Inland Waters &
Catchment Ecology

Biological Review of the Freshwater Fishes of the Western Mount Lofty Ranges

David Schmarr, Leigh Thwaites* and Kristian Peters

SARDI Publication No. F2022/000250-1
SARDI Research Report Series No. 1148

SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

September 2022

*Corresponding author

Report to Green Adelaide, Department for Environment and Water

Government of South Australia
Department of Primary Industries and Regions

Government of South Australia
Green Adelaide

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Biological Review of the Freshwater Fishes of the Western Mount Lofty Ranges

Report to Green Adelaide, Department for Environment and Water

David Schmarr, Leigh Thwaites* and Kristian Peters

***Corresponding author**

SARDI Publication No. F2022/000250-1
SARDI Research Report Series No. 1148

September 2022

The South Australian Research and Development Institute respects Aboriginal people as the state's first people and nations. We recognise Aboriginal people as traditional owners and occupants of South Australian land and waters. We pay our respects to Aboriginal cultures and to Elders past, present and emerging.

This publication may be cited as:
Schmarr, D., Thwaites, L.A. and Peters, K. (2022). Biological Review of the Freshwater Fishes of the Western Mount Lofty Ranges. Report to Green Adelaide, Department for Environment and Water. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2022/000250-1. SARDI Research Report Series No. 1148. 116pp.

Author(s):	David Schmarr, Leigh Thwaites and Kristian Peters
Reviewer(s):	Josh Fredberg and Jason Nicol
Approved by:	Assoc Prof. Qifeng Ye Science Leader – Inland Waters & Catchment Ecology
Signed:	
Date:	12 September 2022
Distribution:	Green Adelaide DEW, SARDI Aquatic Sciences, Parliamentary Library, State Library and National Library
Circulation:	OFFICIAL

ALL ENQUIRIES
South Australian Research and Development Institute - SARDI Aquatic Sciences
2 Hamra Avenue West Beach SA 5024
PO Box 120 Henley Beach SA 5022
P: (08) 8207 5400 **F:** (08) 8207 5415
E: pirsa.sardiaquatics@sa.gov.au **W:** http://www.pir.sa.gov.au/research

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This report was funded by the Green Adelaide Landscape Board (previously Natural Resources Adelaide and Mount Lofty Ranges (Natural Resources AMLR) under the Western Mount Lofty Ranges (WMLR) Fish Community Monitoring Project. It is the culmination of several projects funded by Natural Resources AMLR.

Site selection was informed by early work conducted by Dr Michael Hammer and Dr Dale McNeil, and later by Rehanna Halfyard, Dr Kristian Peters (Green Adelaide, Department for Environment and Water (DEW)) and Dr Douglas Green (DEW). The fieldwork contributing to this study was extensive and took many years of dedicated work. This would not have been possible without the assistance of a range of current and former SARDI staff and volunteers; Dr Dale McNeil, David Cheshire, Rupert Mathwin, Luciana Bucater, Kate Frahn, Josh Fredberg, Neil Wellman, Alex Dobrovolskis, Nat Navong, Zyg Lorenz, and Emma Matthews (Summer Scholarship).

Development of the Biological Condition Gradient (BCG) for WMLR region was made possible through the inspiration of Dr Peter Goonan (EPA) and through years of work by Dr Dale McNeil, David Cheshire and Rupert Mathwin.

Our thanks go to all the numerous community members and stakeholders who allowed us access to their properties and/or providing invaluable information on local conditions and contacts to facilitate fish monitoring activities.

Our thanks also go to the SARDI reviewers Josh Fredberg and Dr Jason Nicol, whose revisions improved earlier versions of this report.

ACRONYMS

AMLR	Adelaide and Mount Lofty Ranges
AMLRNRMB	Adelaide and Mount Lofty Ranges Natural Resource Management Board
BCG	Biological Condition Gradient
CPUE	Catch Per Unit of Effort
DEW	Department for Environment and Water
DEWNR	Department of Environment, Water and Natural Resources
DO	Dissolved Oxygen
ECAT	Estuarine Condition Assessment Tool
EMLR	Eastern Mount Lofty Ranges
GIS	Geographic Information System
GSA	Generalized Stress Axis
GWAP	Goyder Water Allocation Planning
MDBC	Murray Darling Basin Commission
MLR	Mount Lofty Ranges
NRM	Natural Resource Management
NTU	Nephelometric Turbidity Units
PIRSA	Primary Industries and Regions South Australia
PWRA	Prescribed Water Resource Area
SAG	South Australian Gulf (drainage division)
SARDI	South Australian Research and Development Institute
SF	Southern Fleurieu
TL	Total Length
VWASP	Verification of Water Allocation Science Project
WMLR	Western Mount Lofty Ranges
WAP	Water Allocation Planning

EXECUTIVE SUMMARY

This report delivers an updated biological review of fish biodiversity and ecosystem condition for the Western Mount Lofty Ranges (WMLR). This review is a collaboration between Green Adelaide, Department for Environment and Water (DEW) (formerly Adelaide and Mount Lofty Natural Resources Management Aquatic ecosystems program) and the South Australian Research and Development Institute (SARDI). The intent of the review is to consolidate historical and contemporary information on freshwater and estuarine fish biology and ecology for catchments across the WMLR in order to provide up-to-date knowledge that can be applied for future catchment and species conservation management.

The previous biological review of fishes in the Mount Lofty Ranges (MLR) conducted by McNeil and Hammer in 2007 synthesised the basic biological information for freshwater and estuarine fish available at the time. Combined with the Action Plan for South Australian Freshwater Fishes (Hammer *et al.* 2009), these reviews set out strategies for the long-term assessment and management of native fish populations, and through monitoring, develop a broad depth of ecological and landscape knowledge to determine trends in fish population health and condition. The initial biological review (McNeil and Hammer 2007) has since guided the current fish monitoring program in the WMLR region with surveys being conducted across a broad spatial scale incorporating new and previously surveyed sites to provide critical long-term data to assess the ecological health of the WMLR using a modified Biological Condition Gradient (BCG) model (Davies and Jackson 2006, McNeil *et al.* 2011a, Mathwin *et al.* 2014).

The BCG is a conceptual framework for scientists and managers to define and interpret current and historic biological conditions, measure and document incremental changes in condition along a gradient of anthropogenic stress and identify areas of improvement resulting from management interventions (Davies and Jackson 2006). The conceptual framework of the BCG utilises historic information, expert opinion and monitoring data to develop a qualitative model that describes aquatic ecosystem condition. The current biological review utilises a novel quantitative BCG developed by SARDI.

The sampling strategies and methodologies proposed in the previous review and implemented since 2007 have greatly improved knowledge of fish species distribution, abundance and population structure in the WMLR. From 2007 to 2021 a total of 126,954 fish were captured in WMLR surveys conducted at 237 sites over 467 sampling events (spring/autumn seasons) in 24 catchments. There has been no loss of native freshwater fish species across the WMLR region since 2007. Surveys recorded 12 native species (11 repeated from the 2007 report and one new species; bony herring - *Nematalosa erebi*), four of the five previously known translocated species, and eight invasive species including seven repeated from 2007 and one new species (speckled livebearer - *Phalloceros caudimaculatus*).

There were some changes in the conservation status of endemic species since 2007. Mountain galaxias (*Galaxias olidus*) and congolli (*Pseudaphritis urvillii*) were reclassified from rare to vulnerable at a state level. Climbing galaxias (*Galaxias brevipinnis*) were reclassified from vulnerable to rare at a state level but are classified as vulnerable at the regional level. Despite not being captured in the WMLR for several decades, the conservation status of southern purple-spotted gudgeon (*Mogurnda adspersa*) was reclassified from endangered to critically endangered. Murray rainbowfish (*Melanotaenia fluviatilis*) were previously listed as rare at a state level but changed to no listing. All other species remained unchanged at the state level.

With the BCG model applied to all data (2007–2021), a total of 237 sites across the WMLR were scored on 467 occasions. The analyses of BCG scores over time showed no significant temporal trends in native fish populations and condition, but significant differences in aquatic health across catchments of landscape regions in the WMLR resulted in a condition gradient of good to poor from south to north. Catchments of the Hills and Fleurieu landscape region recorded significantly better mean BCG scores than Green Adelaide and Northern and Yorke landscape regions while Green Adelaide recorded significantly better scores than Northern and Yorke. Good BCG scores were generally associated with the presence of all expected native species in high abundance with broad size distribution, the absence of invasive species, and good catchment connectivity with mostly intact riparian vegetation and limited degradation from land use.

The results of the current review have broadened our knowledge of fish populations and ecological health in the WMLR and highlighted future directions and opportunities to guide continuing ecological monitoring, research and management:

- Future monitoring should involve resampling at previous sites to capture long-term fish community trends and at new sites to expand the coverage of species distribution data (i.e. reservoirs, urban areas, estuaries).
- Targeted monitoring programs should provide routine evaluation of areas with high ecological value (including areas with species of conservation concern) in order to provide early detection and mitigation of potentially detrimental impacts (i.e. rapid response to new

invasive species incursion in Back Valley southern pygmy perch (*Nannoperca australis*) population).

- Intervention specific monitoring programs should be designed to evaluate management actions such as the removal of barriers, provision of fish passage, control/eradication of invasive species and changes in land use such as clearing or replanting riparian habitat. The BCG should be used to evaluate outcomes of management interventions in order to provide feedback to support adaptive management. As an example, further investigations should be conducted to reveal the full spatial range of mountain galaxias within catchments and investigate the factors limiting dispersal and migration including barriers to fish passage.
- Design and implement a research program to collect information to support the development of an invasive species management strategy for the WMLR. This program should seek to understand the impacts for all invasive species (i.e. predation, competition, exclusion/overlap with native species) within the WMLR and prioritise control efforts on high impact species.
- Surveys of non-endemic (i.e. stocked or translocated) fish within reaches adjacent to stocked reservoirs should be used to understand potential impacts of these species in WMLR catchments and to inform management strategies if required. This is important as non-endemic species can have devastating impacts on endemic fish populations.
- A collaborative research program should be designed and implemented to document an inventory of in-stream barriers that may impact fish distribution and movement in the WMLR. The addition of a spatial layer will facilitate the development of a data-driven quantitative approach to scoring Attribute 10 (connectivity) in the BCG.
- Where the presence of potential barriers are identified, the impact of the barrier should be assessed with an analysis of fish distribution above and below the barrier as well as an evaluation of fish movement and behaviour in relation to the barrier (e.g. acoustic telemetry). The results of this work will directly inform management decisions regarding the identified barriers which may include removal, modification, construction of fishways, provision of flow or "do nothing".
- It is critical that regional conservation assessments using updated species distribution and abundance data are conducted at regular intervals to improve conservation efforts at local levels (e.g. 5-10 years).
- In order to provide a more comprehensive understanding that the 35 estuaries of the WMLR play in the life cycles of a range of fish species, an estuary monitoring program

that utilises an estuarine specific condition assessment tool (ECAT) (i.e. modified BCG) should be designed and implemented. While a review of historical literature and preliminary surveys to inform an inventory of estuary fish taxa in the WMLR has commenced (Green Adelaide 2022), future development and implementation of the ECAT necessitates seasonal information to capture the breath of community structure and environmental conditions that may drive population dynamics. An ECAT will help managers set priority targets for maintaining or restoring health and prioritise investment with the aim of supporting the State's fisheries by increasing productivity within estuarine nursery habitats.

- The quantitative BCG model provided a rapid, reproducible data-driven approach and should continue to be used to quantify ecosystem health and evaluate the results of long-term and targeted monitoring, and management interventions across the WMLR.

Keywords: Biological Condition Gradient, Western Mount Lofty Ranges, landscape management region, management prioritisation, native and exotic fish management.

1. INTRODUCTION

Since settlement in the mid nineteenth century, freshwater ecosystems in the Western Mount Lofty Ranges (WMLR) have been extensively exploited and degraded, primarily due to the spread of agriculture in the most arable catchment areas, attempts to “naturalise” ecosystems towards a European ideal and later, industrialisation and urbanisation (Armstrong *et al*. 2003). The consequences of this development have resulted in numerous stressors including water pollution, modification of channels and riparian zones, disruption to flow regimes and introduction of invasive species (Dudgeon *et al.* 2006). Further to this, pollution on a global scale has introduced the prospect of climate change exacerbating many of these stressors (Poff *et al*. 2002). This has resulted in often catastrophic and accelerated loss of freshwater biodiversity, increased prevalence of invasive species and altered ecosystem functioning (Dudgeon *et al.* 2006).

This damage prompted scientists and land managers to assess the ecological condition of rivers, initially as a response to practical concerns such as the quality and availability of water for human consumption, and then as the global implications of habitat and biodiversity loss became better known, to understand the extent of damage in ecosystems and implement management actions to halt and ultimately reverse that damage (Ehrlich and Pringle 2008).

Ecological assessments use the relatively recent assumption that catchments should be viewed as ecosystems, composed of complex biological assemblages which interact with the physical environmental conditions, creating complex and idiosyncratic ecosystems. It is a fundamental assumption that biological assemblages have adapted over millennia to the physical and biological parameters of the ecosystem and that changes to these parameters is reflected in observable changes to biological assemblages. This makes them good indicators of catchment ecological condition (Feio *et al*. 2021).

The basic principle of assessing aquatic ecosystem health is that there are predictable and measurable relationships between a biological community and the physical, chemical and biological condition of the ecosystem (Harris 1995). There are predictable relationships between fish assemblage and a wide range of aquatic ecosystem variables including flow regime (Poff and Allan 1995), water quality (Marchetti and Moyle 2001), food source (McQueen *et al.* 1986), competition/predation (Jackson *et al.* 2001), habitat availability and structure (Arthington *et al.* 2010). These relationships are measurable due to some key features of fish: their longevity makes them good long-term indicators, their mobility provides for broad spatial coverage, their range of trophic levels integrates broad ecosystem functions, they are relatively easy to capture, their taxonomy is usually well known and are easily identified in the field, and their habitat and ecology are also well known (Karr 1981).

Occupying higher trophic levels, healthy freshwater fish populations reflect positively on the condition of habitat, food-web structure and flow regime, all of which are key components of healthy functioning aquatic ecosystems. Accordingly, many of Australia's largest aquatic monitoring programs, such as the Murray-Darling Basin's Sustainable Rivers Audit and the Lake Eyre Basin Ministerial Forum's Lake Eyre Basin Rivers Assessment, have strong fish monitoring components as an indicator of riverine condition across large spatial and temporal scales (MDBC 2008, Kiri-ganai Research 2009). Aquatic ecosystems in good condition support healthy native fish populations and should possess:

- All expected native fish species based on natural range and habitat requirements.
- High abundance commensurate with species traits.
- Populations with individuals across a range of ages, including juvenile and adult life stages.
- Signs of regular recruitment.
- Low numbers of invasive species.
- Low incidence of disease and parasites.

