible to erosion, the loss of perennial vegetation cover can exacerbate gullying and scalding, while limiting the landscape's ability to recover.

Tourist visitation rates are low, and tourism and recreation activity is seasonal with few access points to river frontages. There is also negligible mining activity. Consequently there is currently little infrastructure development affecting waterhole and floodplain environments and the natural flow regimes, minimising the external pressures on the system at the landscape scale. However, the region is becoming increasingly popular with tourists seeking an 'Outback' experience, and oil, gas and mineral exploration activities are slowly gathering momentum.

Warburton River channel

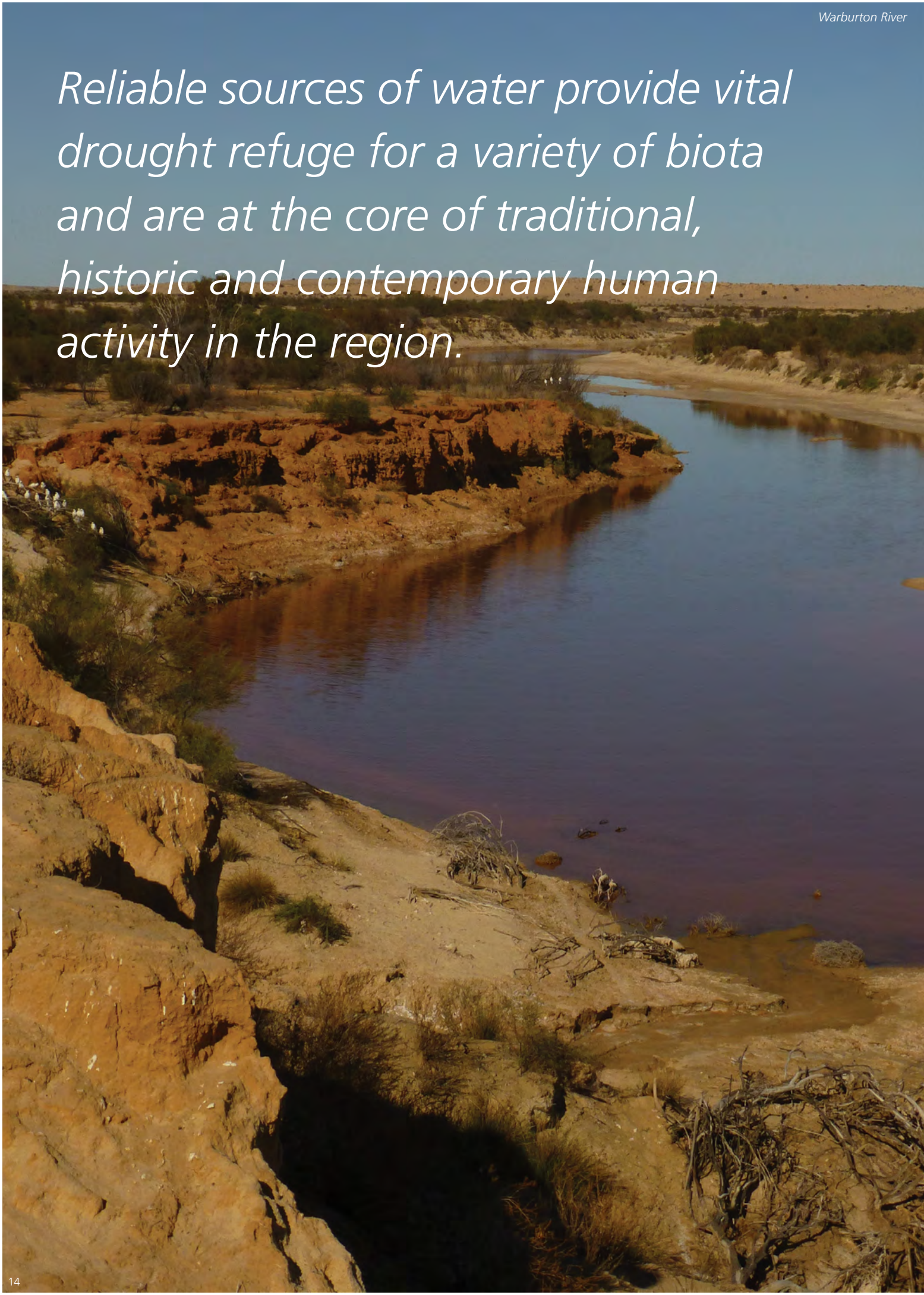
Warburton River channel

FOR FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Mancini, H. 2017. Riparian habitat values assessment of the Diamantina River catchment; Lake Eyre Basin, South Australia. Report by Natural Resources SA Arid Lands DEWNR to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.*

KEY POINT SUMMARY TABLE

Management zones	The distribution of flow and location of aquatic refugia provide a framework for dividing the Diamantina–Warburton system in South Australia into management zones. Proposed management zones: **Diamantina main channel** Birdsville to Goyder Lagoon. Contains the deepest and most permanent waterholes in the region – Andrewilla and Yammakira 'ark' refugia; receives flow every year. **Goyder Lagoon** Distributary channels from Yammakira and Andrewilla Waterholes to the commencement of the Warburton River channel; receives inflow every year. **Warburton–Kallakoopah** Commencement of Warburton channel to Lake Eyre including the Kallakoopah Creek flowpath. Receives flow approximately every 1.5–2.0 years. **Eyre Creek** South Australian border to Goyder Lagoon. This reach does not contain any significant ark refugia and receives flow approximately every five years.
Land use	Grazing is the main industry and occupies the greatest area as a land use. Conservation and heritage areas provide a major focus for a growing tourism industry. Oil and gas exploration / extraction are currently at low levels.
Hydrology	Surface water flow of the SA reaches of the Georgina–Diamantina catchment remains unregulated, unimpeded and water extraction is at low levels and is considered to be near natural condition. The LEB stands out among the great flooded systems of the world because the Channel Country is maintained in relatively unaltered character. These rivers are amongst the most hydrologically variable in the world, unpredictable river flows are the key feature determining the health of the environment.
Local community	Intergenerational involvement of community members in activities such as data collection and analysis and being part of science programs will promote long-term interest in the biophysical values of the region and assist with succession planning.
Aboriginal cultural heritage	There is a long and continuous Aboriginal history in the Diamantina catchment and a rich and complex culture that reflects connection with country. Dreaming stories, traditional knowledge and language are alive and relevant today.
Biodiversity values	Wetlands of the area have been recognized for their high natural values. Goyder Lagoon is one of the most significant wetlands in Australia for supporting large numbers of waterbirds. Goyder Lagoon is a highly complex system with substantial knowledge gaps. Many plants and fish in these diverse aquatic ecosystems only occur in the LEB.
Refuge waterholes	Yammakira and Andrewilla waterholes are the most important aquatic refugia in the SA reaches of the Diamantina River due to their size, cease to flow depth and permanency.
Coolibah research	There was a lower than expected recruitment during the 2009–2011 wet period of the perennial keystone species, *Eucalyptus coolabah* – total grazing pressure and dry conditions in 2013–2014 had a role in limiting the number of successful recruits – this may be of concern to the long-term productivity of the riparian zone. Coolibahs have low transpiration rates to cope with dry conditions, can tolerate a range of soil types and geomorphic positions, and has a high tolerance of salinity – illustrating their ability to dominate the riparian zone along much of the Diamantina and Warburton Rivers in South Australia.
Riparian vegetation	The maintenance of plant species richness and diversity associated with riparian vegetation corridors is essential for overall biodiversity conservation of dryland river systems. The thin corridors of riparian vegetarian extend the range of associated biota into a climatically harsh environment. For example these corridors provide longitudinal connectivity facilitating movement of a range of bird species down the river system. Riparian vegetation is important for maintaining river landform processes , integrity and function which maintain the stability of aquatic habitats, especially the deeper channels and waterholes.
Aquatic ecology	Thirteen fish species occur naturally within the G-D catchment in SA. One exotic fish species is known; eastern gambusia (*Gambusia holbrooki*). Salinity influences fish distribution and movement in the system.
Key threats and pressures	Upstream water resource development; over-grazing through total grazing pressure; weed invasions; increased feral animal populations; climate change; infrastructure development; recreation and tourism activity; contamination and pollution of aquatic ecosystems; high nutrient concentrations; unsustainable resource use.



Warburton River

Reliable sources of water provide vital drought refuge for a variety of biota and are at the core of traditional, historic and contemporary human activity in the region.

UNDERSTANDING THE CHANNEL COUNTRY RIVER SYSTEM

WATER THAT FLOWS *in the Channel Country provides a unique natural irrigation system in the centre of Australia's Outback. The remote rainfall events occur primarily in Queensland and the water feeds into a complex arid environment that could not be sustained by localised rainfall alone.*

The Channel Country rivers include the Georgina River, the Diamantina River and Cooper Creek. From their headwaters in the Northern Territory and Queensland, they flow down a series of wide valleys as a network of channels and shallow floodplain waterways. The Diamantina River enters South Australia along the margin between the Simpson Desert and Sturt's Stony Desert, and the Georgina River (as Eyre Creek) comes down amongst the Simpson Desert dunes. The Diamantina and Eyre Creek empty into the upvalley section of Goyder Lagoon, and the Warburton River drains the Lagoon's downvalley end.

The Diamantina River runs for approximately 900 kilometres. In South Australia the Warburton and Diamantina river system cover an area of approximately 31,500 sq. km from the South Australian–Queensland border to Kati Thanda–Lake Eyre. This river system and its associated wetlands is one of the main desert rivers in the Lake Eyre Basin (LEB), and along with Cooper Creek provides the major flows that periodically fill Kati Thanda–Lake Eyre.

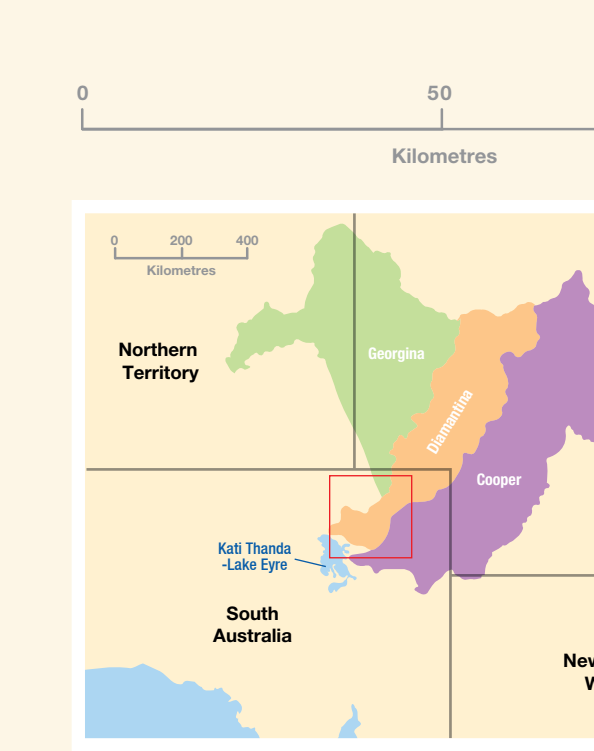
The South Australian portion of the LEB is characterised by catchments that are almost entirely within the arid zone, having low gradients throughout their course, they are internally draining rather than flowing to the sea, have wide floodplains in the mid-lower reaches, large transmission losses, and extremely high flow variability.

This extreme flow variability means that rivers naturally fluctuate between an inland sea of floodwaters and a handful of isolated wetlands or waterholes. Eyre Creek is a tributary to the Diamantina, Kallakoopah is a downstream distributary and Eleanor Creek is a floodplain flow path that carries water during large floods.

The ecological, cultural and economic value of this river system is significant because it provides reliable sources of water during drought conditions and connectivity pathways during more favourable periods. Reliable sources of water provide vital drought refuge for a variety of biota and are at the core of traditional, historic and contemporary human activity in the region.

At any given time there is a mosaic of different aquatic and terrestrial habitats in the LEB. Over time this has created a healthy ecological dynamism, which contrasts favourably with the ecological decline of rivers in the neighbouring Murray–Darling Basin.

PROPOSED MANAGEMENT ZONES



Legend

- Unsealed road
- Vehicular track
- Watercourses
- Places
- Non-perennial waterbodies

Management Zones

- Diamantina River
- Goyder Lagoon
- Warburton–Kallakoopah
- Eyre Creek

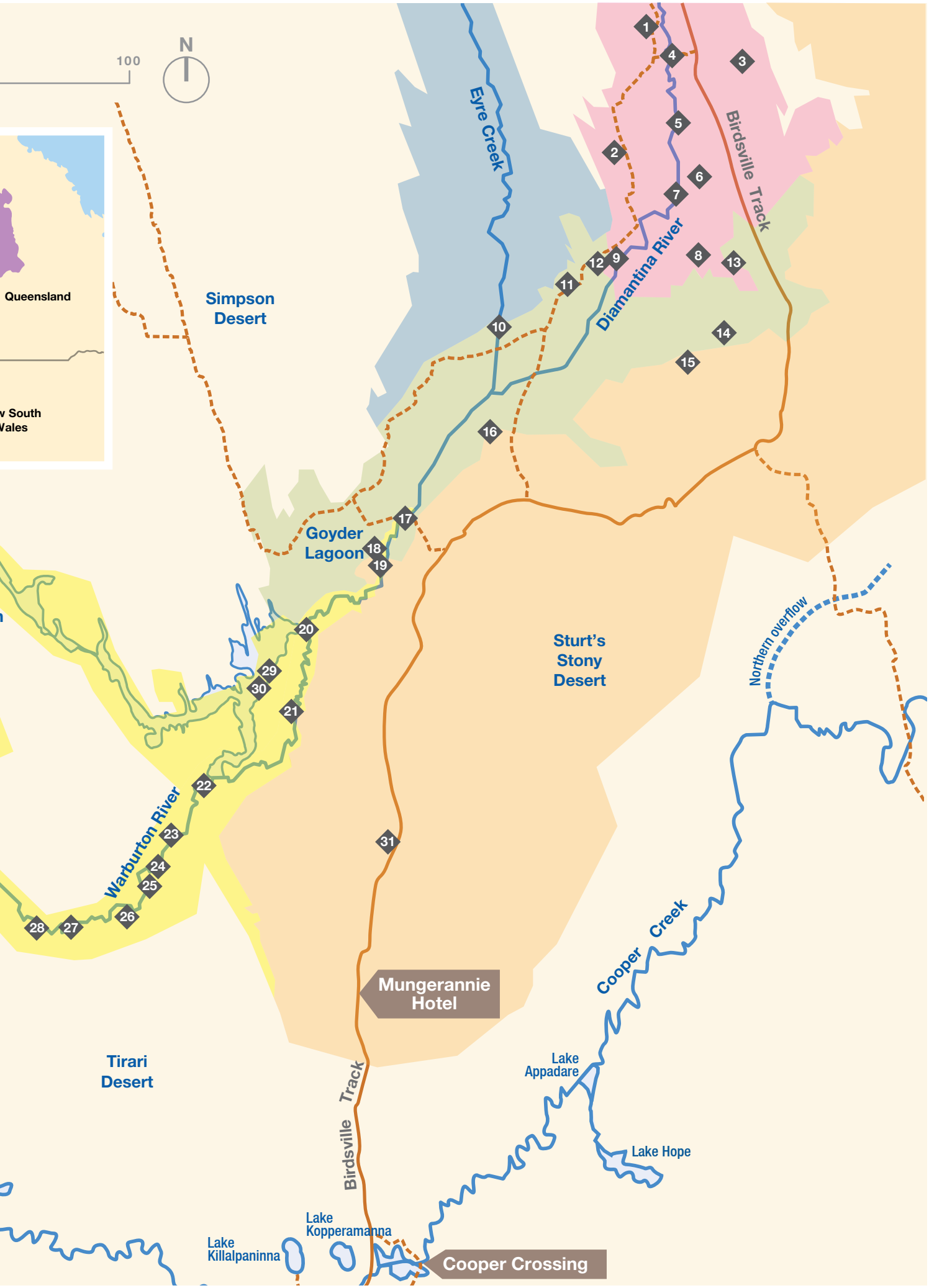
Other landform zones

- Gibber
- Dune fields

Key Field Locations

1 Dickeree Waterhole
2 Eleanor Creek
3 Gumborie Creek (also known as the Eastern Overflow)
4 Windmill Waterhole
5 double bluff waterhole*
6 Lake Uloowaranie
7 Diamantina-split Waterhole
8 Yammakira Waterhole
9 Andrewilla Waterhole
10 Tepamimi Waterhole
11 Burt Waterhole
12 Pelican Waterhole group
13 Peraka lakes
14 Koonchera Waterhole
15 Pandiburra Bore
16 Goyder Lagoon Waterhole
17 Warburton crossing
18 Yelpawaralinna Waterhole
19 Ultoomurra Waterhole
20 Kalamunkinna Waterhole
21 stony point waterhole*
22 Kirrianthana Waterhole and Cowarie Crossing and Derwent Creek confluence
23 Yellow Waterhole
24 stony crossing waterhole* and Oolabarinna Crossing
25 Mia Mia Waterhole
26 Wadlarkaninna Waterhole
27 tinnie landing waterhole* near Murreebirrie Hill
28 cliff camp waterhole* and Poonarunna Bore
29 Kuncherinna Waterhole
30 Mona Downs
31 Mirra Mitta Bore

*Only formal (gazetted) waterhole names are capitalised.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100
Queensland
v South
Wales
Eyre Creek
Birdsville Track
Diamantina River
Simpson
Desert
Goyder
Lagoon
Sturt's
Stony
Desert
Northern overflow
Warburton River
Cooper Creek
Mungerannie
Hotel
Tirari
Desert
Birdsville Track
Lake
Appadare
Lake Hope
Lake
Kopperamanna
Lake
Killalpaninna
Cooper Crossing
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Eucalyptus coolabah tree

Majestic old coolibah plays a major role in supporting the biodiversity of the river system.