For streams and rivers in the Mount Lofty Ranges (MLR), the majority of this information can be surveyed using well developed rapid assessment methodologies (McNeil and Hammer 2007) with findings compared against historic records and known biotic thresholds (McNeil *et al.* 2011a, Schmarr *et al.* 2014). Such surveys, especially those that cover a large number of sites across catchments and regions, provide snapshots of aquatic ecosystems that reflect the current condition of those habitats and regions.

These types of data support a range of management prioritisation and assessment activities. They provide detail on where important or threatened species are distributed, where key populations exist or are absent, where invasive competitors and/or predators may have been introduced, or where populations may be supressed from anthropogenic and natural threatening processes. This information can be extremely effective in directing regional natural resource management (NRM) investment and can assist with the development and setting of condition targets and objectives.

Sequential data sampling (collection of data over time at the same locations) can result in highly effective monitoring programs that provide relevant biological information with excellent temporal resolution allowing objective analysis of key factors (Power 2007). Regional strategic plans and previous NRM frameworks for the MLR have a requirement to assess and report on the condition of their natural resources including aquatic and marine resources, their investment programs, largely against key priorities, focus areas and performance targets set *a priori* in line with investment priorities and available budgets (e.g. Green Adelaide Landscape Plan 2021–2026, Hills and Fleurieu Landscape Plan 2021–2026). As a result, ongoing monitoring programs that utilise consistent methodology at the same sites can be an extremely useful tool for capturing and expressing responses or trajectories in condition that can be measured against desired outcomes or target values. This also includes monitoring population trajectories of specific declining or threatened species to improve or maintain conservation status.

Current South Australian Regional Landscape Plans and South Australian Landscape Act (2019) and previous NRM Strategic Plans outline requirements to maintain knowledge of the state and condition of their natural resources in order to protect, improve condition and function and prevent further declines in the conservation status of native species (Landscape South Australia Act, 2019; Green Adelaide Landscape Plan (2021-2026), Hills and Fleurieu Landscape Plan (2021-2026). Many fish species found in the catchments of the MLR are susceptible to declining water quality and changing habitat provision (Hammer *et al.* 2009). Previous studies have investigated patterns in native fish biodiversity across AMLR (Hammer 2005, McNeil and Hammer 2007, Hammer *et al.* 2009, McNeil *et al.* 2011a, Schmarr *et al.* 2014, Schmarr *et al.* 2018, Schmarr and Thwaites 2019). These projects have identified changes in the distribution and diversity of native species as well as localised depletion or extinction since historical records were published over fifty years ago (Hammer *et al.* 2009). These studies also identified a number of invasive species and translocated native species within the AMLR region that through competition and predation, present considerable concern for the sustainability of native fish stocks. Habitat and catchment modifications and changes to flow regime have also been linked to declining distribution and abundances of native fishes as well as threats to population connectivity presented by barriers to fish movement and migrations (Schmarr *et al.* 2011, McNeil *et al.* 2011b).

The 2007 Biological Review of fish in the Mount Lofty Ranges (McNeil and Hammer 2007) summarised the historical fish distribution data as well as the information relating to fish species' life history, habitat associations, water quality tolerances and environmental water requirements. This information was used as a guide to future research and monitoring programs as well as providing a basis for setting priorities for managing aquatic ecosystems in the region.

To inform the management of water resources and aquatic ecosystems in the Western Mount Lofty Ranges (WMLR) region, there is a requirement for an understanding of the present distribution and health of native fish populations. The status of these populations provides a baseline for comparison against future water management regimes and water allocation plans (WAPS). It also provides data for highlighting and prioritising management actions for improving fish population health.

1.1. Biological condition gradient (BCG) overview

One of the major recommendations of the 2007 review was to implement a comprehensive spatial monitoring program. This monitoring program was developed and implemented over the next 15 years in partnership with previous Adelaide and Mount Lofty Ranges NRM Board, current Green Adelaide Landscape Board (DEW) with links to Aquatic Ecosystem Condition Reporting (AECR) conducted by the Environment and Protection Agency (EPA). It enabled the development and review of methods to assess trends in aquatic ecosystem health that resulted in a BCG modified by SARDI for assessing aquatic ecosystem health using fish assemblage data in the WMLR (McNeil *et al.* 2011a, Mathwin *et al.* 2014). The conceptual framework of the BCG was developed in the United States based on common patterns of biological response to stressors observed empirically by aquatic biologists and ecologists (Davies and Jackson, 2006) and has since been adopted by the European Water Framework Directive and embedded in several prominent other environmental flow (E-flow) assessment frameworks (King *et al.* 2003, Poff *et al*. 2010). In South Australia, the BCG model has also been adopted by the EPA for routine aquatic ecosystems assessments of macroinvertebrate diversity and water quality condition (Goonan *et al*. 2012).

The BCG is a conceptual framework for scientists and managers to define and interpret current and historic biological conditions, measure and document incremental changes in condition along a gradient of anthropogenic stress and identify areas of improvement resulting from management interventions (Davies and Jackson 2006). The conceptual framework of the BCG utilises historic information, expert opinion and monitoring data to develop a qualitative model that describes aquatic ecosystem condition.

The framework describes how 10 characteristics (described as ‘Attributes’) of aquatic ecosystems change in response to increasing levels of stress (described as ‘tiers’), from a natural state (tier 1, e.g. undisturbed/minimally disturbed condition) to severely altered state (tier 6) (Figure 1). The attributes include aspects of fish assemblage (i.e. distribution and abundance of fish species), fish condition, ecosystem function, and connectivity.

A significant advantage of the BCG is that it is an outcome-based measure. It measures the response of the fish community to the cumulative stressors to which it is exposed rather than the direct response of a single species to a specific stressor. The x-axis of the BCG framework (Figure 1), the Generalized Stress Axis (GSA), describes cumulative anthropogenic stress that may adversely affect aquatic biota in a particular area. As multiple stressors are usually present in aquatic systems, the GSA seeks to represent the cumulative stress that may influence biological condition. However, identifying and understanding the nature of the stressors affecting aquatic biota greatly enhances the power of the model.

Another advantage is that the BCG is robust to data quality and quantity. For instance, in the absence of standardized or consistent species abundance data (i.e. CPUE), presence/absence data can be used. The development and calibration of the BCG to different taxa and eco-regions is driven by the expert knowledge base through conceptual modelling of ecosystem function. As more data becomes available and stressor-response relationships are better understood, the method is open to improvement through an iterative approach. The standardised scoring system makes the method consistent and the outcomes comparable between systems with different taxa and in different habitat types or hydro-ecological settings.

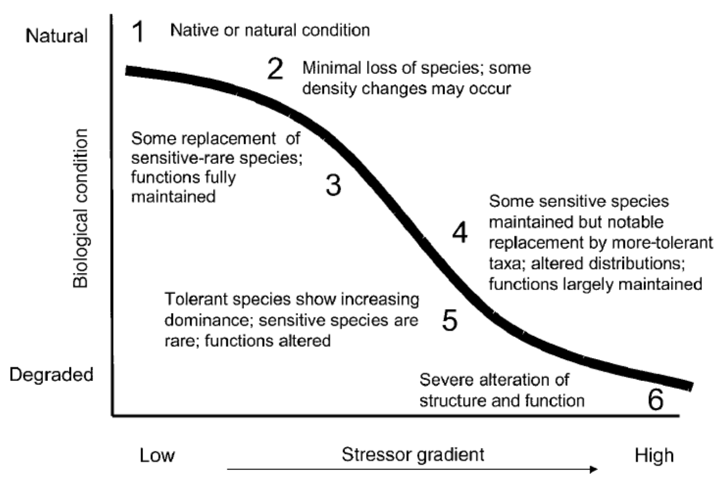

Figure 1. Conceptual definitions of the Biological Condition Gradient tiers 1–6. From Davies and Jackson 2006.

1.2. Objectives

The 2007 Biological Review of fish in the Mount Lofty Ranges was used as a guide for future research and monitoring programs as well as providing a basis for setting priorities for managing aquatic ecosystems in the region. The report guided research and management priorities focussed on protecting or improving the health and condition of catchments within key prescribed

Water Allocation Planning (WAP) areas; Barossa WAP, the Western Mount Lofty Ranges WAP, Adelaide Plains WAP, and the McLaren Vale Prescribed Wells area WAP. This review provides updated comprehensive information on native and non-native fish population biology and aquatic health assessments that will be useful for future WAP and programme planning that entails extensive spatial information across a broader landscape that was not available in 2007. In addition, it highlights successful implementation of the recommendations from the previous report. The successful implementation of a comprehensive spatial monitoring program and refinement of methodology to deliver standardised and consistent landscape scale health assessments over time provides the impetus and objectives of this current review. These objectives are to:

- Review scientific literature for new information relating to fishes of the WMLR. New information will be updated to be used with the BCG.
- Provide a synthesis of new or emerging information for native fish species of conservation concern or significance (e.g. threatened species) and identifying habitat threats or threats to species populations from introduced taxa.
- Describe the methods that have been adopted for assessing fish population and catchment/ sites health.
- Update native and invasive fish distribution maps for the WMLR providing details in the changes in population distributions and community structure since 2007. This includes identifying species declines and expansions of populations.
- Deliver a BCG assessment utilising data from previous natural resource investment on aquatic ecosystem fish monitoring program for the last 15 years (i.e. since 2007).
- Discuss the results in relation to threats, national conservation priorities, management priorities, regional Landscape Strategic Plan, state and national objectives.
- Highlight key knowledge gaps to provide direction for future research and investment.

2. DATA COLLECTION

2.1. Fish sampling

Fish sampling was based on the methods developed by McNeil and Hammer (2007) for fish in the Mount Lofty Ranges. These methods were refined and described by (Schmarr *et al*. 2014) and are summarised below.

To sample fish populations, most sites employed two fyke net designs; ‘small fykes’ (3 m leader, 2 m funnel, 3 mm mesh) and ‘double-wing fykes’ (2 x 5 m wings, 3 m funnel, 3 mm mesh). Nets were anchored using heavy gauge chain clipped to the cod and wing ends. Two polystyrene buoys were placed in each net’s cod end to force a pocket of net above the water’s surface. This created a space where by-catch (e.g. turtles, birds or water rats) could take refuge until the net was processed. Two double-wing and four small fykes were deployed at each site with nets positioned to strategically sample the range of in microhabitats present at the site. Double-wing fyke nets were deployed together and in opposition with one opening upstream and the second opening downstream. Single-wing fyke nets were deployed separately within the microhabitats available at the site (e.g. snag, bare bank, submerged vegetation etc). Where appropriate, an additional large double-wing fyke net (2 x 10 m wing, 12 mm mesh, 5 m funnels, 1.2 m high) was set in estuarine sites. Fyke nets were set before dusk and collected after dawn ensuring that each site was set for a minimum of 14 hours. Set and retrieval times were used to calculate catch per unit effort (CPUE). A subset of nets were deployed at sites where conditions were inappropriate to deploy the full set of nets.

2.2. Fish processing

Fish captured during each survey were taxonomically identified to species. The only exception was carp gudgeon (*Hypseleotris* spp.), which exist in the WMLR as a species complex and were identified to genus. Fish species were considered to be native (endemic to the catchment confirmed by historical data/records), translocated (Australian native fish species not considered endemic to the catchment) (McNeil and Hammer 2007) or invasive (taxa not endemic to Australia). To generate length frequency distributions for each species, total length (TL, mm) was recorded for the first 50 fish collected. The only exception was the invasive species gambusia (*Gambusia holbrooki*). This species reproduces continuously throughout the year (Milton and Arthington 1983) so length frequency does not provide information relevant to the health of the site. In such instances, only the first 20 gambusia recovered at each site were measured. All fish captured were also visually assessed for the presence of fungal infection, subcutaneous endoparasites, spawning condition and congenital abnormalities.

2.3. Water quality and streamflow

Water quality measurements were routinely taken at each site. Water quality parameters were an important tool for providing context around fish diversity and abundance observations as well as establishing the thresholds within which species could survive and carry out their lifecycles. A point of maximum depth was identified within each site where water quality was recorded Dissolved oxygen (DO), water temperature (^{o}C), pH and electrical conductivity (EC, µS/cm) were measured on site using a Horiba U-50 Multiparameter Sonde. To obtain water quality profiles at each site, water samples were assessed at the surface and at intervals of 50 cm depth until the bed was reached.

To provide information to score Attribute 10 (Connectivity) of the BCG, qualitative observations of streamflow (magnitude and connectivity) were made during each survey and were supplemented with streamflow data accessed from https://greenadelaide.waterdata.com.au/ and https://water.data.sa.gov.au/.

3. QUANTITATIVE BCG MODEL

Traditionally, the Biological Condition Gradient (BCG) used a qualitative approach where scoring was conducted through visual interrogation of data, expert elicitation and the application of a series of rules to manually categorise catch and environmental data into tiers under a series of attributes. While this system has been applied successfully in the WMLR, it is difficult to reproduce and verify results, integrate new data and compare systems. This is because the qualitative approach is time consuming, requires recalibration for new systems and inherently has a high level of subjectivity associated with differing opinions and views of individual scorers. To eliminate these issues, SARDI developed a quantitative numerical BCG model that rapidly and systematically calculates BCG scores based on actual fish monitoring data as well as land use data and information pertaining to connectivity (i.e. barriers, flow). This quantitative approach is used throughout this document to evaluate and score the aquatic ecosystem health of the WMLR.

The quantitative BCG model has refined some of the previous qualitative elements (Davies and Jackson 2006, McNeil *et al.* 2011a, Mathwin *et al.* 2014) to improve quantification of the outputs particularly improving key aspects of occupancy (e.g. presence-absence), abundance and defining the size structure of the full range of fish species present. BCG scores are based on 8 of ten biological and physical attributes (Table 3). Attributes 1 (I), 2 (II), 3 (III), 5 (V), and 6 (VI) assess the condition of freshwater fish species articulated as a series of groups; Attribute 1(I) historically documented, sensitive, long-lived, or regionally endemic taxa, Attribute 2(II) sensitive-rare taxa, Attribute 3 (III) sensitive common taxa, Attribute 5 (V) tolerant taxa and, Attribute 6 (VI) non-native or intentionally introduced taxa. Unlike the original BCG model, Attribute 4 (IV) and 8 (VIII) are excluded from the current BCG analyses as there are no species of intermediate tolerance that exist in this region (Attribute IV) and there is limited available limnology data for this region to score Attribute 8 (Ecosystem function). In addition, estuarine species have been excluded from the BCG analyses due to uncertainties about distributions and current attribute status.

The quantitative BCG model does not strictly follow the qualitative rules detailed in the original BCG but rather focuses on the key aspects of presence-absence, abundance and size structure of fish species. Scores for these attributes are a combination of the percentage of historically recorded species present (and absent) as well as the relative abundance of species that are present (as a percentage all CPUE recorded for each species across all sampling rounds for each season: Summer/Autumn, Winter/Spring).

First, BCG scores for presence/absence of species were generated for individual sites grouped within discrete management units. Definition of management units were based upon the likelihood that those species could exist within that location, and also considered knowledge of reach type (Larned *et al*. 2010) and historical fish distribution. A score was allocated for the percentage of historically recorded species present. For example, if >80% of species (in Attribute 1-4) that have been historically recorded were present, then a score of 1 was assigned, while the absence of all species would score 6. Scores were inversely assigned for tolerant (Attribute 5) and invasive (Attribute 6) species. For example, if >80% of species were present then a score of 6 was assigned. Next, the seasonal distribution of all CPUE measurements for each species was divided into six percentiles. For Attributes 1–4, the model then allocated a score based on where each individual sample fell within the distribution, with the final abundance score being the average for each attribute group. Attribute 5 (tolerant taxa) and 6 (invasive species) were inversely scored in recognition that a high abundance of these species is representative of poor conditions (Davies and Jackson 2006). Finally, the score for Attributes 1 to 6 was calculated as the average of the scores for presence and abundance. Lower scores were allocated to sites where all expected species were present and in high abundance relative to all previously recorded abundances.

Attribute 7 in the qualitative BCG relates to organism and population condition (biomass, reproduction, anomalies such as disease and parasites). Disease and parasites did not appear to be prevalent in fish of the WMLR with very few observations recorded. As such, for the quantitative model, the size distribution of each native species at each site was used as a surrogate measure. This was considered appropriate as length frequency distributions are indicative of organism and population condition (i.e. multiple size classes indicate healthy breeding and recruiting populations) and length data is systematically collected during each monitoring event. For Attribute 7, the size distribution for each species was calculated as a proportion of all size classes recorded for that species on a seasonal basis. This proportion data was then averaged for each attribute group (excluding invasive species). The distribution of these average proportions was then used to calculate percentiles with each sample then scored against these percentiles. For native species, if a high proportion of size classes were present then a low score (i.e. 1) was assigned. Invasive species were not used in scoring Attribute 7.

The qualitative BCG defines Attribute 9 as the spatial and temporal extent of detrimental effects. Traditionally, this was subjectively assessed within close proximity to each sampling site (<100m) and did not account for broader effects of land use. As such, we chose to use Australian Collaborative Land Use and Management Program (ACLUMP) land use mapping data (https://data.sa.gov.au/data/dataset/land-use-aclump) to calculate the extent of detrimental effects. To calculate Attribute 9, we took the location of each sampling site, calculated the proportion of undisturbed land (uncleared/native) at three scales (100 m, 400 m and Catchment) using land use mapping data in QGIS geographic information system software version 3.22. The distribution of these proportions at each scale were divided into six percentiles. Each sample was then scored against these percentiles with the average of these scores across each scale and at each site used as the final BCG score for Attribute 9.

Scoring for Attribute 10 (Ecosystem Connectivity) was based on the original BCG scoring method (Davies and Jackson 2006). Scores utilise expert knowledge and consider flow regime, the presence of barriers to fish passage (i.e. waterfalls, weirs, culverts, tunnels, shallow concrete channels and dams) and the ability of fish populations to recolonise within the catchment. In the absence of a complete inventory of all barriers to fish passage in the WMLR, scoring currently uses the precautionary principle and assumes that all catchments within the WMLR contain some barriers to fish passage. Hence, the best score for connectivity was conservatively limited to 2 which were assigned to sites with relatively unmodified flow and minimal barriers. Natural barriers such as waterfalls were only given a poor score if upstream populations were in poor condition or absent and recolonisation from downstream was unlikely.

Similar to the qualitative model, the final score for each sample within the quantitative model is the average of all the individual attribute scores for each sample.

To simplify BCG outputs for each site, scores were standardised by assigning their scored values to three equally distributed condition categories: Good (green), Intermediate (amber) and Poor (red). Scores for the BCG outputs range from 1 to 6. Lower BCG scores (1–2.7) indicate a catchment, reach or site in relatively good condition exhibiting native or natural condition; mid-range scores (2.7–4.3) indicate a catchment, reach or site in intermediate condition with altered species distributions and function; and high scores (4.3–6) indicate a catchment, reach or site in poor condition with a decrease in native species structure and transitioning to species with higher tolerance to habitat and water quality disturbances (e.g. pest species).

Table 1. Attributes contributing to the Biological Condition Gradient (BCG) for the WMLR.

Attribute	Example species
Attribute I (Historically documented, sensitive, long-lived, or regionally endemic taxa)	Short-finned eel
Attribute II (Sensitive-rare taxa)	Climbing galaxias, bluespot goby, congolli, southern pygmy perch
Attribute III (Sensitive-ubiquitous taxa)	Common galaxias, mountain galaxias
Attribute IV (Taxa of intermediate tolerance)	No species
Attribute V (Tolerant taxa)	Flathead gudgeon, dwarf flathead gudgeon, western carp gudgeon, Murray rainbowfish, bony herring
Attribute VI (Non-native or intentionally introduced taxa)	Silver perch, freshwater catfish, goldfish, common carp, gambusia, tench, speckled livebearer, brown trout, rainbow trout, redfin perch
Attribute VII	Organism and population condition (population size distribution)
Attribute VIII	Ecosystem functions (not used)
Attribute IX	Spatial and temporal extent of detrimental effects (land use)
Attribute X	Connectivity

3.1. Model validation

To ensure efficacy of the BCG quantitative model, output BCG scores were compared to those originally assessed using the original qualitative BCG model. Performance was validated using linear regression based on a total of 328 qualitative BCG scores calculated for the WMLR and compared to scores re-calculated for those data points using the quantitative model. The results indicate a strong positive correlation between the quantitative and qualitative BCG scores (R^2 = 0.79, R = 0.89, *n* = 328) supporting the use of the quantitative model (Figure 2).

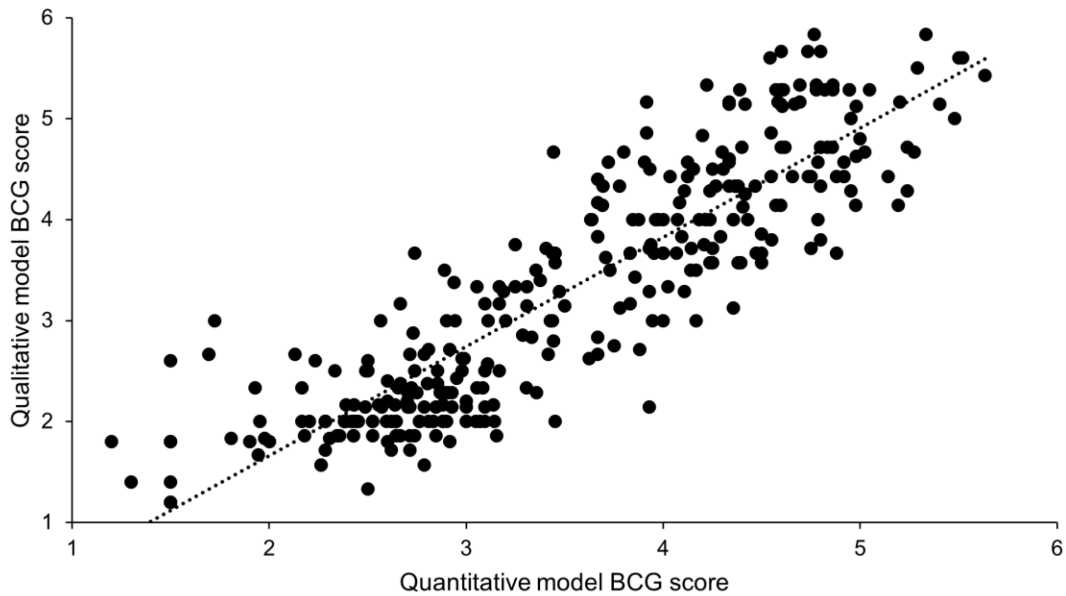

Figure 2. Simple linear regression showing a strong positive relationship between BCG scores derived from the qualitative and quantitative models (R^2 = 0.79, R = 0.89, n = 328).

The BCG scores presented herein are derived from the quantitative numerical model and incorporate all WMLR monitoring data (*n* = 467) collected under monitoring programs funded by Adelaide and Mount Lofty Ranges Natural Resource Management Board, Green Adelaide Landscape Board and Department for Environment and Water (previously Department for Environment) that have occurred since 2011 (McNeil *et al.* 2011a, Schmarr *et al.* 2014, Schmarr *et al.* 2018, Schmarr and Thwaites 2019).

3.2. Data analysis

To test spatial and temporal patterns in BCG scores, we employed a beta regression model using the betareg package (Cribari-Neto and Zeilis 2010) in the R statistical program (R Core Team 2018). This method allows analysis of linear and nonlinear effects of continuous and categorical predictor variables on a discrete or continuous dependent variable for non-normally distributed data that assume values between 0 and 1 (Ferrari and Cribari-Neto 2004). To test for spatial patterns in BCG we employed a beta regression mixed effects model with BCG score as the dependent variable and region as a fixed effect. Due to uneven effort being applied across years in each region, year was included as a random effect in this model. To test for temporal patterns within each region independently we used a beta regression model with year as a fixed effect. As the dependent variable was constrained to scores between 1 and 6, scores were transformed to values between 0 and 1. To summarise the effects of factors in each model, predictions of least-squares (LS) means were generated from the model in the emmeans package (Lenth 2021).

4. FRESHWATER AND ESTUARINE FISHES OF THE WMLR

McNeil and Hammer (2007) provided a thorough description of the distribution, biology and status of freshwater fish species that occur in the MLR. A key outcome of the report was to implement standardised sampling (see above) and assessment methodology at broad spatial scales and using the largest possible number of sites across a range of habitats, flow conditions and seasons. The primary aim of this approach was to capture the breadth of population variability in order to compare temporal and spatial community health (see Schmarr *et al.* (2018). Subsequent widespread monitoring funded through AMLRNRM and Green Adelaide as part of their long-term aquatic ecosystem monitoring programme in partnership with SARDI has since revisited most of the rivers and sites referred to in the previous reports as well as expanding monitoring to many new streams, reaches and sites (McNeil and Wilson 2008, McNeil *et al.* 2009, McNeil *et al.* 2011a, McNeil *et al.* 2011b, Schmarr *et al.* 2014, Schmarr *et al.* 2018, Schmarr and Thwaites 2019). This review primarily focuses on data derived from long-term catchment monitoring conducted through the Green Adelaide Conserving Aquatic Ecosystems Monitoring Program and previous AMLRNRM Board Aquatic Ecosystems Monitoring Program and where appropriate, reviews the results of research generated through other programs.

This section explores the distribution of native and non-native fish species captured during surveys conducted from 2007 to 2021 providing a parallel comparison to distributions provided in the 2007 WMLR Review (McNeil and Hammer 2007). It is not the intent of this section to provide information pertaining to the fundamental biology and ecology of each species recorded in the WMLR, but to present relevant updates regarding the conservation status, threats and impacts, and management considerations for each species. Fundamental biological and ecological information is presented elsewhere (Lintermans 2007, McNeil and Hammer 2007, Ellis *et al*. 2016). For this report, freshwater fish are defined as species that complete their lifecycle inland (obligate freshwater species and select euryhaline taxa) or those that spend considerable time in freshwater for particular life stages (i.e. diadromous species) (*sensu* Hammer and Walker 2004). As with the previous review, several estuarine species that occur in the region such as black bream, jumping mullet and Tamar goby are not discussed in detail but were partly addressed in a specific project assessing the condition of estuaries in the Hindmarsh, Inman, Bungala and Myponga Rivers (Schmarr *et al.* 2018). Since the focus of this report is solely on the WMLR, several species reported in 2007 that are only found in the EMLR and Murray-Darling Basin have been omitted and will not be updated. The species distribution maps were generated using QGIS.

Between 1900 and 2007, fish data was reported at a total of 465 sites over an unknown number of surveys (McNeil and Hammer 2007). The precise number of surveys (including repeated surveys) was not reported and cannot be enumerated because of incomplete records. Importantly, McNeil and Hammer (2007) did not report sites that were sampled where no fish were detected. A total of 13 native, five translocated and nine invasive species were recorded in the WMLR (Table 2). These records were collected from a wide range of sites using verified surveys and museum records dating back to the early 1900s across the WMLR region representing the majority but not all waterways in the WMLR region. There was some uncertainty about the veracity of some of the translocated species (i.e. dwarf flathead gudgeon (*Philypnodon macrostomus*)), invasive species with single observations of stocking (i.e. Murray cod (*Maccullochella peelii peelii*), golden perch (*Macquaria ambigua*), barramundi (*Lates calcarifer*), brook trout (*Salvelinus fontinalis*)), and rare or historical native species records (e.g. southern purple-spotted gudgeon (*Mogurnda adspersa*)).

From 2007 to 2021, a total of 126,954 fish (12 native species, 4 translocated species and 8 invasive species) were captured in WMLR surveys conducted at 237 sites over 467 sampling events (spring/autumn seasons) in 24 of the 32 catchments within the WMLR (Figure 3, Figure 4, Appendix 1). Of these, 80 sites had been sampled prior to 2007 and 157 sites were sampled for the first time (between 2007–2021). Thirty percent of sites (*n* = 72) were monitored on multiple occasions (2–12 times). The current and historic knowledge (McNeil and Hammer, 2007) of the distribution of all native and invasive fish species in the WMLR is presented below as a species by species synopsis (Table 3, Figure 5 to Figure 24). This includes the current conservation status for each native species or biosecurity status for invasive species discussed in the context of WMLR catchments (Table 2).