KEY POINTS

- Coolibah is a hardy, resilient and adaptable species and is the dominant eucalypt species across dryland river systems of the Lake Eyre Basin.
- Radiocarbon dating conducted during this project has revealed that Coolibah is a slow growing, long-lived tree.
- The life-cycle of Coolibah appears attuned to the climate and hydrology of the region. Flowering,fruiting and shedding of seed occur predominantly during the summer months which coincide with a higher likelihood of river flow and flooding events.
- Major flooding events are important for the recruitment of the species. Coolibah seed is dispersed widely across the river system by floodwaters. The establishment and persistence of subsequent saplings are vital in maintaining a range of coolibah ages; an important indictor of demographic health.

COOLIBAHS IN THE CATCHMENT

COOLIBAH AS A SPECIES *plays a highly significant role in directly influencing ecosystem structure, composition and function of the riparian community of the Diamantina–Warburton River system. In this capacity Coolibah is performing as a keystone species, a biodiversity indicator and a potentially valuable surrogate for monitoring the biodiversity health of the river system.*

The iconic Coolibah or *Eucalyptus coolabah* is one of around 900 species and subspecies of the genus Eucalyptus and is recognised as one of the widest-ranging eucalypts in Australia. *Eucalyptus coolabah* subsp. *arida* is the dominant subspecies occurring along the dryland river systems within the arid Lake Eyre Basin.

The word "Coolibah" is derived from Yuwaalayaay (and neighbouring languages), an Aboriginal language of northern New South Wales. The actual meaning is possibly related to "gula" (tree fork) and "–baa" (place of, time of). Within the Lake Eyre Basin the aboriginal name for the species varied according to the language group. Along the Diamantina and the lower Cooper Creek in South Australia the Wangkangurru, and Dieri language groups referred to it as "Pathara".

Coolibah was integral with the human ecology of the region; playing a fundamental role in the economy and social life of the indigenous population. The tree was a direct and indirect source of food, seed, grubs, honey, possum, birds and their eggs. It was a vital source of fuel for fire for cooking and warmth and was incorporated in a variety of built structures including; shelter, shade, fish traps, hunting fences and burial mounds. Its timber was essential for the production of many artefacts ranging from containers, weapons, toas and message sticks. Its leaves and gum were utilised for a variety of medicinal purposes. Culturally, the tree was spiritually incorporated into the meaning of life through mythology and legends.

Coolibah was indispensable during the establishment of the pastoral industry in the region being utilised for the construction of exceptionally durable fences and yards.

Eucalyptus coolabah distribution
(Source: Slee et al. 2006)

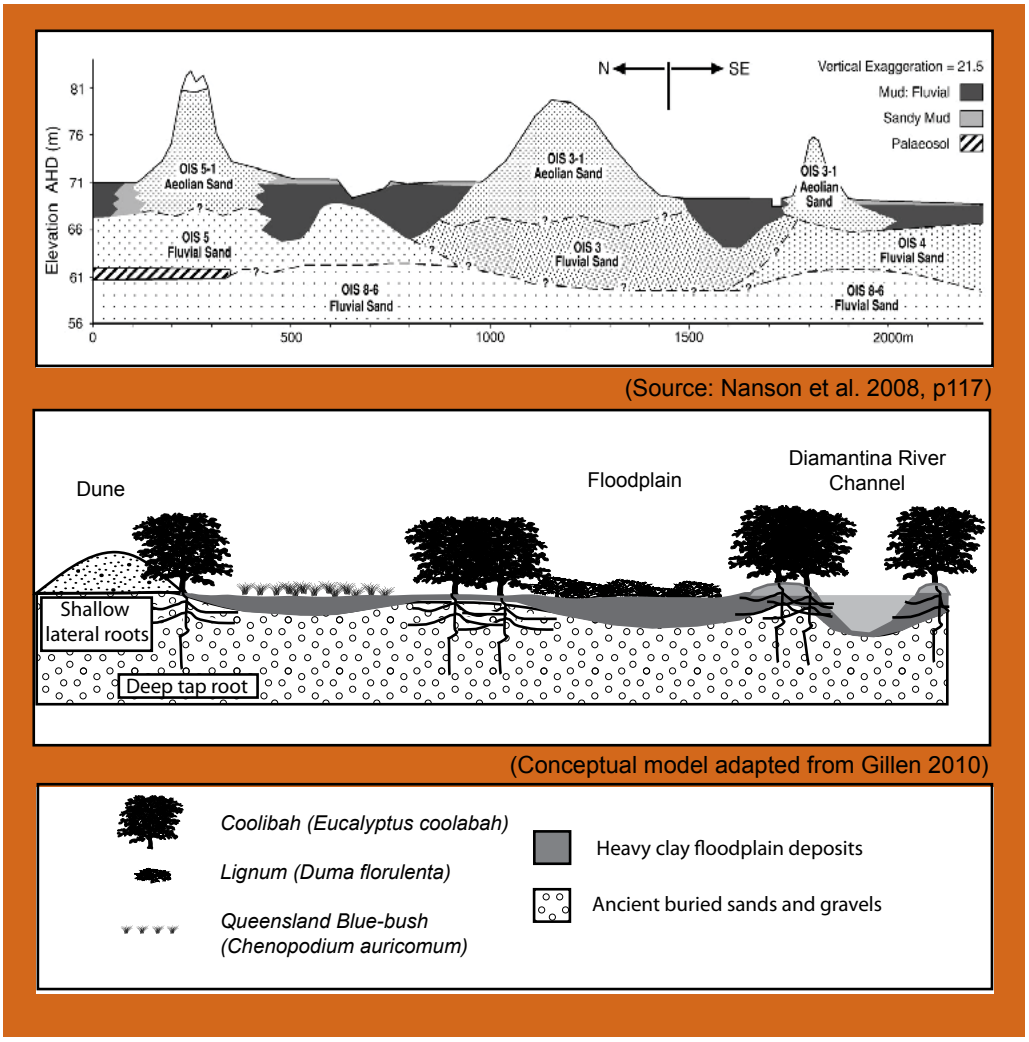
Coolibah is an impressively hardy, resilient and adaptable species. Occurring in some of the harshest landscapes in Australia it has adapted to cope with extreme conditions; drought, flood, high temperatures and saline soils. Radiocarbon dating of individual trees along the Diamantina has revealed that the species is slow growing and significantly long-lived.

The life cycle of the species appears to be particularly attuned to the climate and hydrology of desert river systems. The main flowering period occurs during the summer months when there is a higher likelihood of widespread monsoon influenced rainfall and associated river flooding events. Coolibah fruit matures rapidly and the resulting seed is rapidly shed and can be dispersed widely during major flooding events both longitudinally down the system and laterally across the adjacent floodplain. Major recruitment events are associated with major flood events.

Throughout the Diamantina floodplain clusters of Coolibah cohorts mark the outer edge of previous floods which have extended to varying extent across the floodplain. Most conspicuous, as radiocarbon dating has revealed is a cohort dating to the major flooding events of the 1970's. Cohorts such as these are physical records, 'flood fingerprints' in the landscape of past major floods.

The soils of channel river floodplains are predominantly heavy clays of varying thickness laid down over millennia covering ancient previously deposited sands and gravels. These older more porous deposits potentially provide a valuable groundwater source in the region. The deep rooting ability of Coolibah saplings may enable the species to penetrate the surface clays during periods of flood saturation and tap into this potential groundwater source. Drawing upon this groundwater source is crucial in enabling the species to survive through extended periods of drought. (See conceptual model below.)

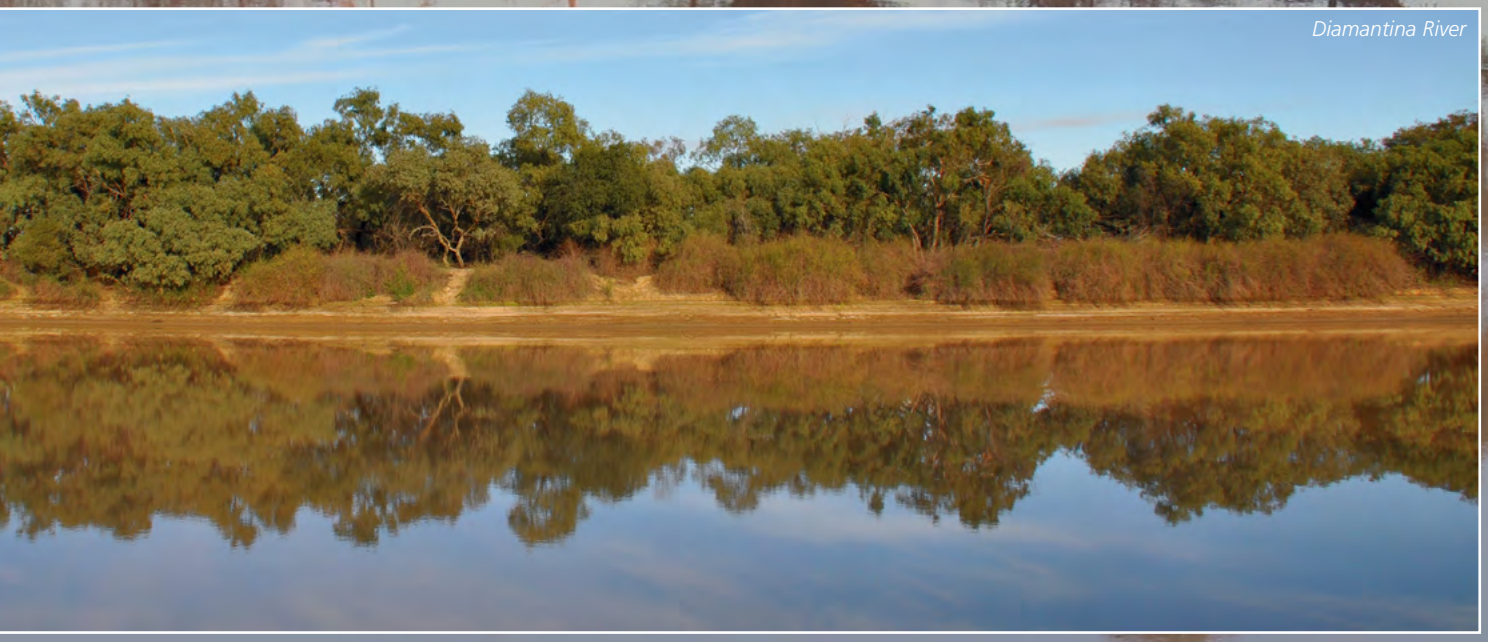
The ecology of the Coolibah dominated riverine ecosystem would be severely and detrimentally impacted should the naturally functioning hydrological regime of the Diamantina River system be disturbed or disrupted.



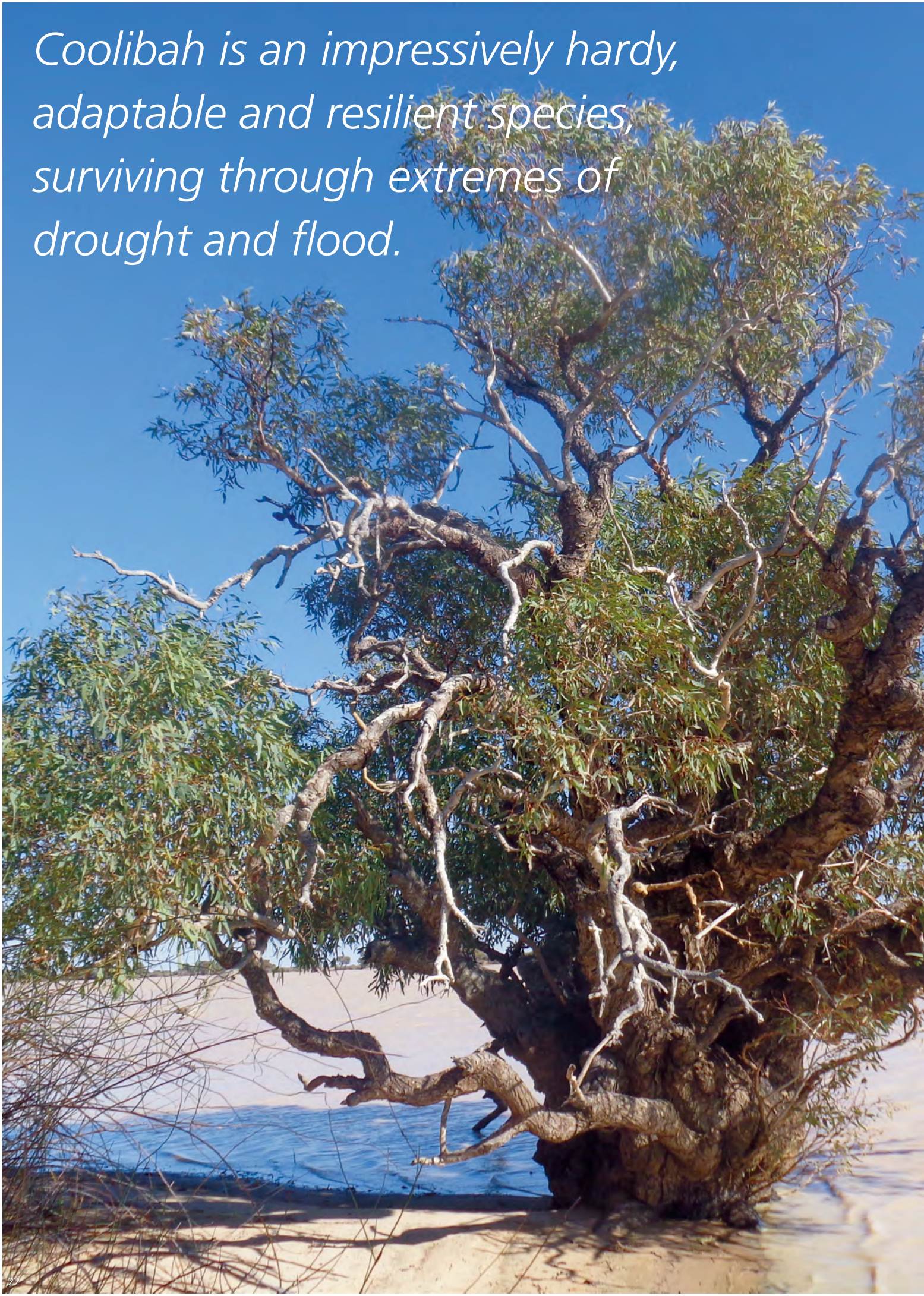
A conceptual model of potential factors influencing Coolibah distribution and persistence across the river floodplain.

Coolibah in flower

Coolibah seedlings establish quickly; display rapid early growth, especially the capacity for tap root extension; and also exhibit the potential to endure extended periods of inundation. This phase of the life cycle is also highly vulnerable to the impact of grazing pressure which can result in significant population recruitment suppression. Once established Coolibah possesses the ability, as do many other eucalypts, to rapidly extend a tap root from seedling stage, directly seeking more reliable sources of soil moisture upon which to draw and support establishment and persistence of the individual.



Diamantina River


Coolibah is an impressively hardy, adaptable and resilient species, surviving through extremes of drought and flood.

Mature coolibah, Diamantina River

THE ECOLOGY OF THE COOLIBAH

The establishment of *Eucalyptus coolabah* in the catchment is very dependent on uncommon but extensive flooding, enabling it to persist and line the often thin vegetation corridors of these rivers.

This sequence of floods strongly correlate with the La Nina cycle of the weather system and can occur as a sequence of floods in consecutive years.

Floods saturate the soil and facilitate the dispersal, germination, and establishment of new Coolibah as seed is dispersed widely during these events, down the system and across the adjacent floodplain.

The contribution of this iconic Australian tree to the composition, structure, function and biodiversity of the riverine ecosystem is significant, particularly in the arid South Australian reaches, where it supports life in this otherwise harsh and stressful environment.

Disrupting the naturally functioning seasonal regime with major upstream water extractions, irrigation activities, diversions or off-stream storage, would have major detrimental ramifications for the species.

In summary, the Coolibah is an 'ecosystem bioengineer' whose trunks intercept and obstruct the flow of wind and water, and trap soil, moisture and nutrients. The shade cast by its canopy also ameliorates the harsh microclimatic and soil conditions thereby enabling an increased number of plant species to survive.

When Coolibah litter breaks down it contributes directly to the cycling of carbon and associated nutrients in situ, contributing in turn to the cycling of nutrients into and through the aquatic ecosystem of nearby waterholes and channels.

Structurally, the Coolibah is a large and long-lived tree that provides a myriad of habitats from roots to branches for a wide range of organisms. Discarded limbs and branches fall directly into the nearby water and provide habitat for a range of aquatic fauna..

FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Gillen, J.S. 2017. Coolibah (Eucalyptus coolabah Blakely & Jacobs) of the Diamantina and Warburton river systems in north eastern South Australia. Report by Australian National University to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.*

Landscape genomics

The project has identified potential patterns and driving processes associated with the recruitment and distribution of Coolibah at a landscape level. An important component of biodiversity conservation is the concomitant conservation of genetic diversity in order to maintain evolutionary processes; e.g. adaptation potential under climate change. The project has undertaken a preliminary investigation into the genetic variability of Coolibah across river catchments in the Lake Eyre Basin and down the Diamantina river system. Future research aims to investigate the potential impact of flood driven seed dispersal upon Coolibah gene flow and associated genetic diversity both temporally and spatially.

Mature coolibah tree, Goyder Lagoon waterhole

The importance of geomorphology – the impact of natural channelling.

KEY POINTS

- There are four management zones within the study area: Diamantina River, Goyder Lagoon, Warburton–Kallakoopah, and Eyre Creek. Each has a characteristic suite of landforms. Two other landform zones, (gibber uplands, and dune fields) which are external to the study area, are nonetheless relevant.
- Differences between the Georgina and the Diamantina catchments (slope, vegetation, valley width, and runoff coefficient of contributing hill slopes) means Georgina's Eyre Creek takes longer to deliver flows to Goyder Lagoon, and more of the water stays along Eyre's Creeks floodplains. Because the confluence between Eyre Creek and Goyder Lagoon is so wide and shallow, connectivity across the confluence may be poor except when flood peaks coincide, or when the Eyre Creek flood peak reaches an already-full Goyder Lagoon.
- Landscape timelines
  - Several million years ago the palaeo-Lake Eyre depocentre was further north than the present day.
  - There have been episodes of dune building over the last several hundreds of thousands of years.
  - Between 1.0 million and 250,000 years ago during the world's glacial climate cycles, there have been periods when Lake Eyre was full, and it is likely that the dunes and playas area north of Lake Eyre was a wetland.
  - Weather cycles produce extreme megafloods (on thousand-year and several hundred-year scales). The LEB rivers in the study area have not experienced an extreme level of flooding since European settlement.
  - There have been few significant changes to landscape after the mid-1970's flood.
- Landform diversity in river channels and floodplains leads to a range of different aquatic and terrestrial habitats. The channel elements most likely to provide variety in aquatic habitat are active meanders, distributary channel and anabranch offtakes, and the diverse flow paths of Goyder Lagoon. The floodplain elements most likely to provide coolibah woodlands are riparian zones, meandering-channel scroll plains, and flood runners. Dense lignum ecosystems grow in Goyder Lagoon's and Eyre Creek's low-gradient areas of unchannelled flow.

GEOMORPHOLOGY UNDERPINNING FLOWS

THE GEOMORPHOLOGY OF THE RIVER *– its landforms and the processes that create them – underpins the ecological processes that sustain the area's biodiversity. No ecosystem can be properly understood without understanding the processes that shape and maintain the ecosystem's physical environment.*

DYNAMICS AND VARIABILITY

The flow regime of the Channel Country rivers encompasses dry periods (with no water in most of the landforms), no-flow but with remnant water in water-retaining landforms, low flows, overbank flows, and large to very large floods. The combination of arid environment and variable flow regime means that these rivers are "unusual" – that is, they are unlike standard expectations of river behaviour.

At certain times, a substantial part of the flow waters of the Channel Country rivers is unconfined floodplain flow, which can take a separate flow path to a main channel, and create a system of secondary disconnected channel segments and waterholes. This challenges our expectations of how rivers behave, and has implications for the regulatory environment (for example, management codes or river condition assessments that focus on channels and banks), and engineering standards (for example, road crossing culverts that don't encompass channel and floodplain volume will be insufficient during floods, and will create self-propagating gully networks).

Vegetation not only responds to landforms, it bioengineers them: trees and understorey obstructing the flow path promote sediment and seed deposition, growing landforms and sheltering seedlings; riparian vegetation promotes bank strength; lignum helps stabilise new floodplain areas in the inside curve of meandering channels; riparian vegetation promotes the in-channel turbulence that keeps banks steep and waterholes deep.

The Mona Downs reach, showing sloping banks, a narrow riparian zone fringing the bank lip

GRADIENTS

All the downvalley gradients are low. However, the downvalley gradient in each management zone is different, and this has a strong effect on the river's channel shape and trajectory of change.

For example, the Diamantina Fan area has the steepest gradient, and many of its channels meander. This produces well-vegetated riparian zones in the new floodplain of the channel's scroll plain. The Goyder Lagoon, however, has an extremely low gradient – it is almost flat – and local microtopography has the dominant effect on flow behaviour and landform type.

CONNECTIVITY

Landforms (such as river banks, distributary channels and dune sets) influence the direction, depth of flow, and connectivity of its rivers and creeks. The Channel Country topography controls what happens to floodwaters supplied by the variable flow regime. At different times and flood heights, different parts of the system become connected. This provides opportunities for fish movement and seed dispersal, as well as the distribution of the water that is the lifeblood of the system.

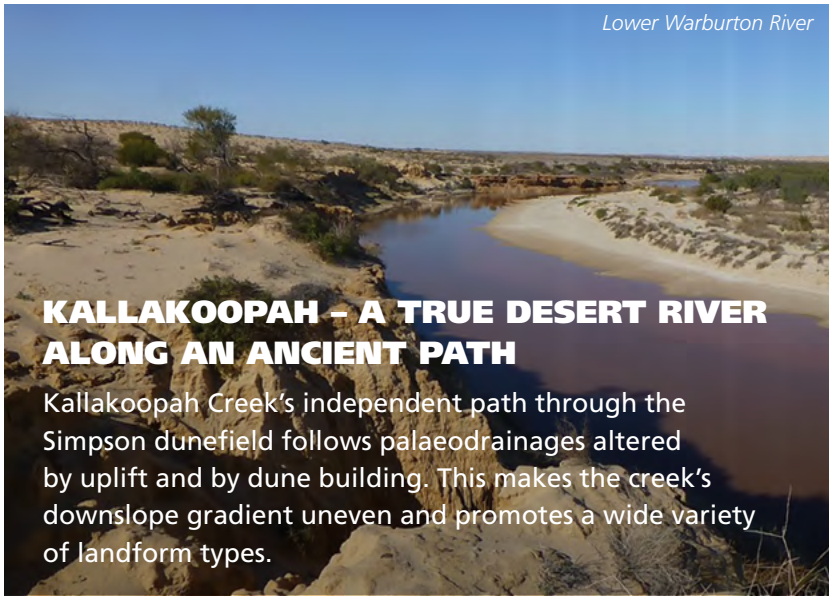
In many parts of the study area, some connectivity also exists between plants growing on the surface and the unconfined aquifer below (probably via deep roots accessing the capillary fringe). Although plants in the main flow paths are most influenced by surface waters, in less frequently inundated areas access to groundwater can be an important resource for plant communities.

BANK STABILITY AND EROSION

Bank stability is used as an indicator of the river's condition, but it is important to recognise that bank erosion can be (and in the study area, usually is) a natural process in how the river functions. In some areas, bank erosion is part of the processes that create productive ecosystems. In meandering reaches, the wide and densely vegetated riparian zone found along the inner bank (or scroll plain) is not possible without erosion on the outer bank.

Bank erosion can be expected in rivers where there is active meandering, and in highly variable flow regimes (such as the Diamantina River). Flood-driven bank breaching – by bank-top lowering, or by incision – can be part of the creation of distributary channel, an important landform for water distribution. In these circumstances, assessing the level of the river's condition is not based on whether or not erosion should be present, it is whether or not erosion-prone landforms are operating outside their expected conditions and in a way that is detrimental to the overall good function of the river. With the Diamantina River's current low level of documentation, this assessment is difficult.

However, most of the large erosion gullies noted during fieldwork were triggered by natural causes: bank undercutting by channel development (for example at the Andrewilla intake and Tinnie Landing) or changes to base level (Cliff Camp). In the dune fields, deflation between the dunes has led to local gullying and is a natural process (although it can be accelerated by grazing and trampling), as is deflation and rill development in palaeosol surfaces along the southern borders of source-bordering dunes.



Lower Warburton River

KALLAKOOPAH – A TRUE DESERT RIVER ALONG AN ANCIENT PATH

Kallakoopah Creek's independent path through the Simpson dunefield follows palaeodrainages altered by uplift and by dune building. This makes the creek's downslope gradient uneven and promotes a wide variety of landform types.

PRIORITIES FOR FUTURE MANAGEMENT

Maintain Riparian Vegetation and Landform – preserving riparian vegetation is important not only to ecosystems, but also to the landforms – riparain vegetation helps to maintain the stability of aquatic habitats in channels and waterholes, and the integrity of water-distributing landscape elements.

Flow Routing Down Eleanor Creek – the relatively small size of the distributary channel at Diamantina-split Waterhole and the behaviour of the Diamantina Fan's flood fronts during the 2009–2010 flow event indicates that during large flood events, floodplain flow down the Eleanor Creek flow path is a significant contributor of water to Andrewilla Waterhole.

Goyder Lagoon waterhole

GOYDER LAGOON – THE HEARTBEAT OF THE SYSTEM

Goyder Lagoon is an extremely low-gradient valley. Because it is also very broad, floodwaters from the Diamantina and Eyre Creek spread out as unconfined flow. There are no continuous channels, and no significant sediment transport. The few waterholes exist in locally high-energy contexts around the valley margins.

Goyder Lagoon's best-known landform-vegetation association is the densely vegetated lignum swamps that occur across wide areas. These swamps tend to be water accumulating 'sinks' and are characterised by reticulate channel networks, long-term inundation, and vertic soils with well-developed gilgai heave.

Groundwater Support For Terrestrial Ecosystems

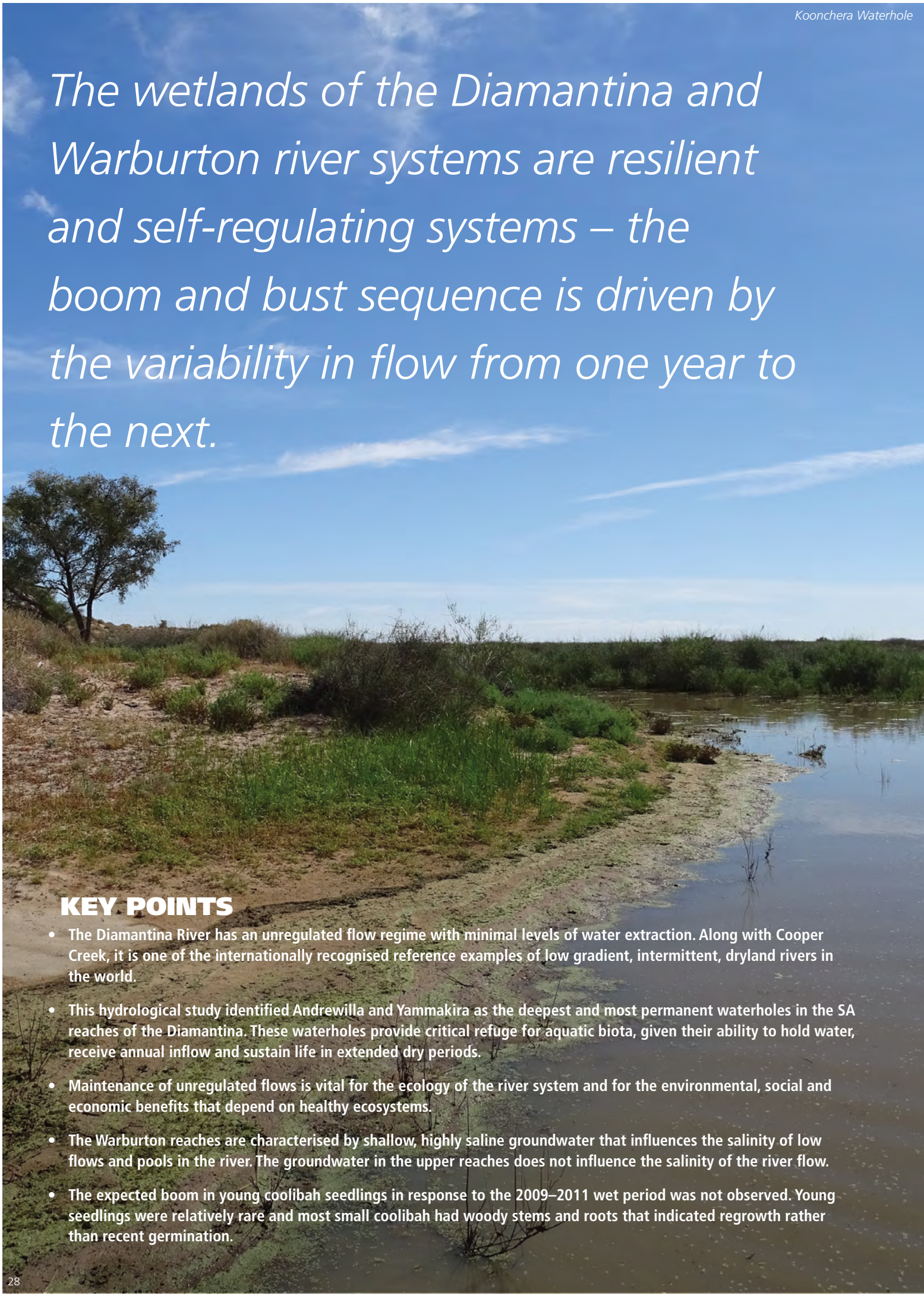
- The unconfined aquifer will be important for interdune vegetation within the Simpson Desert dune field where the depth to water table allows tree roots to access water without the stress of salinity. This may have implications for bird fauna, and for pre-European Aboriginal land use.
- The unconfined aquifer probably explains the widespread but widely-separated coolibah occurrences in places that do not receive much flow or abundant flow e.g. parts of Goyder Lagoon or rarely-inundated valley margins.
- The unconfined aquifer close to the channels is recharged by flow from Queensland. Changes to the amount or frequency of flow coming from Queensland will affect groundwater-supported terrestrial ecosystems, as well as ecosystems along the creeks.

Range and River Condition Assessment

- Grazing pressure may be sustainable in one area but less so elsewhere.
- It is important to know the geomorphological context of the plant community when assessing range condition, especially if comparing vegetation surveys from different locations.
- Many systems of rangeland management apply per-area stocking rates as a management tool, which may be an oversimplification of landscape resources.

FOR FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Wakelin–King, G.A. 2017. Geomorphology of the Diamantina River Catchment (SA). Report by Wakelin Associates to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.*


Koonchera Waterhole

The wetlands of the Diamantina and Warburton river systems are resilient and self-regulating systems – the boom and bust sequence is driven by the variability in flow from one year to the next.

KEY POINTS

- The Diamantina River has an unregulated flow regime with minimal levels of water extraction. Along with Cooper Creek, it is one of the internationally recognised reference examples of low gradient, intermittent, dryland rivers in the world.
- This hydrological study identified Andrewilla and Yammakira as the deepest and most permanent waterholes in the SA reaches of the Diamantina. These waterholes provide critical refuge for aquatic biota, given their ability to hold water, receive annual inflow and sustain life in extended dry periods.
- 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 Warburton reaches are characterised by shallow, highly saline groundwater that influences the salinity of low flows and pools in the river. The groundwater in the upper reaches does not influence the salinity of the river flow.
- The expected boom in young coolibah seedlings in response to the 2009–2011 wet period was not observed. Young seedlings were relatively rare and most small coolibah had woody stems and roots that indicated regrowth rather than recent germination.

HYDROLOGY AND FLOW PATTERNS

THE DIAMANTINA RIVER *has an unregulated flow regime with very little water extraction, and forms one of the type examples of low gradient, intermittent, dry land rivers in the world. As the catchment is unregulated, the natural associations between 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 from one year to the next, and the Diamantina River has one of the most variable flow regimes in the world.

There is little information on the flow regime and general hydrological behaviour of the Diamantina River, particularly for a catchment of this size, although this has improved over the past 15 years. This limits the capacity of water resource managers to identify and manage key aquatic refugia in the catchment, and to monitor hydrological change that could occur from anthropogenic changes (i.e. upstream water extraction, land use changes, infrastructure affecting flooding patterns) or climate change.

Warburton River

UNDERSTANDING FLOW PATTERNS

The hydrology of the South Australian reaches of the Georgina–Diamantina catchment remains unregulated and unimpeded and water extraction from the catchment is at very low levels.

Water quality and groundwater interactions vary between the management reaches. No groundwater data are available for the Diamantina main channel reach but its waterholes remain fresh at all times and this implies that the near channel groundwater is likely to be relatively fresh or the water table is too deep to intersect the main channels.