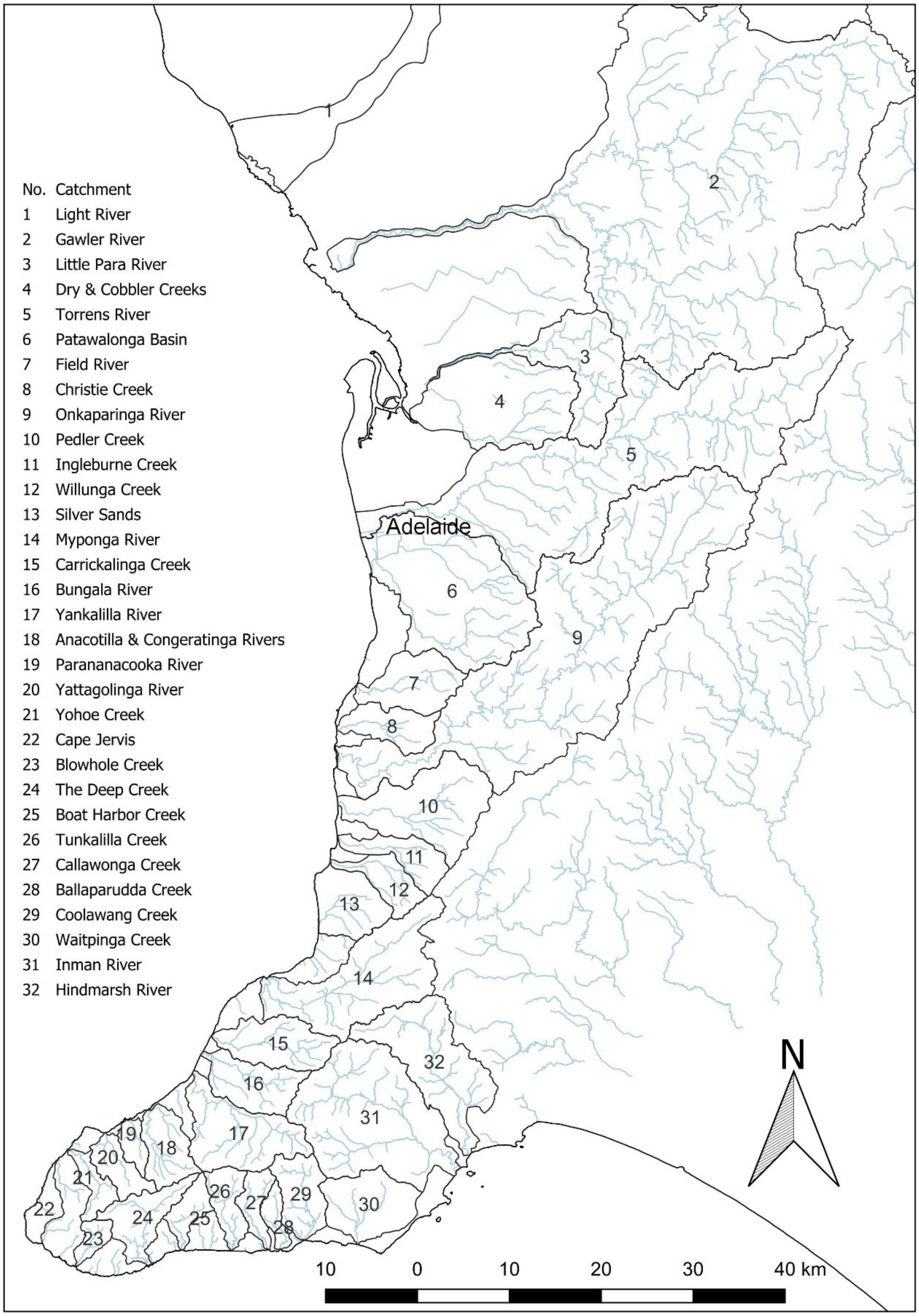

Figure 3. Map of catchments surveyed as part of the long-term monitoring of fish populations in the WMLR between 2007–2021.

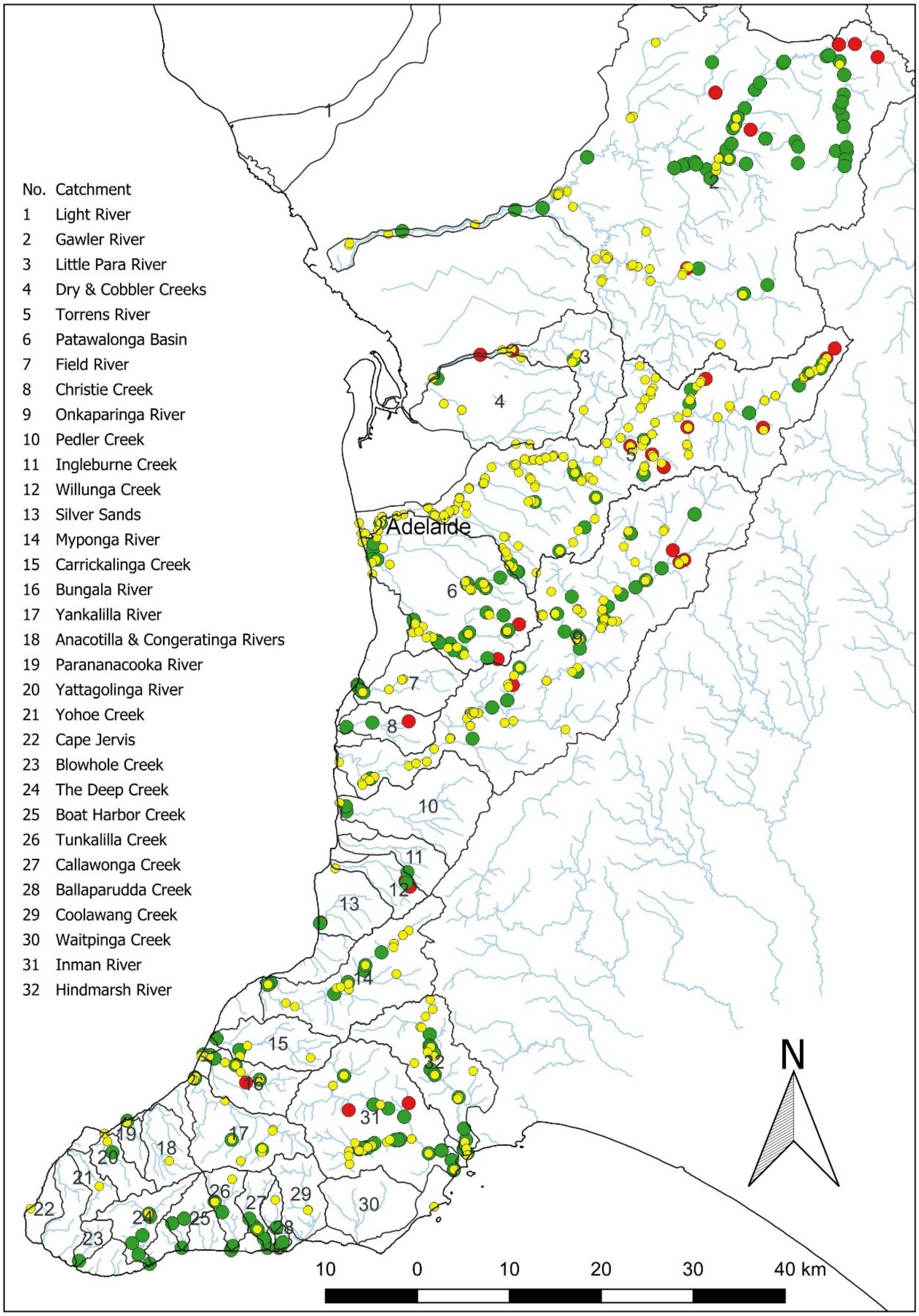

Figure 4. Distribution of fish records prior to 2007 (yellow), recent fish monitoring sites 2007–2021 where fish were detected (green) and not detected (red).

*Table 2. List of species recorded in the Western Mount Lofty Ranges prior to 2007 (McNeil and Hammer, 2007) and from surveys conducted from 2007–2021. Records: 1 = verified records, but limited in number, 2 = species present but which have declined with no recent records, 3 = recent records, at two or more locations, * = translocated, ? = unknown if native or translocated (or both). Conservation status: International (Int.): DD = Data Deficient, LC = Least Concern, NT = Near Threatened. National (Nat.): VU=Vulnerable, CR = Critically Endangered (EPBC Act 1999 (Cth)); State: P = protected (Fisheries Management Act 2007(SA)), CR = Critically Endangered, EN = endangered, VU = Vulnerable, RA = Rare (Action Plan, Hammer et al. 2009); Regional (Reg.): RE = regionally extinct; CR = critically endangered; EN = endangered; VU = vulnerable; RA = rare; NT = near threatened; LC = least concern. Blue coloured cells are translocated native species, orange are invasive species.*

Species	**Scientific name**	**Int.**	**Nat.**	**State**	**Reg.**	**Records Pre 2007**	**Records 2007–2021**
Short-finned eel	*Anguilla australis*	NT	-	RA	RA	1	3
Climbing galaxias	*Galaxias brevipinnis*	LC	-	RA	VU	3	3
Common galaxias	*Galaxias maculatus*	LC	-		LC	3	3
Mountain galaxias	*Galaxias olidus*	LC	-	VU	VU	3	3
Pouched lamprey	*Geotria australis*	DD	-	EN	CR	3	1
Western carp gudgeon	*Hypseleotris spp.*	LC	-	-	-	3	3
Southern purple-spotted gudgeon	*Mogurnda adspersa*	LC	-	P, CR	CR	2	
Shortheaded lamprey	*Mordacia mordax*	LC	-	EN	RE	3	
Southern pygmy perch	*Nannoperca australis*	NT	-	P, EN	EN	3	3
Bony herring	*Nematalosa erebi*	LC	-	-	-		3
Flathead gudgeon	*Philypnodon grandiceps*	LC	-		LC	3	3
Dwarf flathead gudgeon	*Philypnodon macrostomus*	LC	-		RA	3?	3?
Congolli	*Pseudaphritis urvillii*	LC	-	VU	VU	3	3
Western bluespot goby	*Pseudogobius olorum*		-		RA	3	3
Silver perch	*Bidyanus bidyanus*	NT	CR	P, EN	RE	1*	3*
Murray cod	*Maccullochella peelii peelii*	LC	VU	P, EN	RE	1*	
Golden perch	*Macquaria ambigua ambigua*	LC	-		RA	1*	1*
Murray rainbowfish	*Melanotaenia fluviatilis*	LC	-		NT	3*	3*
Freshwater catfish	*Tandanus tandanus*	LC	-	P, EN	EN	3*	3*
Goldfish	*Carassius auratus*					3	3
Common carp	*Cyprinus carpio*					3	3
Gambusia	*Gambusia holbrooki*					3	3
Barramundi	*Lates calcarifer*					1	
Rainbow trout	*Oncorhynchus mykiss*					3	3
Redfin perch	*Perca fluviatilis*					3	3
Speckled livebearer	*Phalloceros caudimaculatus*						3
Brown trout	*Salmo trutta*					3	3
Brook trout	*Salvelinus fontinalis*					1	
Tench	*Tinca tinca*					3	3
Total native						13	12
Total translocated and alien						14	11

*Table 3. Overview of distribution of freshwater and diadromous fish species within the WMLR with historical and current taxonomic notes. New distribution or taxonomic observations (2007–2021) are highlighted in **bold** type.*

Species	WMLR Distribution	Taxonomic observations and comments
Pouched lamprey	Rare. Records from major systems in South Australian Gulf Division (SAG) (Gawler, Torrens, Onkaparinga). • **Recent record in Torrens.**	Some confusion in reports for adults of *Mordacia* and *Geotria*, but keys are reliable.
Shortheaded lamprey	Records from major systems in SAG (Gawler, Torrens, Onkaparinga). No recent records.	Some confusion in reports for adults of *Mordacia* and *Geotria*, but keys are reliable.
Short-finned eel	At western limit of Australian distribution. • **New records in Inman, Hindmarsh and Patawalonga.**	
Freshwater catfish	Introduced from Murray Darling Basin to Field and Torrens (SAG). • **New record in Patawalonga**	MDB population confirmed as one species (Musyl and Keenan 1996, **Rourke and Gilligan 2010**).
Bony herring	Rare • **Inman River (possible translocation)** • **Inter-basin transfer to Torrens River**	
Climbing galaxias	Coastal populations from west of Murray mouth to Onkaparinga Catchment. Landlocked in Onkaparinga, Torrens River and Gawler River systems. • **New record in Patawalonga**	*Likely a species complex*. Initial genetic evidence to suggest Australian and New Zealand fish are not con-specific (Waters and Wallis 2001) • **Australian fish likely to be four, yet to be described species (Raadik *et al.* 2019)**. • **For the purposes of this report, climbing galaxias in the WMLR will be considered as one species.**
Common galaxias	Lower ends of most/all catchment in WMLR. Landlocked populations in Onkaparinga, and Torrens River • **Gawler River (yet to be determined whether this population is landlocked due to poor migration pathways).**	Can be confused with other galaxias (and less likely smelt), especially when juvenile.
Mountain galaxias	Mostly upland populations in WMLR (Yanakalilla to Gawler system) plus Hindmarsh population.	• **Single species confirmed in WMLR including SF (Raadik 2014)**.
Murray rainbowfish	Introduced to lower Torrens via escapes from ponds and dams. • **Single record in Hindmarsh River**	
Murray cod	Introduced in WMLR. Historical record, no recent records.	
Golden perch	Introduced in WMLR. Historical record, • **One recent record in Field River (May 2021)**	Derived from MDB population of golden perch (Musyl and Keenan 1992).
Southern pygmy perch	Inman Catchment (SF), especially Back Valley Creek tributary.	• **Species complex**. 2 species in SE Aust. with a distinct lineage (sub-species) in MDB (Hammer 2001). Can be confused with Yarra pygmy perch, but distinctive (reliable keys). Also highly genetic distinct local sub-populations.

Species	WMLR Distribution	Taxonomic observations and comments
		• **Recent genetic structure analysis by Cole et al. 2016 (Conservation Genetics)**
Silver perch	Introduced in WMLR. • **Rare recent record in Gawler River system.**	
Congolli	Widespread coastally in SAG and SF systems.	
Carp gudgeon species	Inman River including Back Valley Tributary (SF). Introduced into Torrens River • **Recent introduction to Little Para River system**	Species complex. Local species verified with molecular markers, keys partially reliable (Bertozzi *et al.* 2000, Unmack 2000).
Southern purple-spotted gudgeon	Historical records from Onkaparinga and Torrens catchments. No recent record	
Flathead gudgeon	Widespread in WMLR streams and wetlands; lower Hindmarsh and **Inman** (SF); lower to upper stream habitat from Onkaparinga to Light Catchments (SAG).	Can be confused with dwarf flathead gudgeon but distinctive (semi-informative keys).
Dwarf Flathead gudgeon	Sympatric with flathead gudgeon. Patchy distribution in WMLR streams and wetlands; lower Hindmarsh River (SF); Onkaparinga and Torrens catchments (unknown if native, introduced or both).	Can be confused with flathead gudgeon but distinctive (semi-informative keys). • **Genetic work by Hammer *et al.* (2019) inconclusive about translocated status.**
Western bluespot goby	Estuaries and some landlocked populations such as Gawler, and Torrens systems (SAG & SF). • **New records in Patawalonga**	• **Cryptic species complex with eastern and western groups and hybridisation (Hammer *et al.* 2021)**
Goldfish	Patchy distribution in WMLR including Onkaparinga, Patawalonga and Torrens. Widespread in Gawler up to Nuriootpa	Carp x goldfish hybrids occur.
Common carp	Patchy distribution in WMLR including Onkaparinga, Patawalonga, Torrens and Gawler	Carp x goldfish hybrids occur.
Tench	Records from Gawler and Onkaparinga systems (SAG); • **Recent records from Patawalonga and widespread in Gawler River system.**	
Rainbow trout	Historical and recent records in Torrens, , Onkaparinga, and several southern Fleurieu streams. Legally stocked in Hindmarsh. • **New records in Patawalonga**	
Brown trout	Historical and recent records in Torrens, Patawalonga, Onkaparinga, and several southern Fleurieu streams. Legally stocked in Hindmarsh.	
Brook trout	Stocked historically. No recent records.	
Gambusia	Widespread in region, especially Torrens and Gawler. Absent in streams from Yankalilla around to Waitpinga.	
Speckled livebearer	• **New invasive species. Records indicate the species is currently restricted to Willunga Creek.**	
Redfin perch	Widespread in region especially Gawler River. Absent in streams from Bungala around to Waitpinga.	
Barramundi	Single record from Torrens Lake (SAG). No recent records.	