In the Goyder Lagoon and Warburton reaches, the groundwater is saline (typically >30,000 mg L^{-1}) and relatively shallow (3 m to 6 m below the floodplain surface). As a result, the ephemeral Warburton channel frequently intersects the saline water table, and this results in saline groundwater discharge into the channel between flow events, and this reach becomes saline to hypersaline during these periods. Recharge to the saline groundwater is minimised by the high water table and so the riparian vegetation must contend with shallow, highly saline groundwater away from the channel. As a consequence, the riparian zone can be quite narrow around the Warburton channel, and floodplain trees are likely to be more reliant on soil water resources rather than tapping into the highly saline groundwater.

No information is available on the unconfined groundwater in the Eyre Creek reach but it is likely to be saline and relatively shallow.

Koonchera Waterhole

Warburton River

Flooding is a major natural disturbance, providing the key driver for species dispersal, recruitment and nutrient exchange.

Inner meander bends (e.g. Diamantina-split site) show higher densities of trees and some regeneration.

HYDROLOGICAL CONTEXT OF THE STUDY PERIOD

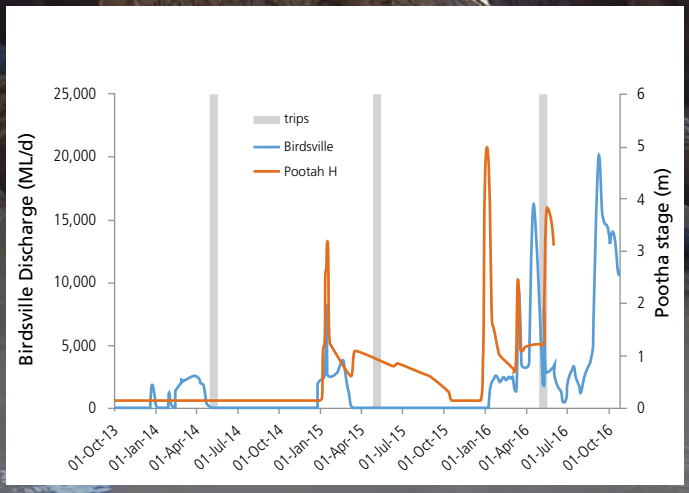
The first two years of the Diamantina River project (2014–2015) were dry years, followed by quite wet conditions in 2016 (see figures on page 33 for streamflow rainfall). The study period was also characterised by significant rainfall and local runoff events in the Warburton reach in 2015 and 2016, which did not generate as much runoff higher in the catchment, particularly in 2015.

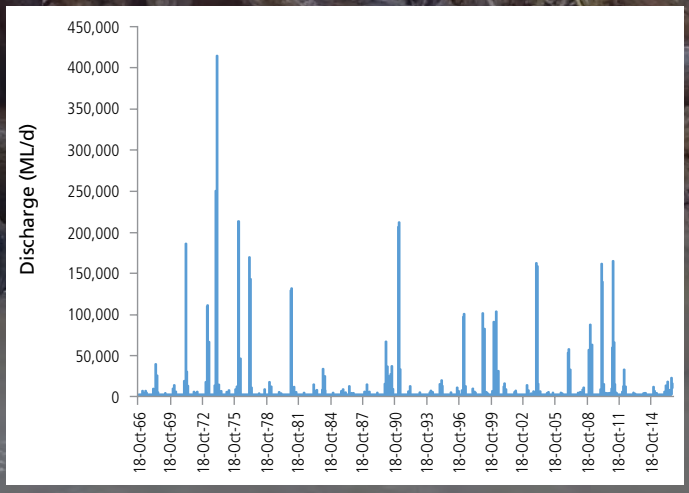
The local rainfall and runoff is important in decreasing the saline conditions typical of the Warburton River and in providing soil moisture for vegetation. The year preceding the study period (2013) was a particularly dry year in terms of streamflow and rainfall (see page 33), with the total volume passing Birdsville in that year being below the 10th percentile of the long-term record.

The ten years prior to the project period were characterised by a mix of dry years and floods, and a wet four-year period (2009–2012) driven by a La Niña episode. During the Millennium Drought (1998–2009) that strongly affected rainfall and streamflow in south-eastern Australia, the Diamantina experienced a large range in annual floods, with significant floods in 2000, 2004 and 2007 and relatively dry years in between with total annual flows less than the long-term median.

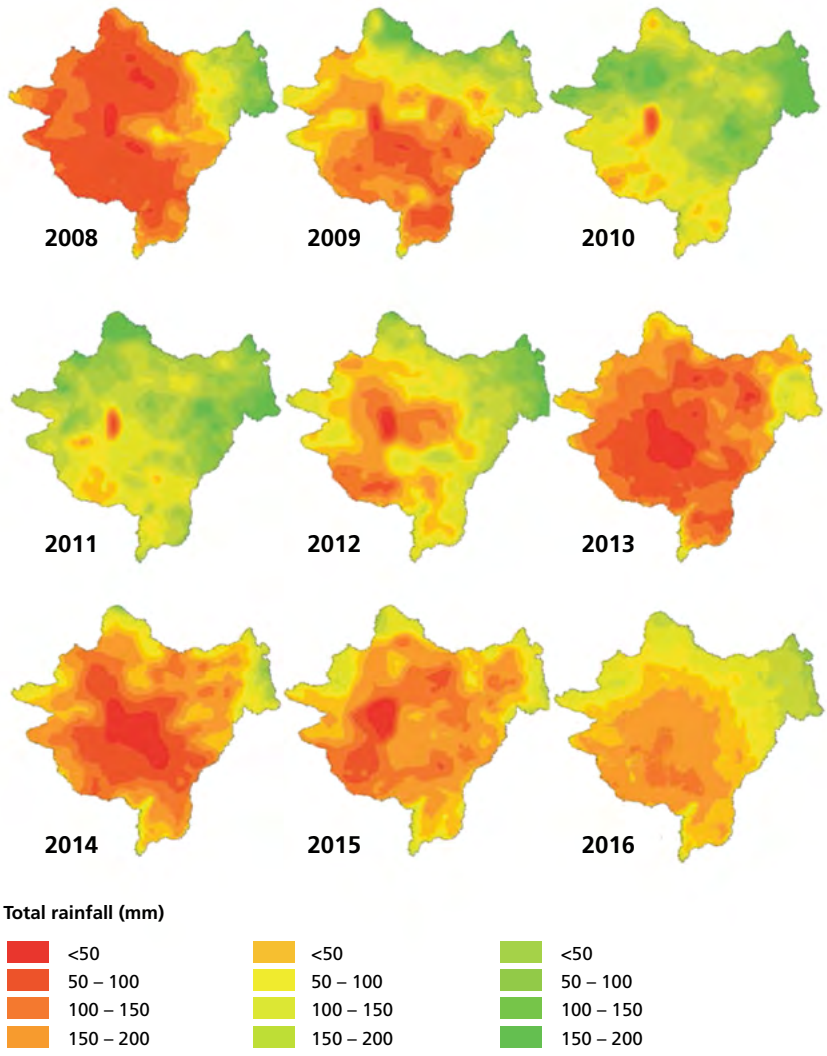
The La Niña episode commenced with a major flood in 2009 and the subsequent large flood years of 2010 and 2011 had annual totals and peak discharges above the 90th percentile, and above average rainfall in the South Australian reaches.

The 2009–2012 period represents a 'flood cluster' and these typically occur in response to significant La Niña episodes and occur on a 20 to 40-year return period. Such flood clusters allow for significant ramping up of recruitment, particularly of fish, and are likely to be critical for the long-term health of the Diamantina River.





Hydrograph of Birdsville gauging station record for Diamantina River for the period 1966–2016 (right panel). The left panel shows the Birdsville discharge hydrograph (blue) and the Poothapoota (Warburton River) stage hydrograph (green) for the flood years of 2014–2016. The periods of Diamantina River fieldwork are shown by the grey columns.



Total rainfall across the LEB in each 'water year' (i.e. 1 October to 30 September) from 2008 to 2015. Mean annual rainfall across the basin ('Average') is also shown illustrating that 2010 and 2011 were much wetter than average while 2008 and 2013–2014 were much drier than average. (Source: Australian Water Availability project, Bureau of Meteorology: http://www.csiro.au/awap)

PRIORITIES FOR FUTURE MANAGEMENT

Hydrological monitoring and modelling – The current level of hydrological monitoring in the SA reaches of the Diamantina River is adequate for a remote, arid region catchment but the flows entering via Eyre Creek are not monitored.

Refugia – The most important refugia in the SA reaches of the Diamantina are Yammakira and Andrewilla Waterholes. Neither have any significant numbers of tourists and development pressures are quite low compared to the major refuges on Cooper Creek.

Tepamimi Waterhole on Eyre Creek is being maintained at cease-to-flow level by artesian bore outflow. This has significantly changed the frequency of inundation and drying for this waterhole and affected in-channel riparian vegetation. It is recommended that outflow from the artesian bore be controlled and fed into troughs rather than the waterhole. The waterhole should be allowed to dry out and return to its natural water regime and Clifton Hills Station are already working towards this objective.

Monitoring of riparian vegetation regeneration – The wet period of 2009–2011 represented a flood cluster that only occurs every 20 to 40 years and so this represented a once-in-a-generation regeneration event. The current project found that regeneration of the key riparian tree species, *E. coolabah*, was limited along most of the SA reaches of the Diamantina. Further monitoring of key locations showing some recruitment would assist in the sustainable management of the area (e.g. protecting key regeneration – recruitment locations from grazing).

FOR FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Costelloe, J.F. 2017. Hydrological assessment and analysis of the Diamantina River catchment, South Australia. Report by the University of Melbourne to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.*

Drought conditions after the 2009–2011 floods may have contributed to lack of survival of seedlings, in addition to grazing.

The perennial vegetation of the Diamantina River presents as a thin green ribbon of productivity in a desert environment.

KEY POINTS

- There have been no previous systematic botanical surveys conducted over the length of the Diamantina and Warburton river systems in South Australia. This survey represents the first.
- During the three assessment periods of the survey project a total of 241 plant species were recorded from the Diamantina study region. This figure would be expected to increase if future assessments are carried out over other months and over a range of diverse seasonal conditions.
- Due to the extended history of stock grazing since the 19th century along the entire Diamantina–Warburton system, all waterholes generally represent disturbed ecosystems in varying degrees of condition or status from severely degraded to currently recovering. There are no areas of riparian vegetation representing natural condition prior to grazing against which to compare the range of current conditions. However, the conversion of Kalamurina Reserve in 2007 by the Australian Wildlife Conservancy to a conservation zone free of cattle provides a significant opportunity for a regional vegetation recovery reference system. The future trajectory of vegetation and biodiversity condition of all sites along the Diamantina can be very usefully referenced against the permanent monitoring sites established on Kalamurina Wildlife Sanctuary.
- A main part of the study was the establishment of a site based systematic monitoring program at 21 permanent sites. Ongoing monitoring will enable the assessment of trends in vegetation condition and associated biodiversity values. Monitoring in the arid zone must be long-term to take into account extreme climatic variability from drought to flood.
- The more reliably watered parts of the Diamantina river system in SA contain the most structurally and floristically diverse examples of the region's flora. The greater diversity in riparian vegetation also influences riparian bird diversity in this zone, compared to the downstream reaches.
- Upstream of Goyder Lagoon, the channel banks of the Diamantina River associated with permanent and semi -permanent waterholes are dominated by stands of *Eucalyptus coolabah* (Coolibah) woodland.
- This is often associated with a mixed understory of Queensland Bean Tree (*Bauhinia gilva*), Whitewood (*Atalaya hemiglauca*), Broughton Willow (*Acacia salicina*), River Coobah (*A. stenophylla*) and Bignonia Emubush (*Eremophila bignoniiflora*).
- In the south of the system, below Goyder Lagoon, Queensland Bean Tree and Whitewood, drop out of the riverine community and Bignonia Emubush occurs more sporadically. The shrub Lignum (*Duma florulenta*) occurs continuously along the entire Diamantina–Warburton river channels in varying degrees of density. The swampy conditions of Goyder Lagoon is dominated by Lignum shrubland.
- This pattern of gradual loss of perennial species down the system is associated with an increase in soil pH and soil salinity levels and occurs as flood pulses and flushing of soils decrease in frequency downstream.
- Of the 241 species recorded during the 2014–2016 assessments, 21 species were identified as introduced or naturalised species.

VEGETATION AND SOIL INTERACTIONS

THE PERENNIAL *riparian vegetation of the Diamantina River provides a corridor for the transmission of a range of biota into this harsh environment. More sensitive plant and animal species are thus able to extend their range into this arid environment increasing the biodiversity of the system.*

SIGNIFICANCE OF THE DIAMANTINA RIVER SYSTEM AND ASSOCIATED COOLIBAH COMMUNITY

The presence of the perennially vegetated riverine communities of the Diamantina River represent a dynamic and bio-diverse ecosystem of incongruous productivity when juxtaposed against the adjacent desiccated dunes of the Simpson Desert and baking gibbers of Sturt's Stony Desert. Generally, the broad, arid landscapes of central Australia's desert dune fields are highly dependent on local rainfall events to drive ecosystem function. However, within these desert landscapes, and those of the Lake Eyre Basin in particular, such rainfall events are highly variable and unpredictable. The life cycle of a typical ephemeral species is highly adapted to these random rainfall events and allocates few resources to developing its biomass. Instead it moves rapidly through its stages of flowering, fruiting and seed dispersal to ensure continuance of the species.

In contrast to the obvious unpredictability of these rainfall dependent systems, the reliable hydrological regimes of the LEB dryland rivers provide a more regular source of moisture that supports the development of a perennial vegetation community of structural and compositional diversity.

Regular flood pulses down the river channel sustain the vegetated riverine corridor and recharge the local groundwater systems, which the long-lived Coolibahs depend on for moisture during natural periods of drought.

During times of major floods, floodwaters break free of the main channel, flowing through the Coolibah corridor and across adjacent floodplains, transporting and depositing debris, seeds and associated nutrients. As the floodwaters draw down and recede back to the channel, nutrients resulting from the biological pulse of activity across the floodplains are drawn back into the channel recharging the associated aquatic ecosystem.

VEGETATION OBSERVATIONS

The more reliably watered parts of the Diamantina system contain the most diverse expressions of the region's flora.

In the north of the Diamantina system, above Goyder Lagoon, the channel banks immediately adjacent to and associated with the extensive range of semi-permanent waterholes, are dominated by riverine stands of Coolibah woodland, often associated with a mixed understorey of Queensland Bean Tree (*Bauhinia gilva*), Whitewood or Cattle bush (*Atalaya hemiglauca*), Broughton willow (*Acacia salicina*), River Coobah (*A. stenophylla*), and Bignonia Emubush (*Eremophila bignoniiflora*).

In the south of the system, below Goyder Lagoon the Queensland Bean Tree and the Whitewood/Cattle bush drop out of the riverine community and the Bignonia Emubush occurs more spasmodically.

The shrub, Tangled Lignum (*Duma florulenta*), is ubiquitous within the riverine community from north to south, albeit in varying degrees of density. This pattern of a gradual loss of a particular perennial species down the system is also experienced on the Cooper Creek system.

NATURALISED AND INVASIVE SPECIES

A total of 14 of the 241 species recorded (6%) during the project were introduced or naturalised species. The two species of most concern are Athel Pine or Tamarisk (*Tamarix aphylla*), which is listed as a weed of national significance and additionally listed as a declared pest plant of South Australia, and Buffel Grass (*Cenchrus ciliaris*).

Buffel Grass is a very aggressive invasive species over significant areas of the arid zone and poses a significant threat to biodiversity values wherever encountered.

VEGETATION COMPOSITION

Species composition and richness is recognised as a useful measure of site condition, particularly in the context of total grazing pressure. A reduction or absence of significant palatable perennials and annuals and an associated increase in the number of less palatable species provides an indication of the significance of grazing pressure and the condition or state of the vegetation community.

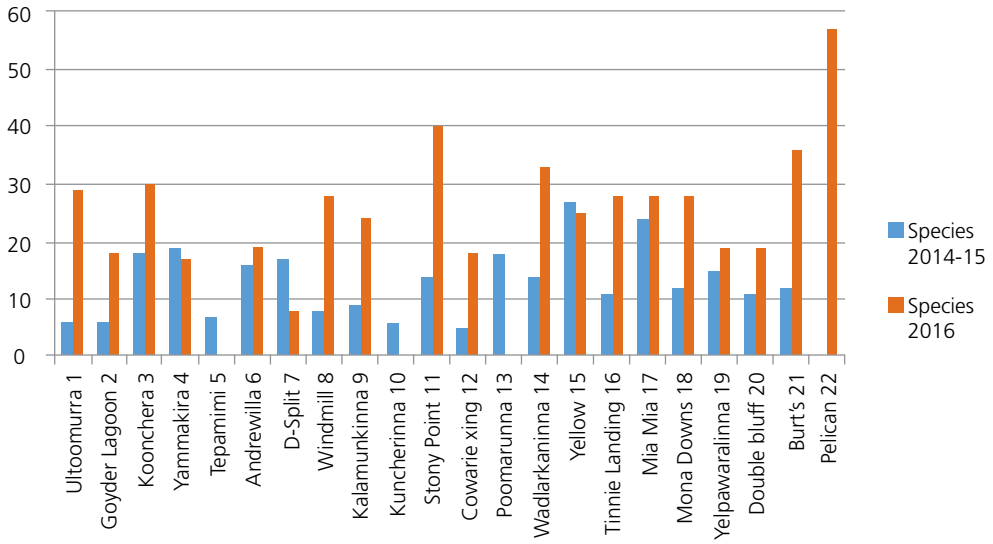
Monitoring for introduced and invasive plant species provides evidence of disturbance and potential state transition. The monitoring of variation in species composition within a shorter timeframe can also provide valuable insight into the influence of seasonal conditions and local rainfall events on the vegetation.

Over the longer timeframe, the condition of dominant long-lived species, particularly those species that act as keystone components of the ecosystem, such as Coolibah, is a vital inclusion in a monitoring program.

VEGETATION STRUCTURE

The most species-rich site assessed during 2014 was located on Kalamurina Wildlife Sanctuary (Yellow Waterhole). This elevated species richness may reflect the response of local annual and ephemeral species to significant rainfall events within this southern region of the study area during February and April.

Widespread heavy rains were experienced across the region in March 2016 with an additional widespread event in May. Both rainfall events preceded fieldwork in the periods April–May and July–August of that year. In most instances annual species numbers recorded at sites significantly exceeded those recorded during the previous two years.



Floristic composition at permanent monitoring sites

Major recruitment periods for Coolibah appear to be strongly associated with large scale floods over a sequence of years.

Very young (3–4 month) coolibah seedling that germinated on Kalamurina Wildlife Sanctuary in response to the local heavy rains and runoff in January 2016.

HYDROLOGICAL INFLUENCE

Tree and shrub diversity is highest in the upper reaches of the Diamantina in South Australia which receive more regular flood pulses. In contrast the more saline reach of the Warburton River does not receive such regular pulses leading to more stressful environmental conditions for plants reflected in a reduction of the range of perennial species.

SOIL CHARACTERISTICS

The Diamantina riverine vegetation communities occur on the deeper alluvial soils deposited close to waterholes, creating low channel levee banks in some reaches. Overflow from the main channel containing fine suspended sediments has developed a blanket of fine-grained clay rich soils (vertosols) of varying depth but typically of 2 m to 3 m in depth. These clay rich floodplain soils, sometimes self-mulching and deeply cracking, are draped over older, extensive, alluvial coarse sand deposits. In areas subject to particular flooding regimes, particularly floodplain depressions, these soils may form a low-relief small gilgai surface pattern or depression.

Arid and semi-arid Australia, particularly in the east, possesses some of the most extensive areas of vertosols, globally. Within the Diamantina system the distribution and depth of these vertosols influences the distribution of floodplain communities of Coolibah (see page 16).

IMPACTS AND THREATS

Climate change

Increased average temperatures across all seasons under climate change will lead to an associated regional increase in the evaporation rates of dry-land river waterbodies and an associated increase in evapotranspiration rates. This, in turn, leads to extended periods of water stress experienced by vegetation.

An expected future increase in the intensity of extreme rainfall events will be accompanied by an extension of periods of exaggerated drought.

The hydrological regularity of the desert river systems of the north east LEB is heavily dependent upon the complex interactions of a range of tele-connected weather systems such as the El Nino – Southern Oscillation (ENSO) system of the Pacific Ocean; the North-West Cloud Banks and the Indian Ocean Dipole; and the inter-tropical conversion zone and its impact on seasonal monsoonal incursions.

The influence of these systems upon Australia is apparently shifting southwards and there is currently a degree of uncertainty regarding their influence upon the hydrology of LEB river systems. Given the dependence of Coolibah upon major flood events for the recruitment of new cohorts of the species across the region, the future hydrological uncertainty relating to climate change is of concern.

Hydrology and geomorphology

Any major interference with naturally functioning hydrological flow regimes along inland rivers and waterways will result in significant negative impacts to associated biological systems and affect the natural recharging of ecologically important groundwater systems.

It is vital that the entire river network and its associated catchment are viewed as one interdependent hydrological system. The key driver for ecosystem function within this interconnected, interdependent dryland river system is the naturally functioning, currently unregulated, hydrological regime. Any attempt to regulate the flow of the system or to extract excessive amounts of water for mining or irrigation development will lead to a negative cascade of impacts upon biotic and abiotic processes, adversely influencing downstream biota. The destructive nature of such impact is clearly evidenced and recorded across a range of riparian systems elsewhere globally.

Kalamurina Wildlife Sanctuary vegetation cover

Equally important are the naturally-functioning landforms, that retain and distribute the river flow. Management actions that impede floodplain flow, concentrate flow, or attempt to change landscape behaviour are likely to be pointless at best and damaging at worst. Across Australia and globally, damaged river landscapes have reduced productivity and amenity, sometimes irrevocably. Attempts to recreate natural functions are now taking place in some catchments, but they are expensive and usually only partially successful.

Total grazing pressure

The most obvious actual and recognised threat upon riparian vegetation along the riverine corridor are the direct and indirect effects of the impact of domestic and feral grazing animals. Grazing influences the compositional, structural and functional components of the riparian ecosystem, upon which a healthy ecosystem and associated biodiversity depends. The impacts upon the individual components (i.e. species composition, vegetation structure, and ecosystem functional process) interact, further degrading overall biodiversity values.

Across the study region the impact includes the loss of perennial and annual palatable plant species. The degree of impact varies across the region's waterholes and may reflect the cumulative history of stocking rates between individual waterholes. The decrease in species can be directly attributed to selective grazing and indirectly due to associated trampling and camping of stock.

Due to an obvious selective grazing pressure on palatable species, the overall composition on heavily stocked sites then shifts to an array of less palatable species. The loss of perennial species, from ground layer species through to upper canopy species, directly reduces the structural complexity of the system.

Fire

At Goyder Lagoon it was observed an extensive area of lignum swamp was destroyed through burning. It is unknown whether this was from natural causes such as lightening strikes.

The inland wetlands of the Channel country have been seen to play an increasingly important role in supplying habitat and breeding sites for a range of significant nomadic and migratory water bird species. Loss through burning of this habitat directly imperils the rich natural ecosystem production and biodiversity values of a wetland of national and international significance such as Goyder Lagoon.

Feral pig at Andrewilla Waterhole

PRIORITIES FOR FUTURE MANAGEMENT

This study has established an inventory of plant species, assessed the vegetation condition associated with selected water holes of the Diamantina and Warburton Rivers systems, and initiated a site-based and systematic monitoring program to establish a benchmark against which to monitor vegetation and associated biodiversity, trends over time.

This assessment and the establishment of a monitoring program represent the very early stages of a long-term monitoring framework; that is, an interactive and adaptive process required to detect positive or negative trends in the composition, structure and functioning of biodiversity over time.

The Diamantina monitoring program should be continued into the future. Regional stakeholders should be directly involved in the evolution of the program, directly educating, informing and providing feedback to all stakeholders.

FOR FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Gillen, J.S. 2017. Vegetation and soil assessment of selected waterholes of the Diamantina and Warburton rivers, South Australia, 2014–16. Report by Australian National University to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.*

Little Corella, a raucous cockatoo that depends on hollows in old Coolibahs for breeding

Waterbirds recolonise the wetlands as they fill and rise and ebb.

KEY POINTS

- Vegetation, particularly the dominant tree and shrub species in the region, explained most of the variability in bird assemblage composition across sites.
- Coolibah proved to be the most dominant factor shaping bird communities, and explained 70% of all variation in bird assemblages.
- The generally north-south alignment of the Georgina–Diamantina catchment rivers raises the possibility that woodland-dependent landbirds undertaking migratory and other dispersal movements may follow the courses of these rivers.
- Despite the extreme irregularity and episodic nature of streamflows in the Georgina–Diamantina catchment, and the consequent boom-bust, pulsed nature of ecological responses, connectivity along the drainage networks remains high.
- A number of Notable Bird Discoveries were made and three bird species of national conservation significance were recorded.
- 150 species of bird were recorded between 2014 and 2016, a moderate diversity for a region in drought over most of the study. Fifty-four were waterbirds which were concentrated in the Goyder Lagoon area.

RIPARIAN BIRD ASSEMBLAGES

Banded Whiteface, a small insectivore and granivore that was infrequently seen in open shrublands and desert country.

RIVER AND STREAM FLOWS *in the Diamantina catchment are the lifeblood of the region in which the great waterbird population boom and bust cycles play out.*

During extreme and extended droughts nearly all waterbirds are forced to vacate the region (or perish). After flood-generating rainfall events anywhere in the Georgina–Diamantina Catchment, waterbirds recolonise the wetlands as they fill and rise and ebb, and there is a general increase in numbers as birds follow the floods downstream into the Channel Country wetlands and beyond, their numbers boosted by in situ breeding and immigration from outside the region.

On the biggest floods, enormous nesting colonies form, and the successful recruitment of a wide range of species from these breeding events has ramifications for populations throughout the Australian continent and beyond.

If there are large floods in the Cooper Creek Catchment occurring in the same summer and autumn period, then waterbirds from the Georgina–Diamantina system can then capitalise on the lakes and wetlands in the greater Coongie Lakes system, which both fill later in the year and persist for two years or more once full.

OBSERVATIONS OF INTEREST

A number of important observations were made during the study:

- One Spotted Bowerbird, an endangered species in SA thought to be extinct in SA, was observed on Pandie Pandie; the last SA record was in the Riverland in the 1930s.
- Painted Honeyeaters were observed at one site each on Cowarie and Clifton Hills; this is a vulnerable species under the EPBC Act.
- A single Olive-backed Oriole, a rare species in SA, was observed on Pandie Pandie; this is only the second record from the far North East of SA, and the first from this river system in SA.
- One Golden Whistler was seen on Pandie Pandie; this species was previously unrecorded from the Diamantina River. One unconfirmed sighting at the Coongie Lakes was recorded in 1908; this bird was previously unknown north of the Flinders Ranges in SA.
- A single Restless Flycatcher, a rare species in SA, was seen at Burt Waterhole on Clifton Hills Station. There are few previous records from the Diamantina–Warburton in SA, and the species is a declining woodland bird in south-eastern Australia.
- Several Tawny Grassbird were seen at Burt Waterhole, a species not known from SA until observed near Innamincka in 2013.

Common Name	Scientific Name
Emu	*Dromaius novaehollandiae*
Stubble Quail	*Coturnix pectoralis*
Brown Quail	*Coturnix ypsilophora*
Plumed Whistling-Duck	*Dendrocygna eytoni*
Musk Duck	*Biziura lobata*
Freckled Duck	*Stictonetta naevosa*
Black Swan	*Cygnus atratus*
Australian Shelduck	*Tadorna tadornoides*
Australian Wood Duck	*Chenonetta jubata*
Pink-eared Duck	*Malacorhynchus membranaceus*
Australasian Shoveler	*Anas rhynchotis*
Grey Teal	*Anas gracilis*
Pacific Black Duck	*Anas superciliosa*
Hardhead	*Aythya australis*
Blue-billed Duck	*Oxyura australis*
Australasian Grebe	*Tachybaptus novaehollandiae*
Hoary-headed Grebe	*Poliocephalus poliocephalus*
Great Crested Grebe	*Podiceps cristatus*
Common Bronzewing	*Phaps chalcoptera*
Flock Bronzewing	*Phaps histrionica*
Crested Pigeon	*Ocyphaps lophotes*
Diamond Dove	*Geopelia cuneata*
Peaceful Dove	*Geopelia striata*
Tawny Frogmouth	*Podargus strigoides*
Spotted Nightjar	*Eurostopodus argus*
Australian Owlet-nightjar	*Aegotheles cristatus*
Australasian Darter	*Anhinga novaehollandiae*
Little Pied Cormorant	*Microcarbo melanoleucos*
Great Cormorant	*Phalacrocorax carbo*
Little Black Cormorant	*Phalacrocorax sulcirostris*
Pied Cormorant	*Phalacrocorax varius*
Australian Pelican	*Pelecanus conspicillatus*
White-necked Heron	*Ardea pacifica*
Eastern Great Egret	*Ardea modesta*
White-faced Heron	*Egretta novaehollandiae*
Nankeen Night-Heron	*Nycticorax caledonicus*
Glossy Ibis	*Plegadis falcinellus*
Straw-necked Ibis	*Threskiornis spinicollis*
Australian White Ibis	*Threskiornis molucca*
Royal Spoonbill	*Platalea regia*
Yellow-billed Spoonbill	*Platalea flavipes*
Black-shouldered Kite	*Elanus axillaris*
Whistling Kite	*Haliastur sphenurus*
Black Kite	*Milvus migrans*
Brown Goshawk	*Accipiter fasciatus*
Collared Sparrowhawk	*Accipiter cirrocephalus*
Spotted Harrier	*Circus assimilis*
Swamp Harrier	*Circus approximans*
Wedge-tailed Eagle	*Aquila audax*
Little Eagle	*Hieraaetus morphnoides*
Nankeen Kestrel	*Falco cenchroides*

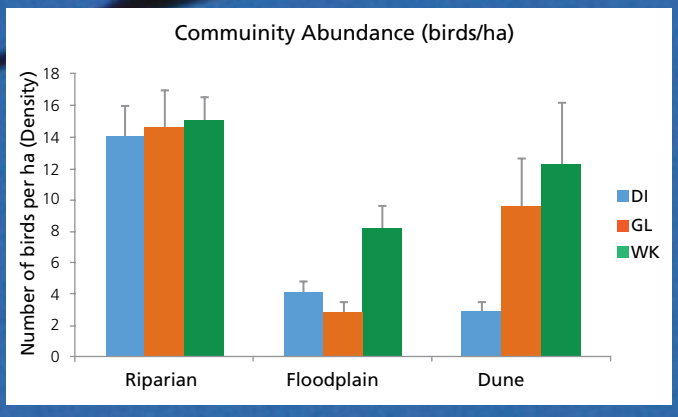
Common Name	Scientific Name
Brown Falcon	*Falco berigora*
Australian Hobby	*Falco longipennis*
Black Falcon	*Falco subniger*
Brolga	*Grus rubicunda*
Purple Swamphen	*Porphyrio porphyrio*
Australian Spotted Crake	*Porzana fluminea*
Black-tailed Native-hen	*Tribonyx ventralis*
Dusky Moorhen	*Gallinula tenebrosa*
Eurasian Coot	*Fulica atra*
Australian Bustard	*Ardeotis australis*
Black-winged Stilt	*Himantopus himantopus*
Red-necked Avocet	*Recurvirostra novaehollandiae*
Banded Stilt	*Cladorhynchus leucocephalus*
Red-capped Plover	*Charadrius ruficapillus*
Black-fronted Dotterel	*Elseyornis melanops*
Red-kneed Dotterel	*Erythrogonys cinctus*
Banded Lapwing	*Vanellus tricolor*
Masked Lapwing	*Vanellus miles*
Common Greenshank	*Tringa nebularia*
Sharp-tailed Sandpiper	*Calidris acuminata*
Curlew Sandpiper	*Calidris ferruginea*
Little Button-quail	*Turnix velox*
Australian Pratincole	*Stiltia isabella*
Gull-billed Tern	*Gelochelidon nilotica*
Caspian Tern	*Hydroprogne caspia*
Whiskered Tern	*Chlidonias hybrida*
Silver Gull	*Chroicocephalus novaehollandiae*
Red-tailed Black-Cockatoo	*Calyptorhynchus banksii*
Galah	*Eolophus roseicapillus*
Little Corella	*Cacatua sanguinea*
Cockatiel	*Nymphicus hollandicus*
Blue Bonnet	*Northiella haematogaster*
Red-rumped Parrot	*Psephotus haematonotus*
Budgerigar	*Melopsittacus undulatus*
Blue-winged Parrot	*Neophema chrysostoma*
Channel-billed Cuckoo	*Scythrops novaehollandiae*
Horsfield's Bronze-Cuckoo	*Chalcites basalis*
Black-eared Cuckoo	*Chalcites osculans*
Pallid Cuckoo	*Cacomantis pallidus*
Southern Boobook	*Ninox novaeseelandiae*
Eastern Barn Owl	*Tyto javanica*
Red-backed Kingfisher	*Todiramphus pyrrhopygius*
Sacred Kingfisher	*Todiramphus sanctus*
Spotted Bowerbird	*Ptilonorhynchus maculatus*
White-winged Fairy-wren	*Malurus leucopterus*
Variegated Fairy-wren	*Malurus lamberti*
Grey Grasswren	*Amytornis barbatus*
Eyrean Grasswren	*Amytornis goyderi*
Southern Whiteface	*Aphelocephala leucopsis*
Red-browed Pardalote	*Pardalotus rubricatus*
Striated Pardalote	*Pardalotus striatus*