4.1. Native fish

***Short-finned eel* (*Anguilla australis*)**

Historical records (McNeil and Hammer 2007) show that short-finned eels (*Anguilla australis*) were recorded in two catchments (Little Para and Onkaparinga Rivers) in the WMLR prior to 2007 (Figure 5). After 2007, short-finned eels were captured in three new catchments (two in the Southern Fleurieu (SF) (Inman and Hindmarsh Rivers) and one in the Adelaide metropolitan area (Patawalonga) expanding the known distribution of this species in the WMLR. Short-finned eels have not been captured in the locations previously recorded (Figure 5). Previous work speculated that short-finned eels may have been distributed in SAG division waters via inter-basin water transfers from the Murray River (McNeil *et al*. 2011b), but the distribution of adult eels in catchments without Murray River water transfers suggests that direct oceanic migration is plausible. This species is listed as "Near Threatened" on the IUCN Red List (Pike *et al.* 2019) with barriers to riverine movement and freshwater habitat loss listed as key threats. This speceis is listed as rare in both the state and regional conservation status (Hammer *et al*. 2009, Gillam and Urban 2014). Rare occurrences of this species in the WMLR over the past two decades (3 events) and their putative western-most limit in the species distribution (McKinnon and Gooley 1998) indicates that detection of short-finned eels is episodic and may not be a good indicator to determine site-specific ecosystem health in the WMLR. However, complete absence of the species over an extended period may warrant further investigation. The single observation of a juvenile short-finned eel in the Inman River further supports the notion that the WMLR is at the western-most extreme of the species' distribution.

The catadromous lifecycle of eels requires a marine and freshwater phase. Juveniles mature in freshwater and migrate into estuaries throughout the year with increasing frequency in summer, spending a median period of 77 days in the estuary before moving into the ocean between late summer and early autumn triggered by lunar phase and temperature (Crook *et al*. 2014) to commence their oceanic spawning migrations to the Coral Sea (Koster *et al*. 2021). Glass eels return to the freshwater environment between May and October when water temperatures are between 10 and 14 degrees (McKinnon and Gooley 1998, August and Hicks 2008). Thus, maintaining connectivity and flow between freshwater, estuary and marine environments at appropriate times is critically important to maintain the life-cycle of not only this species but many other species in the WMLR (Booker and Graynoth 2013).

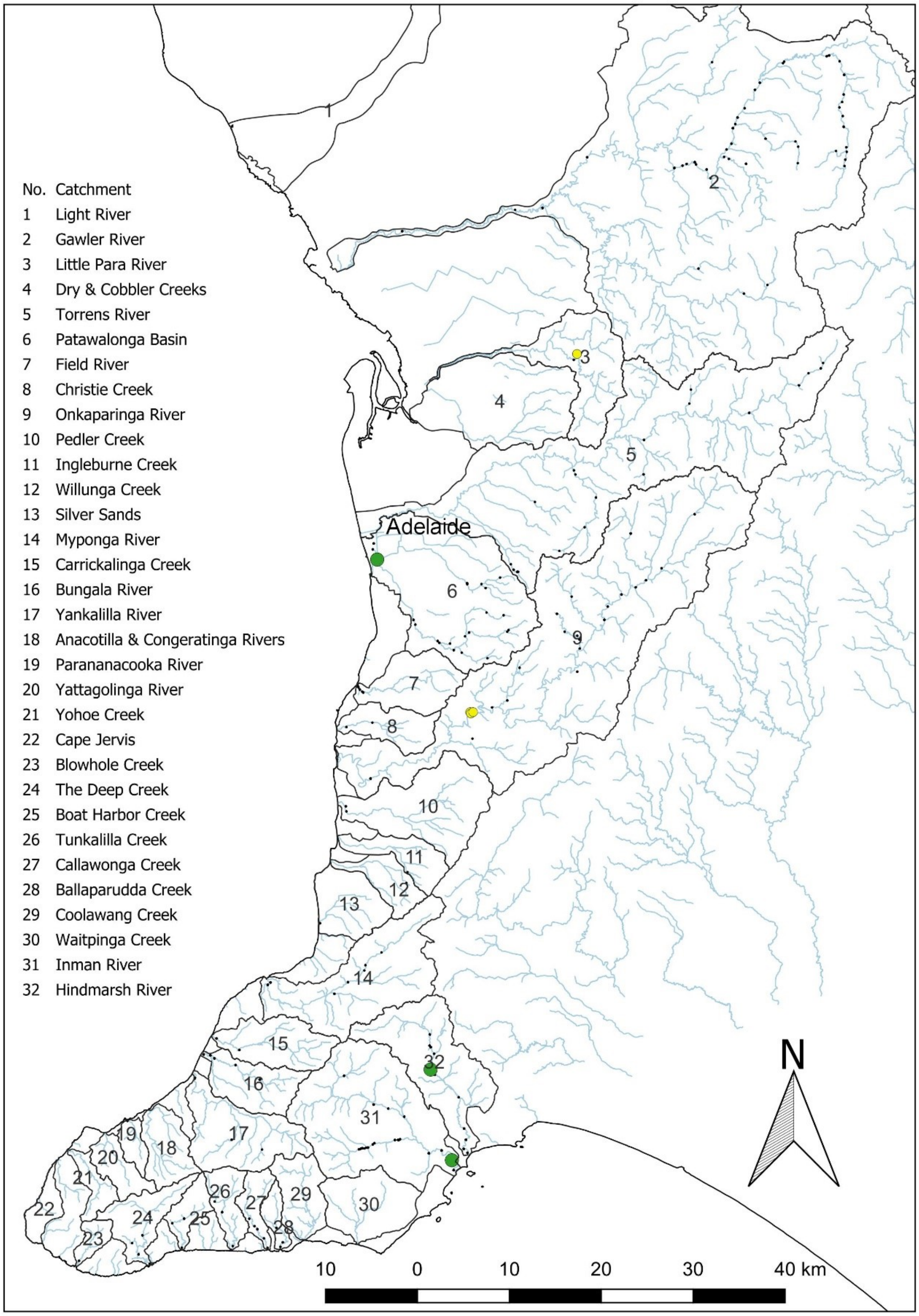

Figure 5. Short-finned eel distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Climbing galaxias (Galaxias brevipinnis)

Climbing galaxias (*Galaxias brevipinnis*) is a confirmed species complex with initial genetic evidence to suggest Australian and New Zealand fish are not con-specific (Waters and Wallis 2001). Australian fish are likely to be divided into four yet to be described species with the New Zealand fish remaining as *Galaxias brevipinnis* (Raadik *et al.* 2019). For the purposes of this report, climbing galaxias in the WMLR will be considered as one species. This species is listed as “Least Concern” on the IUCN Red List (Raadik *et al*. 2019), and “Vulnerable” in the state conservation status (Hammer *et al.* 2009) and “Vulnerable” in the regional status (Gillam and Urban 2014).

Monitoring from 2007–2021 found that climbing galaxias and mountain galaxias have sympatric populations in the Torrens, Onkaparinga, Patawalonga, Myponga, Carrickalinga, Yankalilla and Hindmarsh Catchments (Figure 6). Climbing galaxias were far more prevalent on the Fleurieu Peninsula and occupied most of the southern Fleurieu catchments where mountain galaxias were absent. The species was rare at sites in the northern upper catchments of WMLR and completely absent at sites in the North Para River despite exhaustive sampling and suitable habitat existing in the catchment. Climbing galaxias were observed in all of the catchments that they had previously been observed in the 2007 biological review except for Yohoe, Congeratinga and Coolawang Creeks which were not sampled in the 2007–2021 period. This represents a knowledge gap for this time period. Additionally, they were observed in two new catchments (Rarkang Creek and Callawonga Creek) at sites that were not sampled prior to 2007.

Climbing galaxias are a diadromous species but in the South Para, Torrens, Patawalonga and Onkaparinga catchments, they were not captured at sites downstream of the large reservoirs or dams. This could indicate that these populations may be landlocked in these rivers as they are known to form landlocked populations in the presence of significant barriers such as reservoirs (Mathwin *et al*. 2015). There were at least 12 sites throughout the WMLR where climbing galaxias were observed prior to 2007 but not in the period from 2007–2021 despite surveys being undertaken there.

The species’ extirpation and continuing absence could be due to factors such as poor habitat quality, inadequate flow regime or in-stream barriers to fish passage as well as predation (O’Connor and Koehn 1998, McNeil and Fredberg 2011, McEwan and Joy 2014, Jones and Closs 2017, Amtstaetter *et al*. 2021a, Amtstaetter *et al*. 2021b). Interestingly, redfin perch and trout (notable predators of galaxias species; Wedderburn 2014, Jones and Closs 2017) were observed at many of these sites over the years leading up to 2007 but considerably less sites between 2007–2021. Whilst predation by these species may have contributed to the extirpation of climbing galaxias prior to 2007, their absence from many sites after 2007 may further support the notion that environmental factors are affecting the fish assemblage.

Climbing galaxias have a high re-colonisation ability due to high fecundity, strong dispersal and migratory ability, and diadromy (Jones and Closs 2017). However, recolonisation is only likely to occur in the presence of suitable environmental conditions. Thus, future management strategies should consider timing, duration and magnitude of flow to support spawning and recruitment, maintain migratory pathways from marine to freshwater, provide appropriate habitat (depth, structure, substrate size, riparian spawning substrate) and optimal water quality (O'Connor and Koehn 1998, Jung *et al*. 2009, McNeil and Fredberg 2011, McEwan and Joy 2014, Amtstaetter *et al*. 2021a, Amtstaetter *et al*. 2021b).

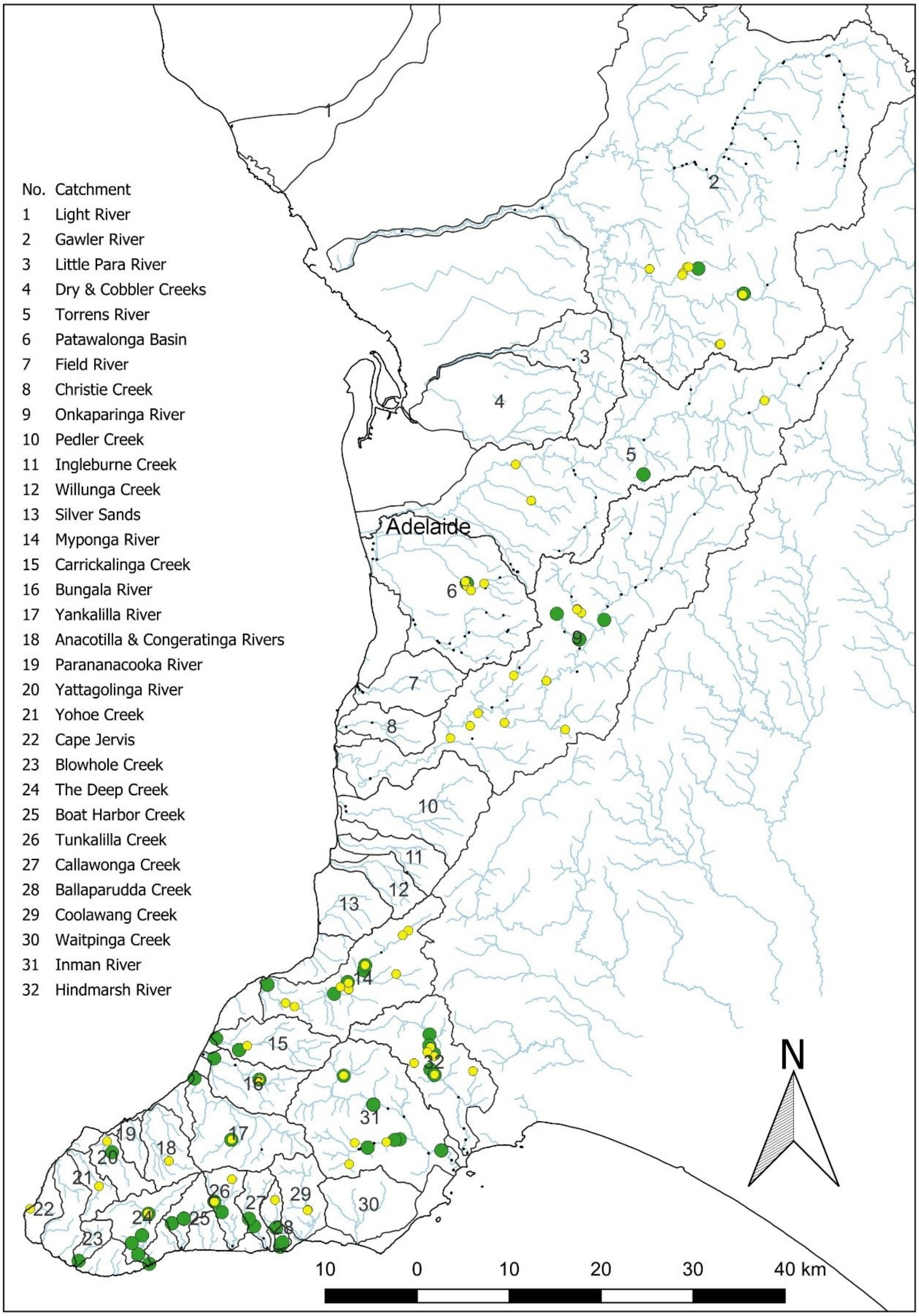

Figure 6. Climbing galaxias distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Common galaxias (Galaxias maculatus)

Monitoring from 2007–2021 found that common galaxias have a coastal and lowland distribution. They were observed in coastal or estuary sites in every river surveyed between 2007–2021, except for Little Para River (Figure 7). Little Para River was the only catchment where common galaxias were observed prior to 2007 and not post 2007. This species is listed as “Least Concern” on the IUCN Red List (Bice *et al.* 2019) and “Least Concern” in the regional conservation status (Gillam and Urban 2014). The widespread distribution of this species is tempered by the apparent limitations to its distribution to coastal areas in many catchments. With the exception of a land-locked population above Mount Bold Reservoir on the Onkaparinga River, previous records in the WMLR as well as the distribution of common galaxias in the Murray River and catchments interstate (Atlas of Living Australia) indicate that it should be more broadly distributed inland. Indeed, previous research has shown the behavioural and morphological plasticity of the species has permitted them to colonise a wide geographical range (Barbee *et al*. 2011, Barriga *et al*. 2012, Kilsby and Walker 2012).

The restoration of fish passage and lowland stream habitat, provision of adequate flow regime to facilitate spawning and larval recruitment and migration (Amtstaetter *et al*. 2021a, Amtstaetter *et al*. 2021b), the preservation/rehabilitation of riparian spawning habitat (Hickford *et al.* 2010, Hickford and Schiel 2014), the maintenance of estuarine transitional habitats (Jung *et al*. 2009), and management of large invasive predatory fish species (McDowall 2006, Jones and Closs 2017) should all be considered in improving the distribution of this species.