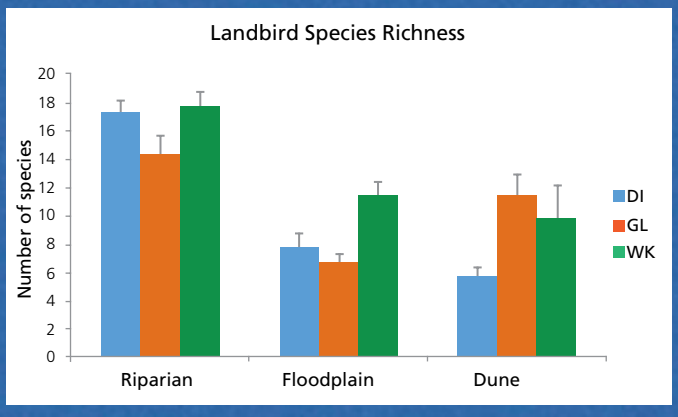
Common Name	Scientific Name	Common Name	Scientific Name
Pied Honeyeater	*Certhionyx variegatus*	Australian Raven	*Corvus coronoides*
Singing Honeyeater	*Lichenostomus virescens*	Little Crow	*Corvus bennetti*
White-plumed Honeyeater	*Lichenostomus penicillatus*	Restless Flycatcher	*Myiagra inquieta*
Yellow-throated Miner	*Manorina flavigula*	Magpie-lark	*Grallina cyanoleuca*
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*	Red-capped Robin	*Petroica goodenovii*
Crimson Chat	*Epthianura tricolor*	Australian Reed-Warbler	*Acrocephalus australis*
Orange Chat	*Epthianura aurifrons*	Tawny Grassbird	*Megalurus timoriensis*
Painted Honeyeater	*Grantiella picta*	Little Grassbird	*Megalurus gramineus*
White-browed Babbler	*Pomatostomus superciliosus*	Rufous Songlark	*Cincloramphus mathewsi*
Chestnut-crowned Babbler	*Pomatostomus ruficeps*	Brown Songlark	*Cincloramphus cruralis*
Cinnamon Quail-thrush	*Cinclosoma cinnamomeum*	White-backed Swallow	*Cheramoeca leucosterna*
Chirruping Wedgebill	*Psophodes cristatus*	Welcome Swallow	*Hirundo neoxena*
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	Fairy Martin	*Petrochelidon ariel*
White-winged Triller	*Lalage sueurii*	Tree Martin	*Petrochelidon nigricans*
Golden Whistler	*Pachycephala pectoralis*	Common Starling	*Sturnus vulgaris*
Rufous Whistler	*Pachycephala rufiventris*	Mistletoebird	*Dicaeum hirundinaceum*
Grey Shrike-thrush	*Colluricincla harmonica*	Zebra Finch	*Taeniopygia guttata*
Olive-backed Oriole	*Oriolus sagittatus*	House Sparrow	*Passer domesticus*
White-breasted Woodswallow	*Artamus leucorynchus*	Australasian Pipit	*Anthus novaeseelandiae*
Masked Woodswallow	*Artamus personatus*	Cattle Egret	*Ardea ibis*
White-browed Woodswallow	*Artamus superciliosus*	Black-breasted Buzzard	*Hamirostra melanosternon*
Black-faced Woodswallow	*Artamus cinereus*	Grey Falcon	*Falco hypoleucos*
Australian Magpie	*Cracticus tibicen*	Inland Dotterel	*Charadrius australis*
Grey Fantail	*Rhipidura albiscapa*	Banded Whiteface	*Aphelocephala nigricincta*
Willie Wagtail	*Rhipidura leucophrys*	Gibberbird	*Ashbyia lovensis*

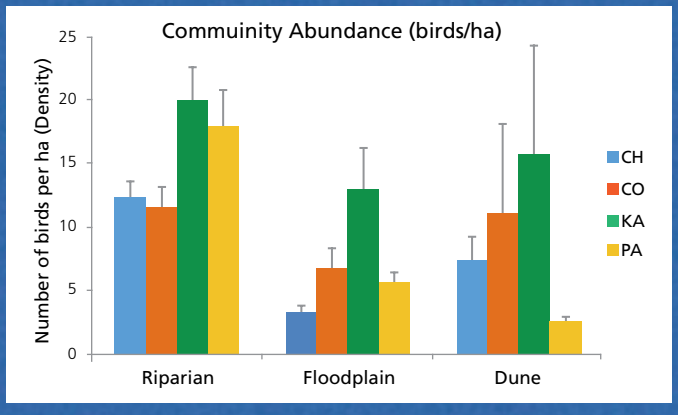
White-backed Swallow, an elegant aerial insectivore, common in the region; they snuggle close together in burrows in the sand during the coldest parts of winter, entering a torpid state (lowered body temperature) to conserve energy when insect activity is low.

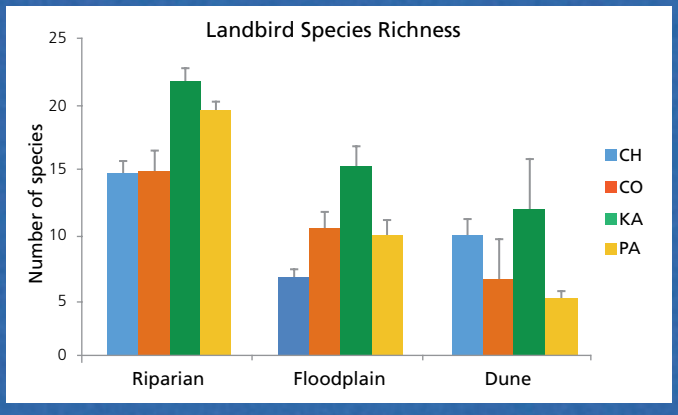
LAND BIRD DIVERSITY AND ABUNDANCE

The highest diversity of landbirds – 22 or more species on transect – was found at "Diamantina Split" Waterhole and Double Bluff Waterhole in the north, Ultoomurra Waterhole in the northern parts of the Warburton River, Stony Point and Cowarie Crossing areas on Cowarie, and at all the riparian sites surveyed on Kalamurina Wildlife Sanctuary, with the highest number being 27 landbird species at "Mia Mia" Waterhole in 2016.









RIPARIAN FLOODPLAIN CONNECTIVITY

The functional connectivity of Lake Eyre Basin rivers remains high, due largely to their hydrological integrity. The low level of hydrological modification means that critical aquatic ecosystem processes remain intact.

Many bird species use riparian vegetation for food, breeding and shelter (roosting) or regularly visit waters to drink while spending most time away from the rivers in adjacent habitats. Similarly, many riparian bird species use the resources of adjacent landscapes on an occasional basis.

There is a distinct possibility that these riparian corridors act as 'highways' for landbirds on the move, which means the rivers may play an important role in connecting bird populations across different regions in Australia.

The interface between the aquatic and dryland ecosystems is also a highly significant facet of ecological connectivity. The two-way transfer of energy and nutrients across riparian zones and adjacent floodplains has many pathways; one critical pathway for landbirds is the flow of energy from aquatic environments in the form of food, a phenomenon known as food web subsidy.

For many species of Australian waterbirds, which can move continental distances, the wetlands of Goyder Lagoon periodically support hundreds of thousands of individuals, in response to large floods. Waterbirds are thought to move into this region and the wider Channel Country region from all parts of the continent to breed. Channel Country wetlands, including Goyder Lagoon, also provide important stopover habitat for migrating shorebirds, including endangered species such as the Curlew Sandpiper. Over 20 species of migratory shorebirds, protected under international treaties, and to which Australia is a signatory, have been recorded in the wetlands of the far north-east of South Australia.

Waterbirds in the Channel Country appear to capitalise on the different timing of floods across the major rivers and Kati Thanda–Lake Eyre by vacating one region as conditions become unsuitable (e.g. drying, high salinities) to relocate to an adjacent river system where rich feeding grounds are inundated more slowly or persist for longer periods after the passage of a major flood. A major flood-generating, rainfall event which is coincident across the upper parts of the Georgina, Diamantina and Cooper catchments will travel most quickly down the Diamantina–Warburton system, followed by flows down the Georgina River–Eyre Creek drainage, with floodwaters taking considerably more time to progress to the Coongie Lakes and lower reaches of Cooper Creek in South Australia.

The shifts in the timing of flooding, which become more pronounced in the lower reaches of these rivers, combined with annual differences in the location, intensity and timing of flooding rains in the upper (and all parts of the) catchments, create an unpredictable range of challenges and opportunities for waterbirds in the Lake Eyre Basin, to which they appear to be well adapted. Despite the often prolonged dry spells of wetlands in the interior, waterbirds view and use these intermittently inundated wetlands as dynamic, intermittently connected landscapes.

PRIORITIES FOR FUTURE MANAGEMENT

Coolibah as a Keystone Species

The Coolibah is a keystone species in the study area.It is the dominant large tree of the region and occurs along the length of the rivers surveyed. It is a keystone species for a wide range of birds because of the shade and shelter, breeding habitat (including hollows and the strength to support large stick nests for large nocturnal and diurnal birds of prey, cockatoos etc), canopy insect resources, and buds, fruit and seeds that it provides. Its keystone role extends to the drought-refuge function that riparian environments provide; unlike ephemeral plant species that dominate the flora of the region, long-lived trees like the Coolibah, acting as water and transformed organic energy (food-resource) pumps, continue to put on new growth, flowers and fruits, and so buffer the ecosystem from the most severe effects of drought conditions. Very little recruitment of Coolibah was noticed while conducting the site-based surveys, and an intensive study into the species' demography and recruitment needs is urgently required.

Riparian Woodland Management

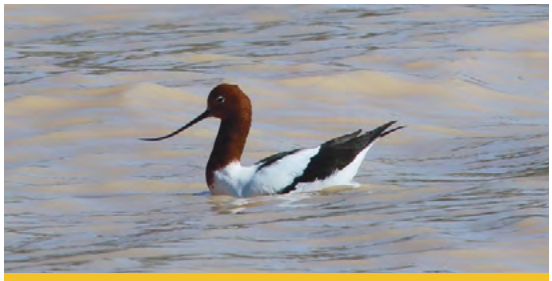
Collaborative research between rangelands scientists and the properties in the study area should be undertaken to examine how the intensity and timing of cattle grazing in riparian areas affects the vegetation and bird communities. The research presented here shows that woodland bird diversity and abundance are associated with increasing cover of several shrub species in riparian environments, and so it is important from a sustainable grazing perspective, that recruitment and health (vigour) of the dominant trees and shrubs, and maintenance of ground cover attributes (grasses, forbs, litter, dead wood) be optimised under commercial grazing regimes. Other potentially degrading activities by feral herbivores (pig, rabbit, camel etc.) and natural disturbance events (flood scour, drought etc.) should be investigated as part of a balanced approach to this research.

Maintenance of Natural Flow Regime

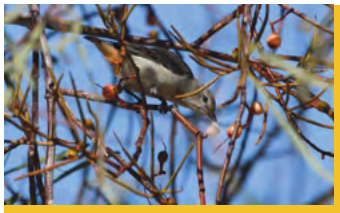
Although a higher-order issue and not able to be managed at the scale of properties, it is essential that both the volume and natural regime of river flows be maintained.

Fire Management in Goyder Lagoon

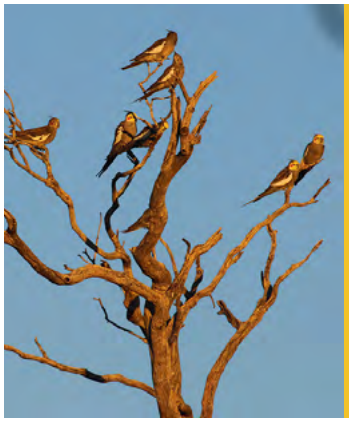
A fire in the late 2000s severely damaged a highly significant site for colonially nesting waterbirds in Goyder Lagoon. These sensitive



Red-necked Avocet
Avocets are a specialised type of wader or shorebird, and their up-turned bills are used to scoop up abundant insect larvae in shallow waters and muddy sediments. They often feed in flock formation, moving together in synchrony as they swathe their bills from side-to-side. When larval and small fish are abundant, as they can be especially in saline waters, avocets can also turn their bills to fishing. Avocets are often found in saline pools where fish are absent which allows small aquatic insects and crustaceans to build up in huge abundance and make easy pickings for the birds. However, they choose to nest in freshwater floodplains, dispersing into pairs and small groups and finding small dry islets on which to lay their eggs, and wait for heavy rainfall events or a large flood to provide the ideal conditions for breeding. After breeding is finished they regather into large flocks.



Female Mistletoebird
It is perched inspecting the fruits of the mistletoe, *Amyema preissii*, which the bird disperses. Three bird species are the main consumers of mistletoe berries in the region – Mistletoebird, Spiny-cheeked Honeyeater and Painted Honeyeater. The Mistletoebird has evolved, as have the many similar species found in the rest of the world, to digest the fruit and eject the pip rapidly, and to perch along the length of branches to maximise the chances of dropping the seeds onto a suitable host tree or shrub. Mistletoes are an important component of natural healthy ecosystems, and support many herbivorous insects (which, after all, are bird food), and their flowers are an important nectar source for honeyeaters, a few other birds and insects.



Cockatiel
Cockatiels are flocking nomadic species that visit the study area in the better seasons, or which capitalise on the drought refuges provided by the greened-up river flats in times of drought after small Queensland floods have progressed through the region. The Cockatiel is a small member of the cockatoo family which, in the study area, is represented by Galahs, Little Corellas and Red-tailed Black-Cockatoos.

DROUGHT REFUGE

Because regional floodwaters emanating from Queensland reach the Diamantina River and upper parts of Goyder Lagoon, at least, in virtually all years, even if the study area has suffered consecutive years of rainfall deficit or drought, the riparian and floodplain environments that have benefited from flows and limited flooding provide critically important drought-refuge habitat for birds and other plants and animals.

LAND BIRD DIVERSITY AND ABUNDANCE

The highest diversity of landbirds – 22 or more species on transect – was found at "Diamantina Split" Waterhole and Double Bluff Waterhole in the north, Ultoomurra Waterhole in the northern parts of the Warburton River, Stony Point and Cowarie Crossing areas on Cowarie, and at all the riparian sites surveyed on Kalamurina Wildlife Sanctuary, with the highest number being 27 landbird species at "Mia Mia" Waterhole in 2016.

sites need to be identified, through further waterbird research during big flood events, and through liaison with station managers and authorities with appropriate fire protection and management strategies developed and implemented. Funding is required to monitor waterbird responses to flooding in Goyder Lagoon and how this important site recovers. Lignum and River Cooba (or Belalie) are the key wetland plant species that allow large aggregations of waterbirds to gather and nest. These vegetation communities need to be mapped and protected. Coolibahs are also important nest trees for some colonially nesting waterbirds.

Waterbird Surveys of Goyder Lagoon

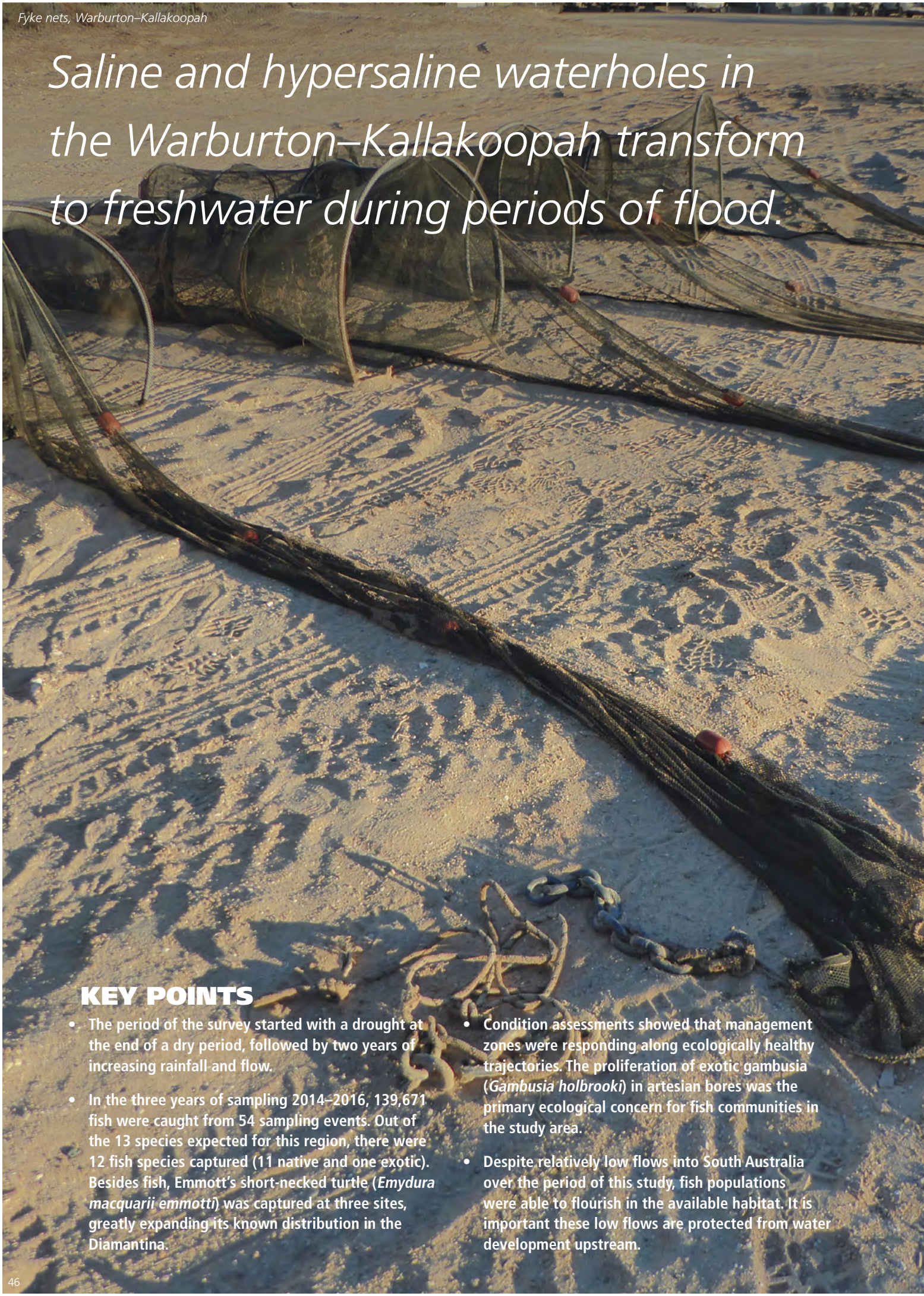
A priority is to conduct aerial surveys of waterbirds, tied in with on-ground investigations of breeding responses, to achieve a better understanding of the relationships between waterbird responses and flood size and timing.

Threatened Bird Species Research

Two endangered Australian endemic bird species occur regularly in the study area, namely the Australian Painted Snipe and Plains-wanderer. It is advised to survey and monitor populations of these two species in partnership with property owners and managers to develop sustainable grazing management strategies to ensure their persistence and population health. Studies or surveys of the isolated Red-tailed Black Cockatoo population on Pandie Pandie, Painted Honeyeater, and Spotted Bowerbird are required. Studies and population monitoring of landbird species dependent on ephemeral wetlands vegetation in Goyder Lagoon for their occurrence or persistence in SA – Grey Grasswren, Yellow Chat and potentially Tawny Grassbird – are also required.

FOR FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Reid, J. R. W. 2017. Birds of the Diamantina River and associated channel country wetlands of South Australia. Report by Australian National University to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.*



Fyke nets, Warburton–Kallakoopah

Saline and hypersaline waterholes in the Warburton–Kallakoopah transform to freshwater during periods of flood.

KEY POINTS

- The period of the survey started with a drought at the end of a dry period, followed by two years of increasing rainfall and flow.
- In the three years of sampling 2014–2016, 139,671 fish were caught from 54 sampling events. Out of the 13 species expected for this region, there were 12 fish species captured (11 native and one exotic). Besides fish, Emmott's short-necked turtle (*Emydura macquarii emmotti*) was captured at three sites, greatly expanding its known distribution in the Diamantina.
- Condition assessments showed that management zones were responding along ecologically healthy trajectories. The proliferation of exotic gambusia (*Gambusia holbrooki*) in artesian bores was the primary ecological concern for fish communities in the study area.
- Despite relatively low flows into South Australia over the period of this study, fish populations were able to flourish in the available habitat. It is important these low flows are protected from water development upstream.

FYKE NET FISHING FOR ANSWERS

THE REGION

The Diamantina Management Zone is characterised by large deep permanent waterholes that receive annual flow regardless of flood or drought years. The fish community here is diverse, comprising most of the species present in the catchment, with most species displaying a broad range of sizes. The Diamantina is a key aquatic refuge and source population for several fish species in the Georgina–Diamantina catchment.

Goyder Lagoon is a broad open floodplain with a complex microtopography that includes scours and lignum swamps. It has no waterholes in its main area, and a few waterholes around the Lagoon edges. It functions predominantly as a corridor to migrating fish species.

The Warburton–Kallakoopah is characterised by permanent and semipermanent saline and hypersaline waterholes in years of drought that transform to freshwater during periods of flood. The fish here are dominated by highly abundant salt tolerant species in drought periods followed by increases in diversity with increases in the magnitude, duration and frequency of freshwater flow.

WATER QUALITY

The Diamantina receives annual channel flow to all of its reaches. These freshwater flows contain low levels of dissolved salts and, in combination with minimal infiltration from saline groundwater, results in the Diamantina remaining fresh throughout the hydroclimatic cycle.

In 2014 the Warburton–Kallakoopah had received very little channel flow for several years. During this period, the infiltration of saline groundwater and in situ concentration of salts through evaporation drove this reach along a trajectory of increasing salinity. In 2014 aquatic salinity measurements throughout were hypersaline. Strong flow was observed during early 2016 resulting in lowered salinity in the Warburton–Kallakoopah.

Sites fed by artesian bores did not follow the flow-driven trends in salinity observed elsewhere. These habitats instead represent stable environments where the water quality parameters of influent artesian water is the strongest influence.

Salt is a dominating feature of large parts of the central LEB, and has been a defining characteristic of many LEB aquatic landscapes since earliest Euoropean explorers described the region.

Salinity profiles for the South Australian section of the Georgina–Diamantina catchment describe a typical trend of increased salinity of waterholes towards the downstream sections of the catchment. Hypersaline environments, usually only encountered during the bust phase, typically start near the downstream (southern) end of Goyder Lagoon, where the Eyre Creek and Diamantina Rivers converge to become the Warburton. Most on channel sites from Ultoomurra onwards (downstream) typically present as hyper saline during the bust period. These sites are predominantly characterised by both extremophile fish species, Lake Eyre Hardyhead and desert gobies, which are capable of living in environments that reach saline levels several times that of sea water (>100 ppt).

NATIVE FISH

Common Name	Scientific Name	Comments
Barcoo Grunter	*Scortum barcoo*	Mainly observed in the Diamantina management zone; less frequent in downstream management zones. Key breeding populations for this species are probably upstream of the South Australian border in Queensland. Furthest downstream observation was at Cowarie Crossing (on the Warburton River), in 2016 when sampling took place during strong channel flows. They move during large flows but are slower to move than other species.
Barred Grunter	*Amniataba percoides*	A highly mobile species, one of the least abundant species detected. Found in the Diamantina; Goyder Lagoon; and Warburton–Kallakoopah management zones, in varying degrees of abundance and when flows were observed. They are tolerant of high salinity levels and commonly found in salinities of up to 7 ppt (average ocean salinity 35 ppt).
Bony Herring	*Nematolosa erebi*	Present in all 4 management zones. A highly mobile species they move quickly on commencement of flow with a strong migratory capacity. Bony herring feed on algae and dead organic matter. Capable of shifting dietary preferences depending on hydrological conditions. High mobility with a broad salinity tolerance and limited dietary overlap with other fish species makes bony herring one of the most abundant and commonly encountered fish in the LEB.
Desert Goby	*Chlamydogobious eremius*	Desert goby are adapted to survive in harsh very saline, low oxygen conditions. Highest abundance was found in the Warburton–Kallakoopah management zone, where drier conditions and saline ground water resulted in poorer water quality and elevated salinities.
Desert Rainbow Fish	*Melanotaenia splendida tatei*	Desert rainbowfish are highly mobile and a common, widespread species throughout the LEB. Low abundances were recorded suggesting source populations originate in Queensland. Furthest south observation was in the Warburton–Kallakoopah management zone. This species disperse on flow but populations do not boom immediately, and will typically require a delay of several months before spawning takes place.
Hyrtl's Tandan	*Neosilurus hyrtlii*	Present during all sampling events in the Diamantina; Goyder Lagoon; and Eyre Creek management zones. Fish of the Diamantina management zone displayed the maximum size class for this species suggesting this zone is a key refuge for this species. After connectivity was re-established with the lower catchment, this species displayed modest downstream range expansion when compared to other species, not detected in the Warburton–Kallakoopah management zone.
Lake Eyre Golden Perch	*Macquaria sp.*	This is a large-bodied species with strong migratory capacity. Detected during all sampling events in the Diamantina management zone and Tepamimi (Eyre Creek management zone). This distribution highlights a preference for permanent habitats with low salinity where it is capable of reaching large sizes. This species moves during flow periods occurring throughout the life span of the fish. In 2015 moderate channel flows reconnected the Diamantina management zone to the upper reaches of the Warburton–Kallakoopah management zone.
Lake Eyre Hardyhead	*Craterocephalus eyresii*	Able to tolerate extreme conditions; specialises in water conditions too saline to support most other species in the catchment. Populations are highest in the lower reaches only detected in the Warburton–Kallakoopah management zone where lower rainfall and saline groundwater results in higher salinity waterholes. During low flow years (2014 & 2015), where salinity remained high they were the highest recorded species. In 2016 channel flows lowered salinity with large numbers of immigrants greatly decreasing the Lake Eyre Hardyhead population. An apparently normal phenomenon.
Silver Tandan	*Porochilus argenteus*	A species of catfish found throughout the Diamantina and Cooper Creek systems that moves on large flow events. They can grow up to 300mm and are known to migrate in large numbers. Present in the Diamantina; Warburton–Kallakoopah; and Eyre Creek (at Tepamimi) management zones. Very large specimens found in the Diamantina management zone indicate this is a key refuge for this species.
Spangled Grunter	*Leiopotherapon unicolour*	This species (a.k.a. spangled perch) are highly mobile moving into newly flooded habitats soon after flow commences. They have a large gill-heart surface area compared to other fishes facilitating oxygen uptake and improved endurance. The source populations for this species are in the upstream section of the catchment in Queensland. Despite their capacity for strong, long-distance swimming, they appear to be poor competitors and tend not to feature strongly in stable commzoneies in South Australia.
Welch's Grunter	*Bidyanus welchii*	High numbers recorded on most sampling events with a limited capacity for migration. This species moves during large flows but is slower to move than other species. Detected on every sampling occasion in the Diamantina management zone, including maximum reported size class for this species, indicating in dry times (e.g. 2014) this management zone is a high quality refuge for its long term survival and is probably acting as a source population for this species.
INTRODUCED FISH		
Eastern Gambusia	*Gambusia holbrooki*	This is an invasive, pest species with a restricted distribution, typically centred on anthropogenic habitats fed by artesian bores. Tolerant of harsh water chemistry typical in artesian bores, preferring these stable habitats, where they often dominate the fish assemblage reaching very high densities. During periods of connectivity this species appeared to move out of anthropogenic refuges and entered the main channel waterholes.

FISH MONITORING

In the three years of sampling approximately 140,000 fish were caught from 54 sampling events. This incorporated 12 fish species: 11 native and one exotic.

The most abundant fish species were Lake Eyre hardyhead (*Craterocephalus eyresii*, 61,787 fish), bony herring (*Nematolosa erebi*) (24,475 fish) and Lake Eyre golden perch (*Macquaria* sp., 17,185 fish).

The least abundant species were desert glassfish (which were not detected in this study), desert rainbowfish (*Melanotaenia splendida tatei*, 54 fish) and barred grunter (*Amniataba percoides*) (161 fish).

The most frequently encountered species were bony herring, silver tandan (*Porochilus argenteus*) and Lake Eyre golden perch.

The least commonly encountered species were desert glassfish (not detected in this study), desert rainbowfish and barred grunter.

OTHER NATIVE FAUNA

Crustaceans

A high degree of variability was observed in the seasonal distribution and abundance of crustaceans.

Catches of yabbies in this study were insufficient to show definitive patterns in distribution and abundance, but they appear to be restricted to Goyder Lagoon and upstream. This is most likely due to the shallow saline aquifer in the lower reaches producing surface water too salty for yabbies to tolerate and preventing burrowing. Habitats in the Warburton–Kallakoopah region where saline groundwater is absent were subject to drying periods too long for yabbies to survive in burrows. Further study into the drivers of yabby population dynamics is required to properly ascertain their status in this system.

Shrimp species were restricted to the Goyder Lagoon and Diamantina management zones in 2014 and 2015. They were absent from the Warburton/Kallakoopah at this time due to lack of freshwater flows large enough to decrease salinity in the region. The shrimp species present in the Diamantina tolerate salinity up to 30–40 mS/cm. Salinity values in the Warburton–Kallakoopah region were well in excess of these values in 2014 and 2015.

As large flows in 2016 provided connectivity throughout the catchment and kept salinity low in the lower reaches, these shrimp species, which have effective dispersal capabilities, became more prevalent. The timing of this dispersal is important, as they are a significant prey item for many fish species that also became more prevalent in this area in 2016.

Freshwater crabs are highly adapted to arid conditions through their adoption of burrowing behaviour and physiological dormancy. This strategy enables freshwater crabs to conserve water by slowly metabolising fat to access water whilst losing very little water to the humid conditions in their burrows. This strategy has enabled them to occupy ephemeral habitats throughout the arid zone.

Given that freshwater crabs were present in saline waters when yabbies and shrimp were absent, they appear to have a higher tolerance of salinity than yabbies and shrimp, although their salinity tolerance is not reported in the literature.

In 2014, most of the waterholes in the Warburton–Kallakoopah region were extremely hypersaline and crabs were not captured, although they had been present there prior to the survey as evidenced by large numbers of dead crabs at this time. Smaller flows in 2015 decreased salinity in the lower reaches enabling crabs to emerge from burrows and survive in the fresher water. Large flows in 2016 were also favourable for crabs to survive in the lower reaches of the study area.

Yabbie (Cherax destructor)

Crustaceans

Emmott's Short-Necked Turtle (aka Cooper Creek Turtle)

The current study detected Emmott's short-necked turtles (*Emydura macquarii emmotti*) at three sites.

This species is known predominantly from the Cooper Creek catchment where they are commonly observed in deep permanent waterholes or in nearby waterholes during dispersal and boom phases. Prior to this study only a single definitive record of turtles in the Georgina–Diamantina catchment existed when two individuals were caught at Clifton Hills Outstation (a sub-site within Yammakira Waterhole) in 2003.

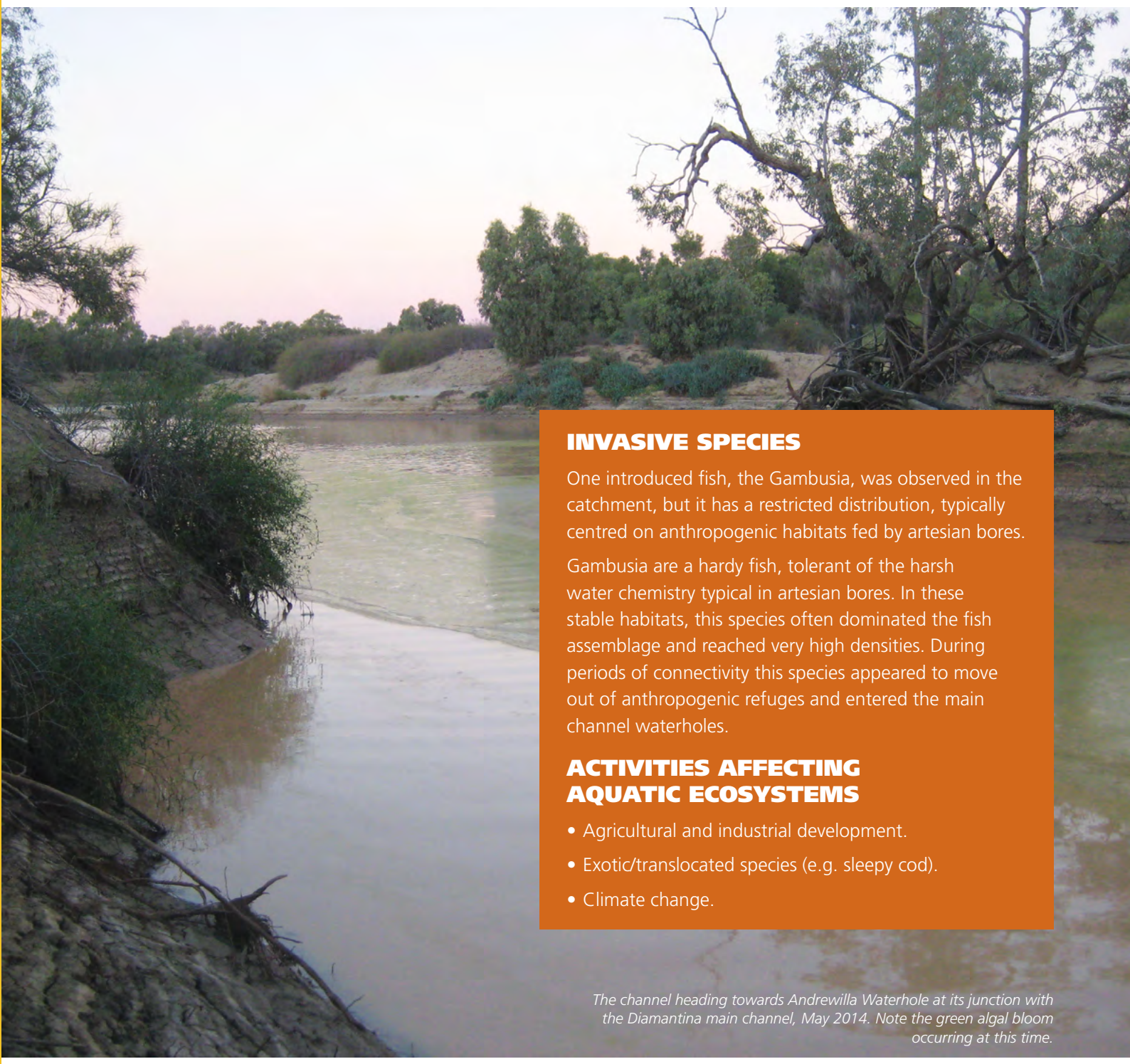
Although this species is widespread and abundant in the Cooper Creek catchment only 17 turtles were detected in the current study. These were restricted to three sites within a localised area in the Diamantina (Diamantina Split, Yammakira and Andrewilla). Andrewilla and Yammakira are large, deep permanent waterholes similar to the habitats associated with this species in the Cooper catchment.