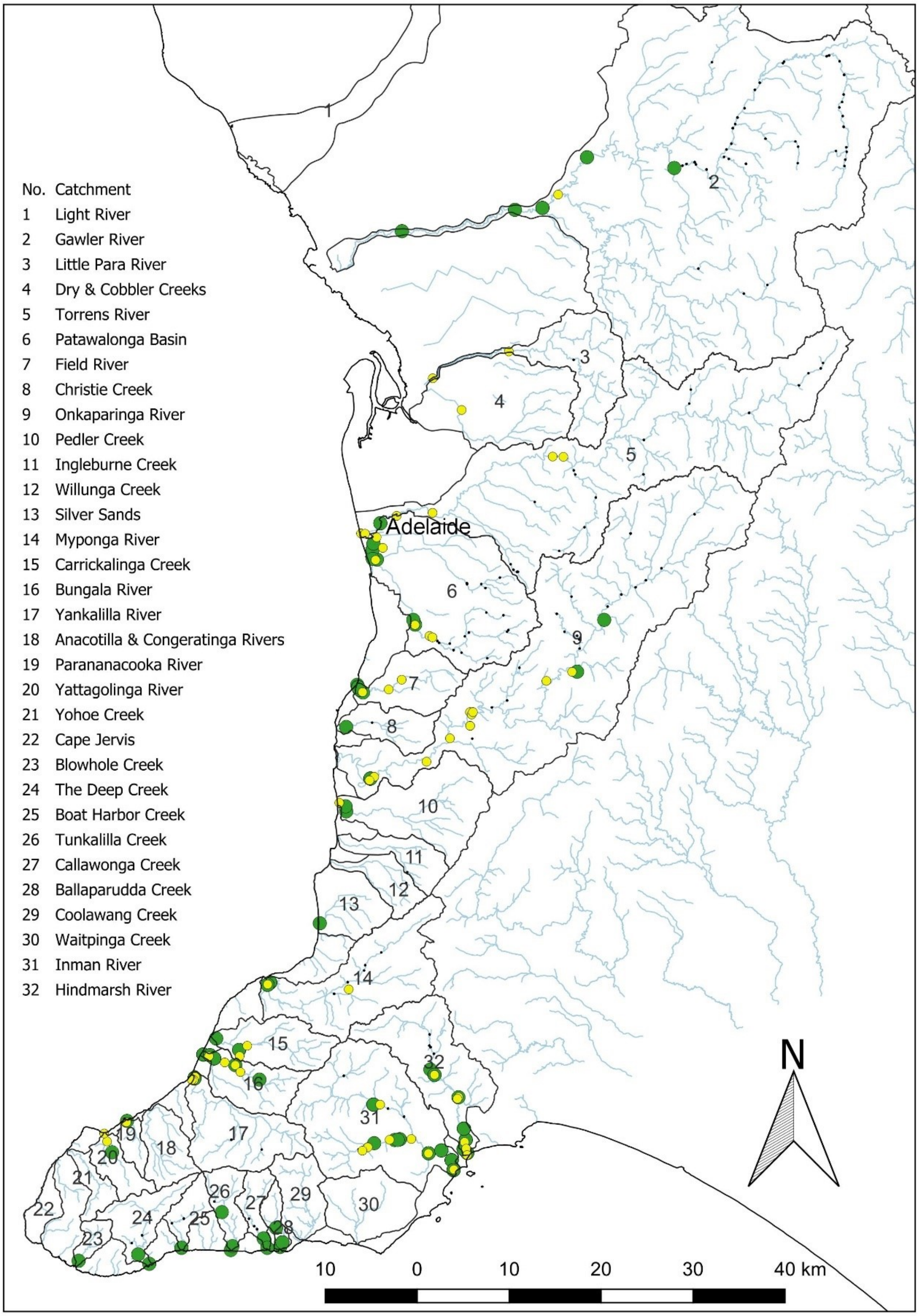

Figure 7. Common galaxias distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Mountain galaxias (Galaxias olidus)

The taxonomy of mountain galaxias was revised in 2014 (Raadik 2014). Mountain galaxias captured in the Southern Fleurieu catchments of the WMLR were considered previously to be a separate, unnamed species. These fish are now grouped with *Galaxias olidus*, while mountain galaxias in the EMLR are grouped with *Galaxias oliros* sp. nov. Mountain galaxias from the EMLR and WMLR are listed as “Least Concern” on the IUCN Red List (Raadik 2019), and “Vulnerable” in both the state and regional conservation status (Hammer *et al*. 2009, Gillam and Urban 2014). The state conservation status of mountain galaxias was changed from rare to vulnerable (Hammer *et al.* 2009) on the basis that decline in its distribution was a result of threatening processes including altered flow regime, reduced habitat quality, and predation and competition from introduced fish species.

Monitoring from 2007–2021 found that mountain galaxias (*G. olidus*) inhabit the upland reaches of streams across most of the WMLR with the exception of streams on the southern Fleurieu Peninsula west of Inman River (Figure 8). Mountain galaxias were observed in all rivers that they had previously been observed in the 2007 biological review except for Bungala River (recorded from 1963). Additionally, they were observed in two new catchments (Pedler Creek and Wirra Creek) at sites that were not sampled prior to 2007. There were at least 13 sites throughout the WMLR where mountain galaxias were observed prior to 2007 but not in the period from 2007–2021 despite surveys being undertaken. Mountain galaxias were rarely detected in reaches in the WMLR where trout were present. Displacement of galaxias species is commonly associated with the presence of invasive predators such as trout (Closs and Lake 1996, McDowall 2006, Green 2008), as was observed at these sites.

The distribution of freshwater obligate species mountain galaxias was frequently limited to one or two sites per catchment and only ten catchments in this study. The fragmented and limited distribution of mountain galaxias led to it being designated as “vulnerable” in the 2009 freshwater fish action plan (Hammer *et al.* 2009), and it should remain in this category. Further investigations should be conducted to reveal the full spatial range of mountain galaxias within these catchments and investigate the factors limiting dispersal and migration including barriers to fish passage. Monitoring of mountain galaxias populations in extremely isolated and fragmented habitats should continue to be conducted on an occasional basis to avoid inadvertent harm.

Management strategies should seek to control invasive predators and to ensure appropriate habitat and flow regimes are provided. *G. olidus'* major habitat preference is for pool areas with slow-flowing deeper water in streams containing abundant instream habitat including wood debris, submerged tree roots, undercut banks, intact riparian vegetation and suitable spawning substrate (boulders) (O'Connor and Koehn 1991). In addition, natural hydrological regimes and natural patterns of hydrological connectivity are extremely important for the conservation of this vulnerable species particularly for the completion of its lifecycle (Dexter *et al*. 2014, Cook *et al.* 2019).

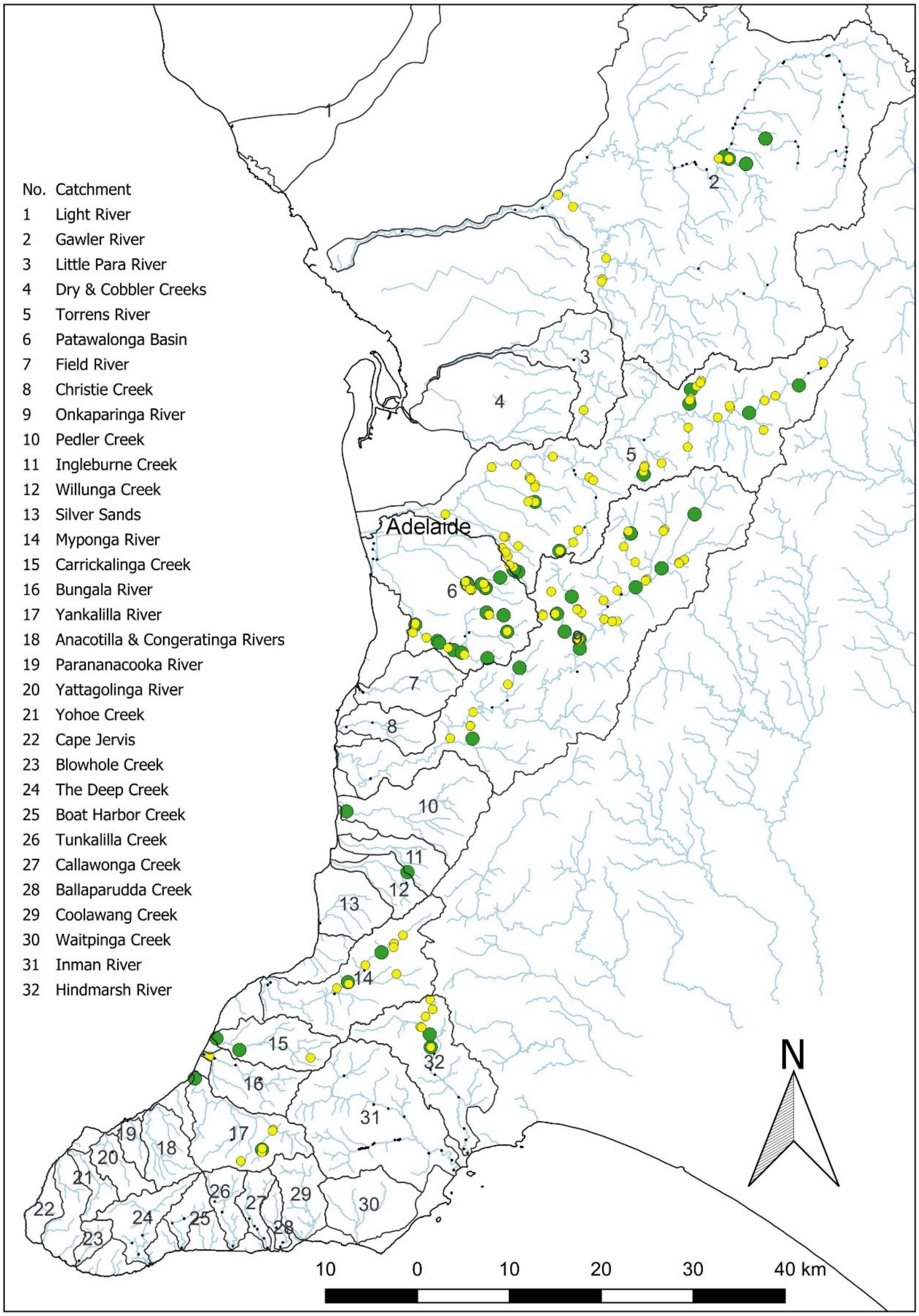

Figure 8. Mountain galaxias distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Western carp gudgeon **(*Hypseleotris* spp.)**

Carp gudgeon (*Hypseleotris* spp.) found in the WMLR are part of a species complex comprising western carp gudgeon, Murray-Darling, Midgley's and Lake's carp gudgeon (Bertozzi *et al*. 2000, Unmack 2000). Only western carp gudgeon (*Hypseleotris klunzingeri*) is listed as "Least Concern" on the IUCN Red List (Unmack 2019) due to its widespread distribution in eastern Australia, all other species were not considered. Due to difficulties in species identification and hybridisation, the species complex is referred to as western carp gudgeon or the carp gudgeon complex (*Hypseleotris* spp.) (Bertozzi *et al*. 2000, Unmack 2000). For the purpose of this review, western carp gudgeon will be referred to as carp gudgeon.

Monitoring from 2007–2021 detected carp gudgeon in one more catchment (Little Para River) than previously recorded prior to 2007 (Inman and Torrens Rivers) and remains to have limited distribution across the WMLR. The species was recorded in 2007–2021 in both catchments previously reported by McNeil and Hammer (2007) (Figure 9). The species occupied habitat characterised by submerged and emergent macrophytes in the lower reaches of the Inman, Torrens and Little Para Rivers with a small population in the Back Valley tributary. Similar habitat preferences were reported by Bice *et al.* (2014) when studying the main channel of the highly regulated lower Murray River under low flows.

Carp gudgeon are possibly a Murray River–Torrens translocation, particularly in the Torrens and Little Para (Hammer *et al*. 2012). In the Back Valley tributary of Inman River, it is possible the population could be endemic due to the historical links and proximity of the Inman catchment to the Murray River and sympatry with other distinct local aquatic fauna with links to the Murray system (Hammer *et al*. 2012). This species is predominantly found in low flow reaches (Humphries *et al.* 1999) and was absent from areas of higher flow or in the presence of redfin perch.

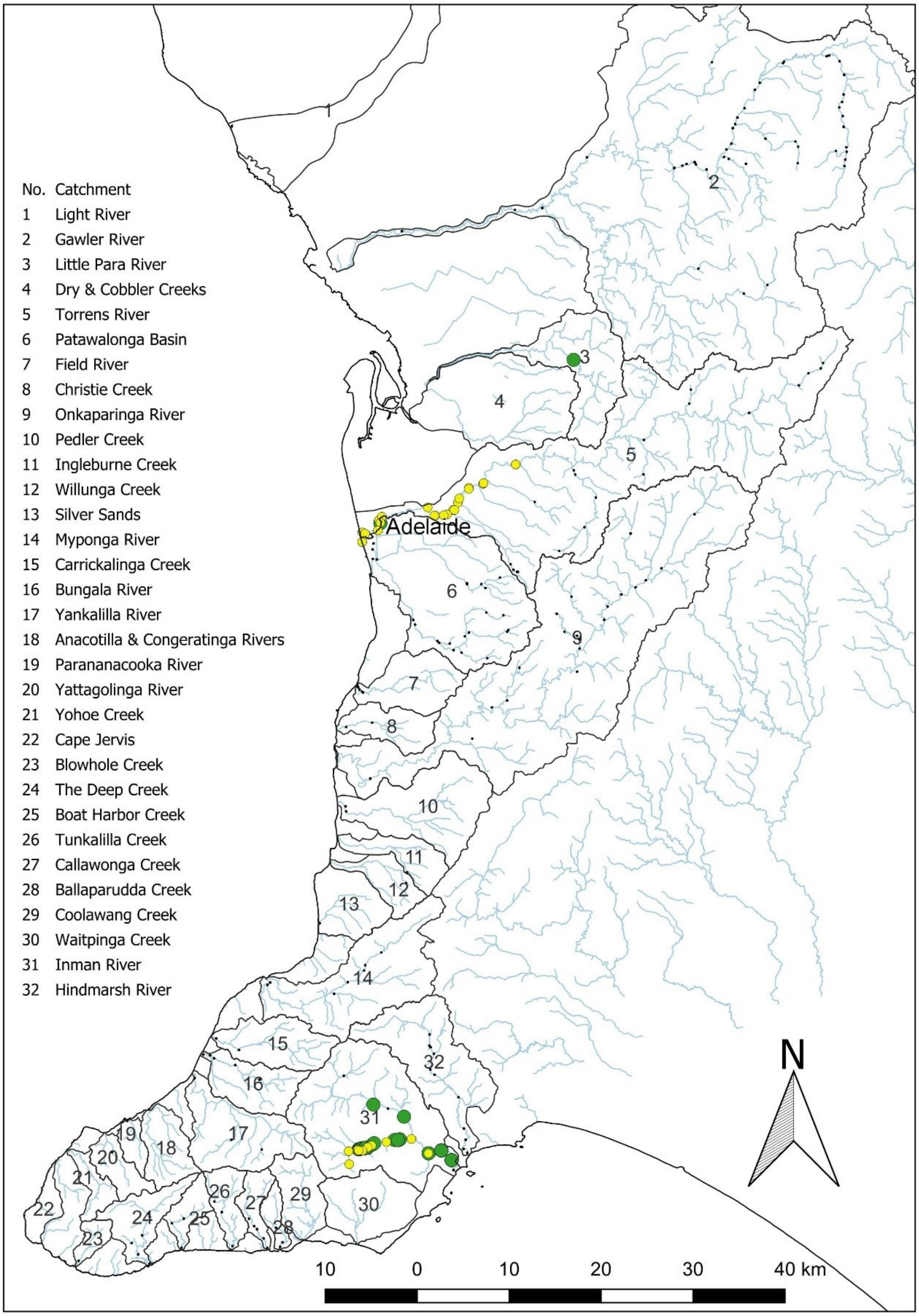

Figure 9. Western carp gudgeon distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Murray rainbowfish (Melanotaenia fluviatilis)

Monitoring from 2007–2021 indicated Murray rainbowfish are relatively rare across WMLR but were present in two more catchments in the WMLR (Hindmarsh and Patawalonga) than recorded prior to 2007 (Figure 10). The species occupied habitat characterised by submerged and emergent macrophytes in the lower reaches of the Hindmarsh, Patawalonga and Torrens Rivers. Similar habitat preferences were reported by Bice *et al.* (2014) when studying the main channel of the highly regulated lower Murray River under low flows. This species is listed as "Least Concern" on the IUCN Red List (*Bice et al.* 2019), and "Near Threatened" in the regional conservation status (Gillam and Urban 2014).