It would seem that the Georgina–Diamantina turtle population is much smaller than that of the Cooper (with both fewer individuals and a smaller range). This may be because the population has only recently translocated to the catchment, habitat characteristics may be unsuitable, or the result of interspecies competition or predation.

Redclaw (*Cherax quadricarinatus*)

Redclaw crayfish (*Cherax quadricarinatus*), are a species of freshwater crayfish endemic to tropical and sub-tropical parts of northern Australia. Considered to be a translocated pest species within the LEB, they have been recorded in the upper to mid reaches of the Georgina, Diamantina and Cooper catchments. In the Georgina catchment, redclaw have previously been collected at sites as far south as Bedourie, whilst in the Diamantina catchment, redclaw were found as far south as the Diamantina National Park. Despite extensive sampling, redclaw were not captured below the South Australian border during this study. Redclaw are a moderately mobile species and it is unclear why they have not dispersed into South Australian waters yet. It is essential that ongoing monitoring remain in place to detect encroachment of redclaw into South Australian waters.

Emmott's Short-Necked Turtle or Cooper Creek Turtle (Emydura macquarii emmotti)



INVASIVE SPECIES

One introduced fish, the Gambusia, was observed in the catchment, but it has a restricted distribution, typically centred on anthropogenic habitats fed by artesian bores.

Gambusia are a hardy fish, tolerant of the harsh water chemistry typical in artesian bores. In these stable habitats, this species often dominated the fish assemblage and reached very high densities. During periods of connectivity this species appeared to move out of anthropogenic refuges and entered the main channel waterholes.

ACTIVITIES AFFECTING AQUATIC ECOSYSTEMS

- Agricultural and industrial development.
- Exotic/translocated species (e.g. sleepy cod).
- Climate change.

The channel heading towards Andrewilla Waterhole at its junction with the Diamantina main channel, May 2014. Note the green algal bloom occurring at this time.

PRIORITIES FOR FUTURE MANAGEMENT

The findings from this study have highlighted a range of management recommendations:

- Adopt the proposed management zones to frame future management in the region.
- Manage artesian bores to control or eliminate source populations of gambusia.
- Recognise the importance of low magnitude flows and work to limit upstream and cross-border water development.
- Continue to educate the public about the risk of translocating fish species.
- Consider a further survey to examine the Goyder Lagoon management zone.

FOR FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Schmarr, D.W., Mathwin, R. and Cheshire, D.L. 2017 Aquatic ecology assessment and analysis of the Diamantina River catchment: Lake Eyre Basin, South Australia. Report by South Australian Research and Development Institute to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.*

Managing tourism and the Outback experience presents an ongoing challenge for local pastoral leaseholders and natural resource managers.

KEY POINTS

- The region encompasses a number of sites of cultural and historical significance to the Wangkangurru Yarluyandi Traditional Owners.
- The Traditional Owners have a growing concern and desire to have a more prominent role in managing and protecting key sites in consultation with the relevant land managers.
- Interpretation through a range of available mediums is seen as a key tool in future management of both tourism and Aboriginal interests to raise the awareness and direct best-practice for the growing numbers of visitors that are seeking to experience and enjoy the natural, cultural and historical assets of the Diamantina catchment.
- As the effects of tourism on this important ecosystem and its Aboriginal cultural heritage are relatively minimal so far it provides an outstanding opportunity to develop a cohesive management approach by the key land managers and Aboriginal stakeholders that will enhance the visitor experience and protect cultural heritage and biodiversity values.

Pelican Waterhole, Andrewilla floodplain

THE MANY LAYERED LANDSCAPE

FROM THE EARLIEST EXPLORATION *and occupation by Aboriginal groups, the study area has been subject to a variety of different land uses – each having its own impact and bringing its own demands on to the natural resources of the existing ecosystem. Today, Aboriginal, pastoral, mining and petroleum, conservation and tourism interests all vie for a place in the landscape. Of these, tourism is the only use that does not operate within a specific legislative framework.*

Currently, within the Diamantina catchment study area tourism does not present a significant threat. However the potential nature of impacts upon biodiversity values should be investigated and monitored. Rain events and the filling of Kati Thanda–Lake Eyre generate spikes in interest and demand on resources. This is often fuelled by media publicity and may impact on some of the local landholders and infrastructure.

The Birdsville Track is the main avenue available for tourists to enter the region. It has long been established as one of the iconic 'Outback' travel routes and is a major flow path for visitors. It provides the main access route to a small number of locations where tourists can experience the waterholes and river channels of the Warburton and Diamantina.

A number of key areas are of natural, cultural and historical interest and warrant consideration as to how they may, or may not be, incorporated into the tourism experience.

This presents an ongoing challenge for local pastoral leaseholders and natural resource managers about how to best manage the demands for access to this 'Outback' experience and any likely impacts to fragile ecosystems – especially the aquatic refuges of the Diamantina catchment.

Pelican Waterhole, Andrewilla floodplain

ABORIGINAL PRE-HISTORY

Four decades of archaeological fieldwork in desert landscapes of the Interior has placed Aboriginal occupation at around 40,000 years before present (BP). A significant number of Aboriginal language groups were spread over the one million square kilometres of the LEB.

The many different eco-systems in the LEB presented its Aboriginal inhabitants with major challenges as they strove to preserve its natural balance. Water was the key, and adjusting to the boom and bust cycle of drought and flood, which made the desert at times barren and deadly, and at other times filled it with water and made it lush with resources, was essential to survival.

A network of soaks, rockholes, refugia waterholes and native wells (mikiri) allowed people to move freely through these desert regions. The creation stories of the Dreamtime and their related Dreaming tracks linked disparate groups from all corners of the Basin and beyond. Over the thousands of years many different Aboriginal language groups developed, bound by highly complex belief systems that interconnect the land, spirituality, law, social life and care of the environment.

The widely-spread Aboriginal groups of the LEB occupied a landscape patterned with stories that encoded the knowledge passed down by the actions of the ancestral creators. It was along some of the most important of these Dreaming tracks that an extensive communication, cermonial and trade network criss-crossed the Basin, which became one of the most important Aboriginal landscapes in Australia.

Times of periodic flood and plenty determined periods of intense interaction, when many neighbouring groups would gather at prime locations to conduct ceremonies and exchange goods, practicing sacred rituals that celebrated the jointly-shared Dreamings. Gatherings of 600 to 1000 people were recorded.

The river systems, channel country, refuge water holes, freshwater soaks and mound springs provided the life-giving arteries for extensive Aboriginal occupation and movement across the land, most of which was severely disrupted with the European settlement over the past 150 years. Today there is extensive evidence of this past human activity throughout the LEB.

Bush camping at Goyder Lagoon waterhole

Stone implements

Stunted coolibah at Goyder Lagoon waterhole

Times of periodic flood and plenty determined periods of interaction, when many neighbouring groups would gather at prime locations.

CONTEMPORARY LAND USE

Human interaction with the landscape since the very first occupation by Aboriginal groups has looked to use the natural resources of the landscape to further their social and economic interests.

The predominant land uses in the Georgina–Diamantina catchment are:

Pastoralism – The study region encompasses five pastoral leases, of which four are actively operating as cattle grazing properties and one is leased by a private philanthropic conservation organisation and managed as a sanctuary. The area is considered a premium cattle-producing region with the river system and associated channel country/wetlands in good rainfall boom seasons considered one of the most productive in the pastoral rangelands. In good seasons pastoralism is one of the major economic drivers of the region.

Mining and petroleum – Extensive exploration and drilling for oil and gas took place from 1958 to 1984, mainly in the Cooper Basin and Simpson Desert. Significant environmental degradation occurred with thousands of kilometres of seismic shot lines bulldozed across the fragile desert landscape. There has only been minimal activity in the Georgina Diamantina region since then, mainly affecting the Simpson Desert region near the Kallakoopah.

Aboriginal interests – Since the Mabo decision in 1992 the Wangkangurru Yarluyandi to the north and Dieri to the south have won their native title rights and formed declared corporate bodies. These now have an evolving role in key development and land management decisions as well as a growing desire to identify, protect and conserve important cultural and historic sites.

Conservation – Only a very small portion of the region falls into state-managed conservation reserves. Kalamurina Wildlife Sanctuary has been leased since 2007 by the Australian Wildlife Conservancy (AWC) and is managed as a private conservation reserve and sanctuary. It offers controlled and highly-managed access to selected commercial tourism operators and some independent travellers on application. All of the Kallakoopah Creek system in the Simpson Desert Regional Reserve has in the past years been closed to tourism visitation and the South Australian Wilderness Society has recommended this section of the region be declared a wilderness zone.

Tourism – Outback SA is heavily promoted as being a key destination for people wanting to experience unique and remote landscapes. Demand for access to remote areas is increasing, with travellers in 4WD vehicles being the main users either in organised tour groups, as members of different clubs and associations or as independent travellers.

The Diamantina Catchment study area has very low tourism activity largely because the main tourism flow route is now aligned away from the river and its water holes. Most of the areas that would be of tourism interest are on land under pastoral lease, where access is limited and often discouraged.

Kati Thanda–Lake Eyre remains the key attraction in the area, particularly during flood events when major tourism spikes occur and place the greatest demand on infrastructure, information and access.

EXPLORERS, SETTLERS AND PASTORAL PIONEERS

In 1840, Edward John Eyre was the first of the white explorers to venture into the region. Others followed, only to be beaten back, or to perish in what was considered an alien and inhospitable land.

Sturt was stopped by the rolling red dunes of the Simpson Desert. He named Strzelecki, Cooper and Eyre creeks – important ephemeral watercourses in a largely parched landscape. Mitchell and Kennedy meandered in the tangle of waterways in mid-west Queensland, naming the Thompson and Barcoo and discovering the braided streams of the Channel Country.

In 1866, Peter Warburton was sent to explore the north-east end of Lake Eyre. He determined the northern limit of the lake and proceeded to follow up a river that drained into the lake and which he believed was Cooper Creek. He examined it as far as latitude 27 degrees

Camel trekking in the Simpson Desert

PRIORITIES FOR FUTURE MANAGEMENT

Establish better protocols regarding road closures and road opening, particularly to minimise road damage during rain and flood periods.

The sensitive Kati Thanda–Lake Eyre and Outback environment needs to be managed sustainably to ensure items of historic, cultural and natural value are not damaged and are retained for the benefit of future generations.

Education of tourists so that their impact on the environment (particularly water sources) and locals is minimised.

FOR FURTHER INFORMATION

The information in this summary report is sourced from the technical report: *Schmiechen, J. S. 2017. Human footprint on the landscape – cultural landscape assessment and tourism management of the Diamantina River catchment, South Australia. Report by Ausabout to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.*

and longitude 140 degrees 20' where it disappeared into the sand. It was later named after him. Warburton was beaten by the lack of water and he gave up further exploration in the Channel Country.

Surveyor J.W. Lewis was sent out by the South Australian government in 1874 to complete the exploration of Lake Eyre, to determine its north-eastern limits and to discover its tributaries. His party followed the Warburton as far as Goyder Lagoon, and followed the Diamantina River almost to the Queensland border, before turning south and exploring the eastern shore of the lake, thus determining the lake's limits. He was scathing of the potential of the lake and its region, reporting that it was 'useless in every respect, and the very sight of it creates thirst in man and beast'.

The Burke and Wills expedition and subsequent relief efforts in 1860 aroused settler interest in the Cooper Creek region. In 1862, Thomas Elder established the first pastoral runs in the Lake Eyre region.

In the 1860s, the Birdsville Track was opened to walk cattle from northern Queensland and the Northern Territory out of the Channel Country to the nearest railhead at Hergott Springs, later named Marree. In 1916, bores were sunk, which tapped in to the Great Artesian Basin, making the route easier and safer.

Over the years the Birdsville Track became one of the country's most isolated and best-known stock routes as well as a mail route made famous by Outback legend Tom Kruse, whose mail run and the track were immortalised in the 1954 documentary film *Back of Beyond*. Today, the Birdsville Track is seen as one of the iconic Outback adventure drives.

GLOSSARY

anabranch
a section of a river or stream that diverts from the main channel or stem of the watercourse and rejoins the main stem downstream

avulsive
channels that relocate to other parts of the floodplain, usually abruptly during flood events

bankfull
refers to the water level stage that just begins to spill out of the channel into the floodplain

Dreaming
The Dreaming is a term used by Indigenous Australians to describe the relations and balance between the spiritual, natural and moral elements of the world. It is an English word but its meaning goes beyond any suggestion of a spiritual or dream-related state

Dreaming tracks
the journey of the Spirit Ancestors across the land is recorded in Dreaming tracks. A Dreaming track joins a number of sites which trace the path of an Ancestral Being as it moved through the landscape, forming its features, creating its flora and fauna and laying down the Laws

endorheic
a closed drainage basin that retains water and allows no outflow to other external bodies of water, such as rivers or oceans, but converges instead into a lake or swamp

gilgai heave
roughly undulating ground produced by the shrink-swell action of vertosols (cracking-clay black-soil country)

hypersaline
a body of water that contains significant concentrations of sodium chloride or other salts, with saline levels surpassing that of ocean water (3.5%, i.e. 35 grams per litre or 0.29 pounds per US gallon)

Mabo
the Mabo Case was a significant legal case in Australia in 1992 that recognised the land rights of the Meriam people, Traditional Owners of the Murray Islands (which include the islands of Mer, Dauer and Waier) in the Torres Strait

Management zone
these are areas with defined characteristics and qualities for which there are related user expectations, management guidance and defined levels of development

palaeosol
a fossil soil preserved within a sequence of geological deposits, indicative of past conditions

refugia
an area where special environmental circumstances have enabled a species or a community of species to survive after unfavourable circumstances or isolation, such as an ice age, deforestation, or hunting

riparian
related to or situated on the banks of a river

scroll plain
low-lying ridge-and-swale floodplain inside the curve of a meandering channel; looks like striped ground on satellite imagery

tele-connected
refers to climate anomalies being related to each other at large distances (typically thousands of kilometres)

vertic
soil material with a clayey field texture (i.e. light clay, medium clay, heavy clay) or 35% or more clay, which cracks strongly when dry

vertosols
a clayey soil with strong shrink-swell characteristics and little organic matter which occurs in regions having distinct wet and dry seasons

TECHNICAL REPORTS

This report summarises information from the Australian Government funded project 2013–2017: "Improving habitat condition and connectivity in South Australia's channel country – The Diamantina and Warburton river system in South Australia" and is sourced from the following technical reports:

Riparian Habitat Values

Mancini, H. 2017. Riparian habitat values assessment of the Diamantina River catchment; Lake Eyre Basin, South Australia. Report by Natural Resources SA Arid Lands DEWNR to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

Geomorphology

Wakelin–King, G.A. 2017. Geomorphology of the Diamantina River Catchment (SA). Report by Wakelin Associates to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

Hydrology

Costelloe, J.F. 2017. Hydrological assessment and analysis of the Diamantina River catchment, South Australia. Report by the University of Melbourne to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

Coolibah

Gillen, J.S. 2017. Coolibah (Eucalyptus coolabah Blakely & Jacobs) of the Diamantina and Warburton river systems in north eastern South Australia. Report by Australian National University to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

Vegetation and Soils

Gillen, J.S. 2017. Vegetation and soil assessment of selected waterholes of the Diamantina and Warburton rivers, South Australia, 2014–2016. Report by Australian National University to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

Riparian

Reid, J. R. W. 2017. Birds of the Diamantina River and associated channel country wetlands of South Australia. Report by Australian National University to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

Aquatic Ecology

Schmarr, D.W., Mathwin, R. and Cheshire, D.L. 2017 Aquatic ecology assessment and analysis of the Diamantina River catchment: Lake Eyre Basin, South Australia. Report by South Australian Research and Development Institute to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

The Many Layered Landscape

Schmiechen, J. S. 2017. Human footprint on the landscape – cultural landscape assessment and tourism management of the Diamantina River catchment, South Australia. Report by Ausabout to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

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