Threats to this species include low temperatures during winter drought conditions (driven by climate change) and predation by redfin perch and gambusia (*Bice et al.* 2019). This species is likely to have been translocated from the Murray River to the Torrens via escape from ponds or dams (Hammer *et al*. 2012). The new record of this species in the Patawalonga is also possibly a result of human aided introduction either via deliberate release, or translocation from the Torrens River. Unlike the metropolitan occurrences of the Murray rainbowfish in the Torrens and Patawalonga, it is unclear whether the fish observed in the Hindmarsh are translocated or endemic to that catchment. It is possible the Hindmarsh population could be endemic due to the historical links and proximity of the Hindmarsh to the Murray River and sympatry with other distinct local aquatic fauna with links to the Murray system (Hammer *et al*. 2012).

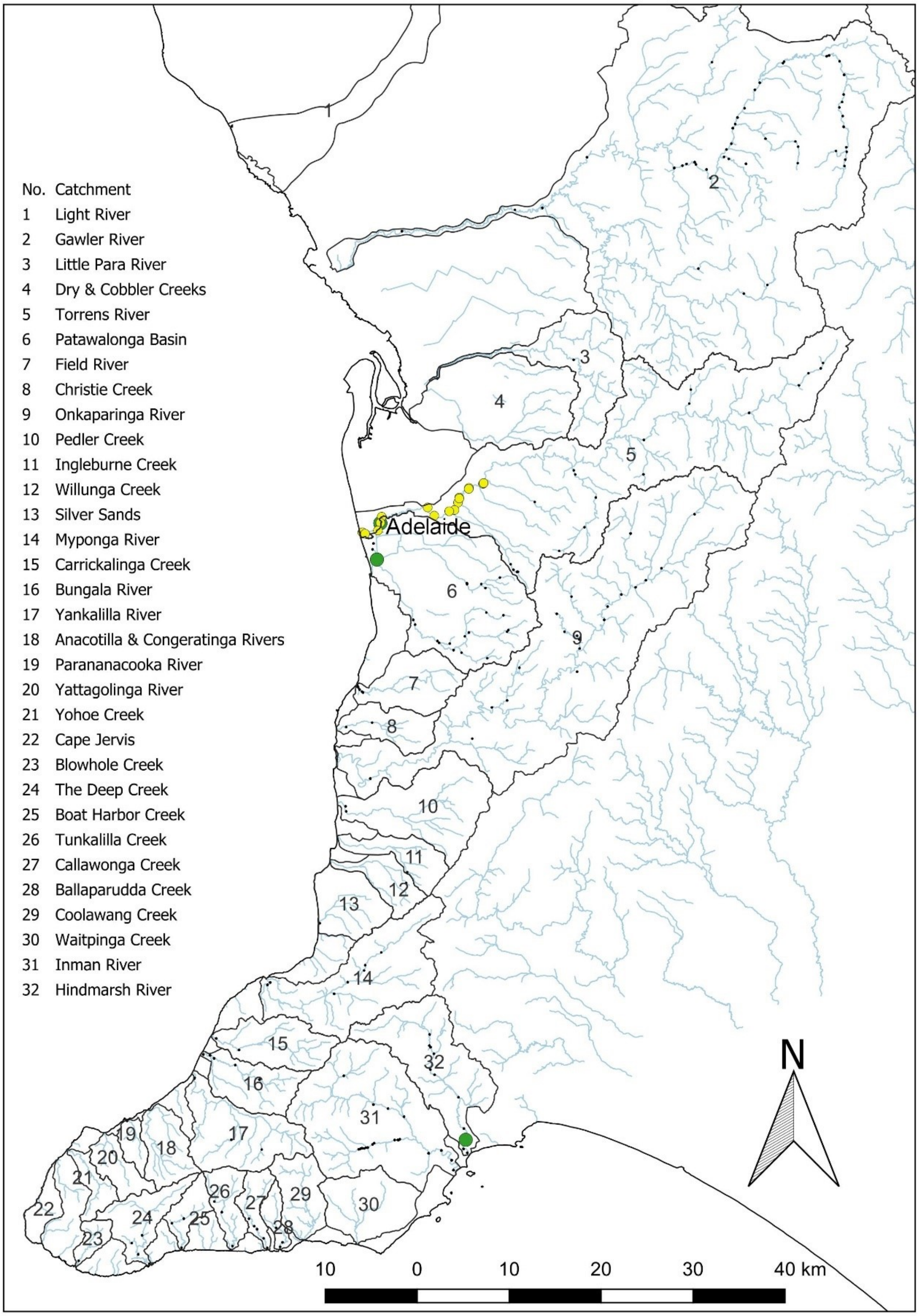

Figure 10. Murray rainbowfish distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Southern pygmy perch (Nannoperca australis)

Monitoring from 2007–2021 confirmed data prior to 2007 indicating populations of southern pygmy perch are restricted to the Inman catchment in the WMLR, with populations in Back Valley Creek and Boundy River tributaries (Figure 11). Extensive sampling in Back Valley during 2019/20 expanded the number of pools containing this species within this catchment and found increased abundance in comparison to previous years. The sites that were sampled in 2007–2021 overlapped all the sites where southern pygmy perch were sampled prior to 2007 indicating that the range of this species is unchanged. This species is listed as "Near Threatened" on the IUCN Red List (Pearce *et al.* 2019), and "Endangered" in both the state and regional conservation status (Table 2; Hammer *et al.* 2009, Gillam and Urban 2014). The state conservation status remained as endangered, primarily due to declines in the range, abundance and area of occupancy in the Murray River (Hammer *et al*. 2009), but these concerns also hold true for the regional status. The current state conservation status of the southern pygmy perch is currently under review. The southern pygmy perch populations may be under threat from invasive species (redfin perch and gambusia) that occur in connected systems and this risk should be carefully managed.

The Back Valley refuge is critically important for the survival of this species in the WMLR. *N. australis* generally has isolated local populations with varying but limited dispersal capabilities (Cook *et al*. 2007, Dexter *et al*. 2014). Previous research into the conservation of the species has recommended protecting and augmenting refugial habitat, restoring corridor functions between refugia and providing environmental flows to create floodplain inundation to stimulate spawning and recruitment (Cook *et al*. 2007, Tonkin *et al*. 2008). However, given that this population has persisted in what appears to be a relatively degraded system, caution should be taken in developing and implementing any management interventions. To date, no invasive species have been detected in this reach and interventions that establish greater connectivity may facilitate invasion by species already present in nearby reaches in the catchment. Other management scenarios that consider translocation or captive breeding (Marshall *et al*. 2022) will require careful consideration as the removal of fish for these purposes may have detrimental impacts on the viability of the population (Todd *et al*. 2017).

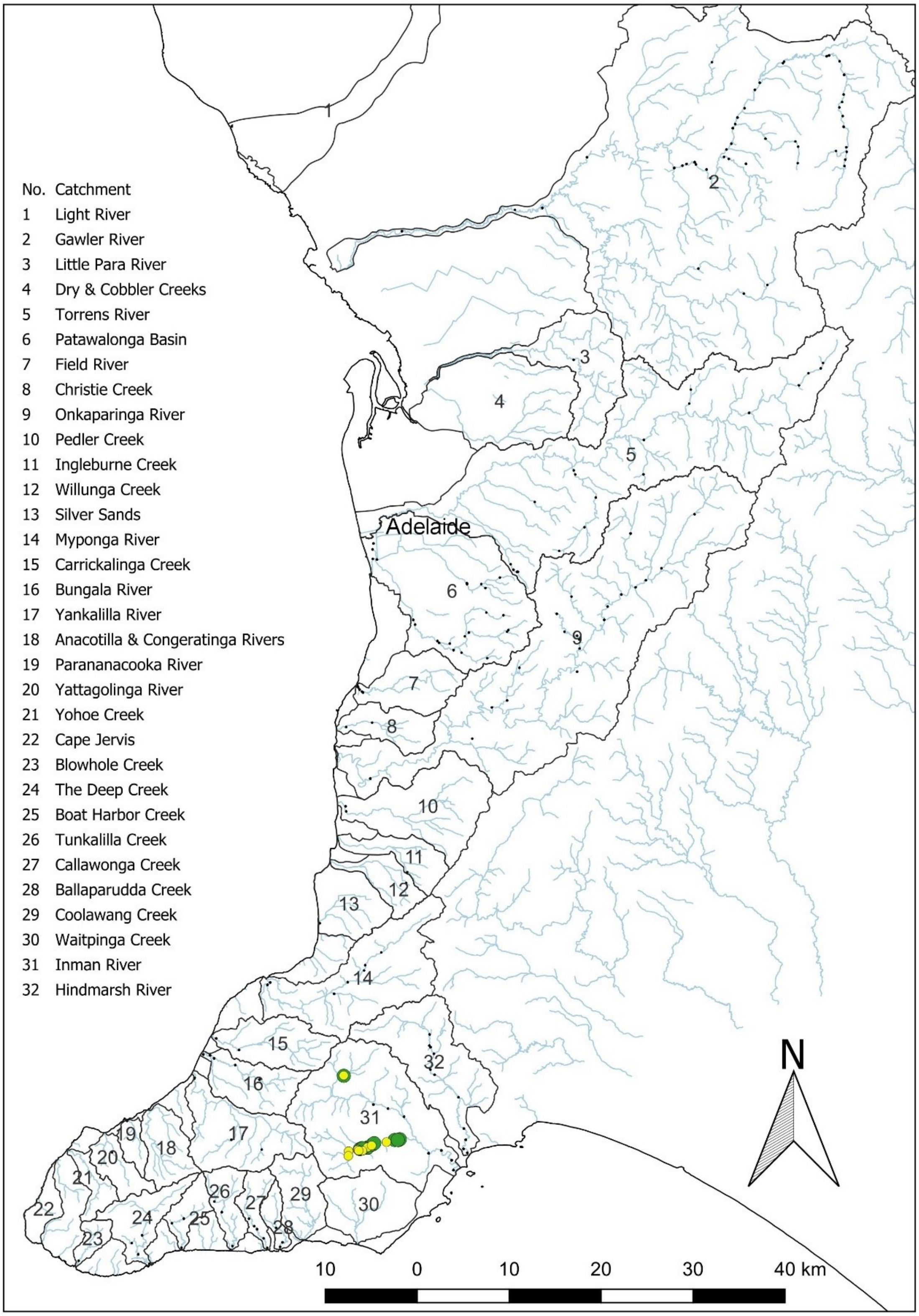

Figure 11. Southern pygmy perch distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Bony herring (Nematalosa erebi)

Monitoring from 2007–2021 captured bony herring for the first time in the WMLR in the Inman River (Figure 12). Bony herring is listed as "Least Concern" on the IUCN Red List and the regional conservation status (Ebner *et al*. 2019, Gillam and Urban 2014).

Bony Herring is a medium-sized freshwater and estuarine species that is widespread across much of northern Australia and in the Murray Darling Basin (Lintermans 2007, Gomon and Bray 2021). It is a hardy species that displays an opportunistic life history strategy (Winemiller *et al*. 1992, Ferguson *et al.* 2013). The species are algal detritivores, highly fecund (up to 880,000 eggs), tolerant to high temperatures (up to 38^{o}C), high turbidity and salinity (up to 39 ppt) and low dissolved oxygen (Lintermans 2007). They are known to spawn in shallow sandy bays or backwaters during floods (Humphries *et al.* 1999, Lintermans 2007); however recruitment is not dependant on river flow (Puckridge and Walker 1990). Recently, Bice *et al*. (2014) found that bony herring were not positively associated with any microhabitats. However, they appear to prefer the shallows of still or slow-flowing rivers, streams, lakes and waterholes, particularly in turbid conditions (Gomon and Bray 2021). The restricted distribution and abundance of bony herring in the WMLR is likely to be associated with the limited availability of suitable habitat.

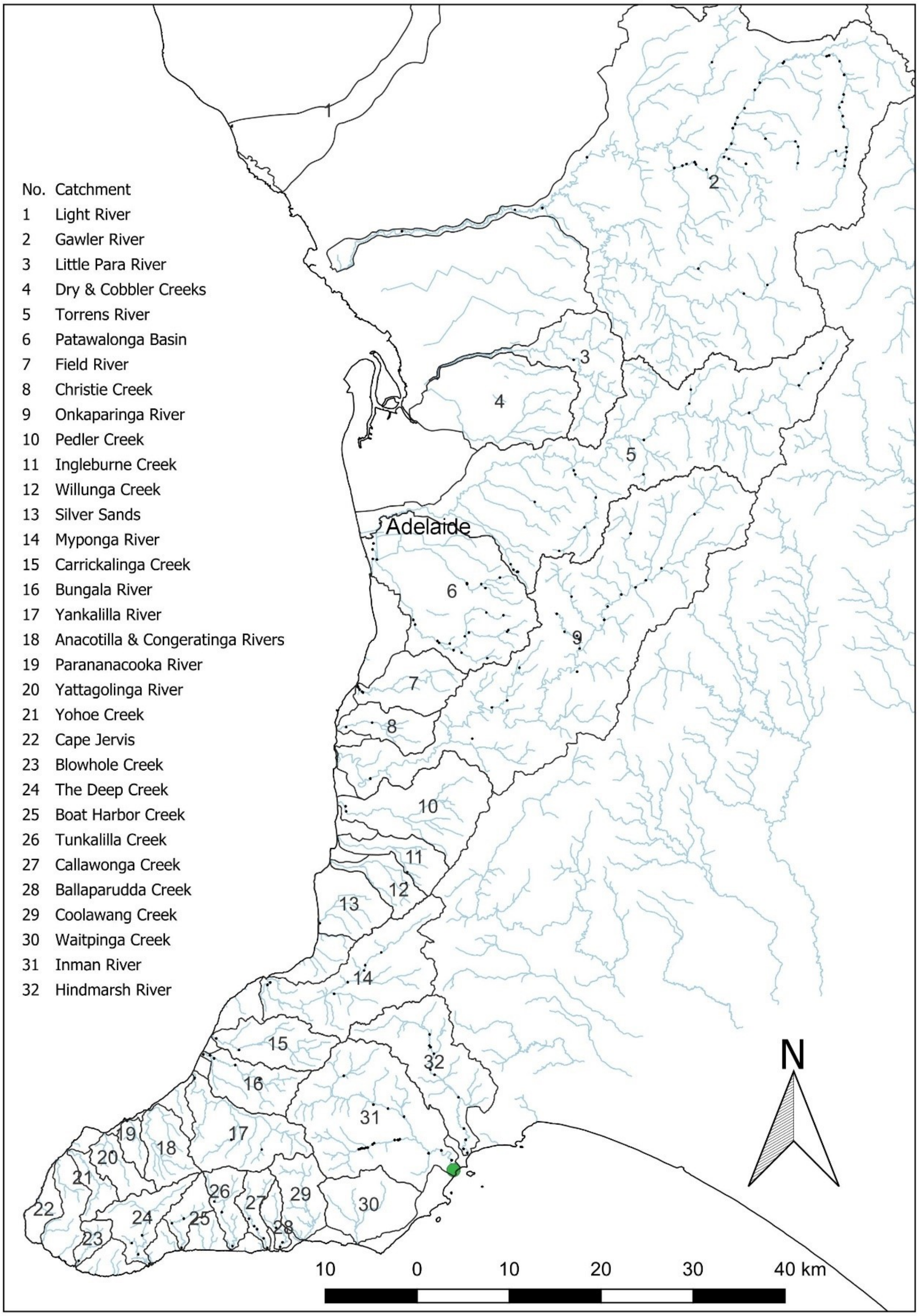

Figure 12. Bony herring distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Flathead gudgeon (Philypnodon grandiceps)

Monitoring from 2007–2021 indicated flathead gudgeon were present in five more catchments (2007 *n* = 6, 2007–2021 *n* = 11; Washpool, Myponga, Bungala, Yankalilla, Inman) in the WMLR than recorded prior to 2007 (Figure 13). Typically, presence of flathead gudgeon occurred in habitats in the lower reaches of the Hindmarsh, Inman and several streams on the northern side of the Fleurieu Peninsula (Washpool, Myponga, Bungala and Yankalilla Rivers) with records in lower urban catchments of the Field and Torrens Rivers. Based on current and previous records, the species appear to be more prevalent in the upper reaches of the Onkaparinga, Torrens and Gawler catchments, with highest population abundances in the upper North Para River within the Gawler catchment. Flathead gudgeon is listed as “Least Concern” on the IUCN Red List and the regional conservation status (Bice and Hammer 2019, Gillam and Urban 2014).

McNeil *et al.* (2011b) suggested that this species may be more tolerant of river regulation and degradation than other species due to its tolerance of poor water quality including high salinity and low dissolved oxygen conditions. McNeil *et al.* (2011b) also reported that the main threats to flathead gudgeon were predation by redfin perch and competition and predation by gambusia (*Gambusia holbrooki*). However, Wilson *et al.* (2008) found that predation by redfin perch had no impact on the abundance or size structure of flathead gudgeon populations in the South Para River in South Australia. They further suggested redfin perch affects their use of microhabitats, concluding that maintaining habitat complexity and aquatic vegetation cover is an important factor in their survival in the presence of this predator. Wilson *et al.* (2008) also found that in extreme drought conditions, flathead gudgeon populations were more resilient to declining water quality in drying pools than sympatric redfin perch. The ability of flathead gudgeon to tolerate poor water quality while also surviving in the presence of invasive predators suggest that high abundance populations of this species may not be a good indicator of healthy aquatic ecosystems.

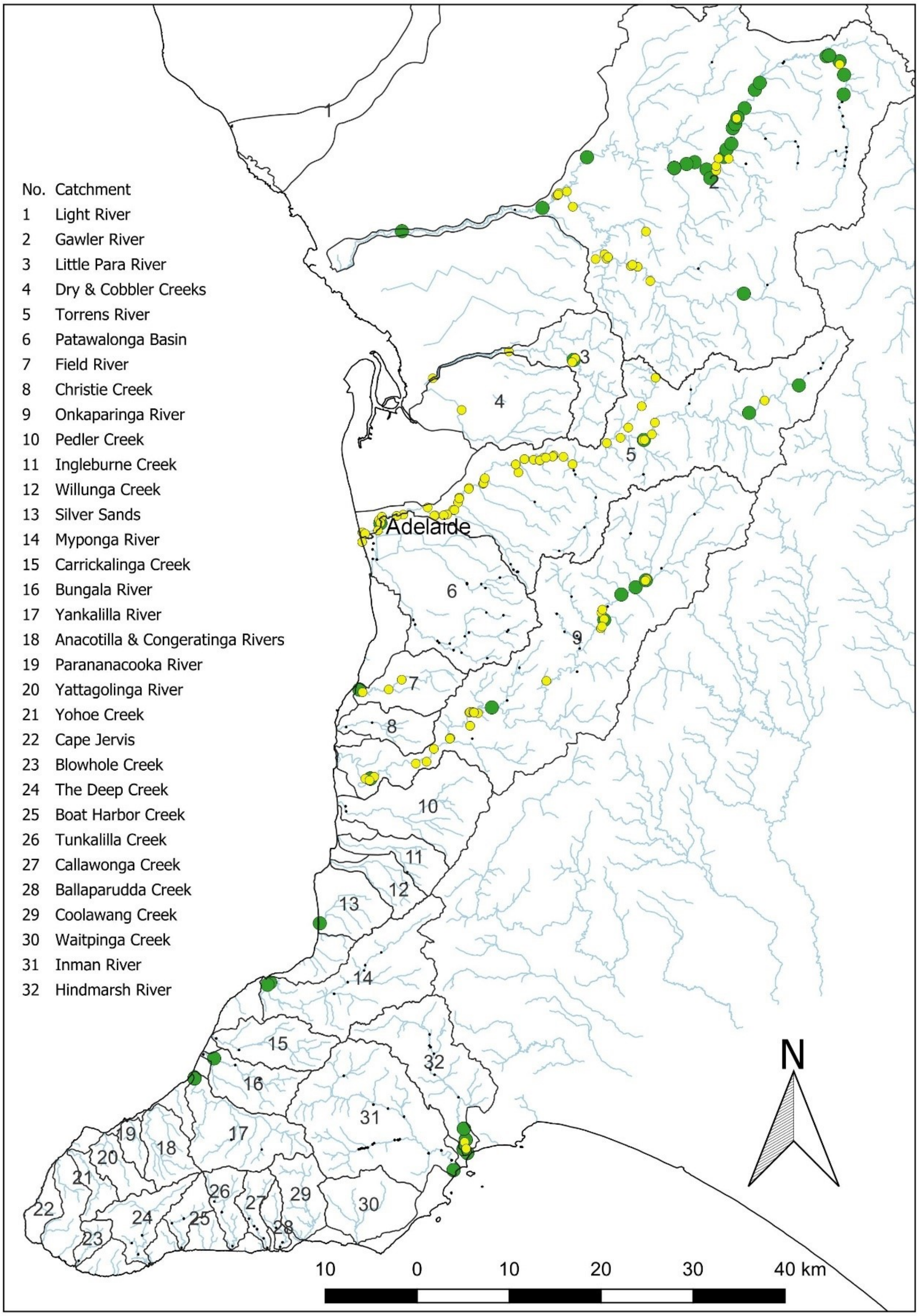

Figure 13. Flathead gudgeon distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Dwarf flathead gudgeon (Philypnodon macrostomus)

It is suspected that SAG division populations of dwarf flathead gudgeon are introduced, however Hammer *et al*. (2019) state that they should be treated as native until evidence to the contrary is provided. The species is relatively rare across WMLR catchments based on historical and current (2007–2021) distribution records. This species has populations sympatric with flathead gudgeon in many of the streams that it occupies, although it was far less common.

Monitoring from 2007–2021 found that dwarf flathead gudgeon were present in two more catchments of the Southern Fleurieu (Myponga and Yankalilla) than recorded prior to 2007 (Figure 14). The species occupied habitat in the lower reaches of the Hindmarsh, Myponga, Yankalilla and Onkaparinga and two sites in the upper reaches of the Torrens and Onkaparinga Rivers. Dwarf flathead gudgeon is listed as “Least Concern” on the IUCN Red List (Scott *et al.* 2019) and “Rare” in the regional conservation status (Gillam and Urban 2014). It has similar ecological traits to flathead gudgeon, with habitat complexity and aquatic vegetation cover likely important factors for population survival particularly in the presence of predators (Wilson *et al*. 2008). Similar to flathead gudgeon, the ability of dwarf flathead gudgeon to tolerate poor water quality while also surviving in the presence of invasive predators suggest that populations of this species may not be a good indicator of healthy aquatic ecosystems.

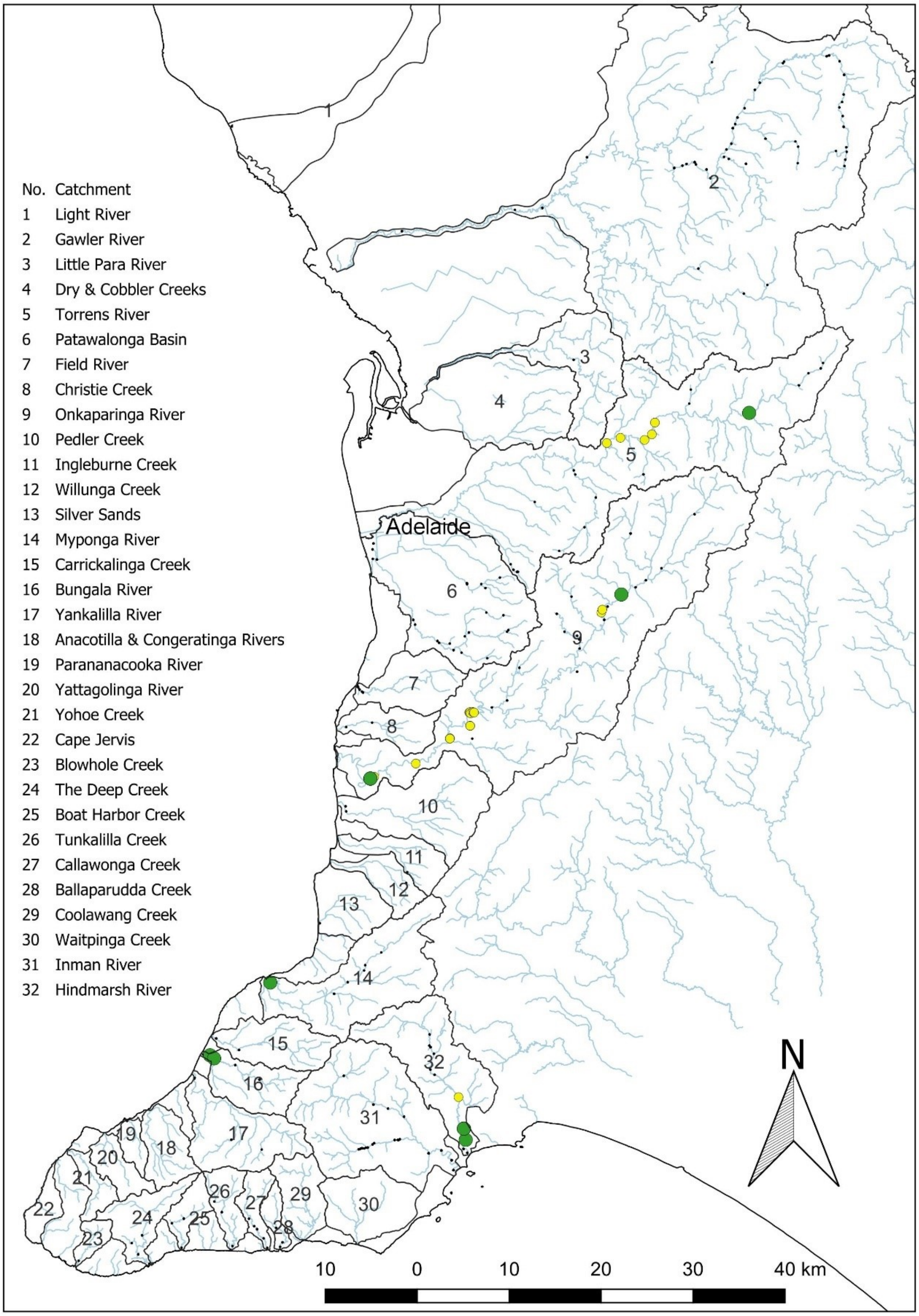

Figure 14. Dwarf flathead gudgeon distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Congolli (Pseudaphritis urvillii)

Congolli are considered a key indicator species for connectivity within estuarine and freshwater habitats. Female congolli are 'catadromous' maintaining relatively small home ranges and displaying strong site fidelity in freshwater reaches before undertaking annual rapid spawning migrations into estuaries or the ocean during May and August when photoperiods are at a minimum and water temperatures are relatively low (Crook *et al*. 2010; Bice *et al*. 2018). Males appear to be non-diadromous inhabiting euryhaline estuarine/marine environments and only occasionally entering the lower freshwater reaches of rivers and streams (McNeil *et al.* 2011). Migrations into estuarine and freshwater habitats are undertaken by juveniles <70 mm in length and ~120 days of age in spring–summer (October–February) (Bice *et al.* 2018).

This species is listed as "Least Concern" on the IUCN Red List (Bice *et al*. 2019) and "Vulnerable" in both the state and regional conservation status (Hammer *et al.*2009, Gillam and Urban 2014). The state conservation status of congolli was determined largely on the basis of population declines in the Murray River. Threatening processes impacting congolli populations include reductions in flow and lack of river discharge to the ocean, barriers to movement and reduced habitat quality (Hammer *et al.* 2009, Bice *et al*. 2018).

Monitoring from 2007–2021 indicated congolli are widespread in catchments of the WMLR. The species was present across a range of northern, mid and lower WMLR sites and recorded in 16 out of the 25 catchments sampled from 2007–2021 with the notable exception of the Little Para and Torrens Rivers (Figure 15). The spatial expansion of the monitoring program post 2007 has significantly improved knowledge of the species' distribution. Congolli were recorded in 11 new catchments (from 16 catchments), which are new South Australian distribution records for the species. The species were not captured in two catchments (Torrens and Little Para) where they had been recorded prior to 2007 (McNeil and Hammer 2007), although catch data from other projects not considered in this review showed that they were detected in the Torrens during this time (McNeil *et al*. 2011b).

Of note, congolli appear to be limited in distribution to coastal sites in all but three catchments despite extensive sampling upstream in almost all catchments. This restricted range may be due to natural (waterfalls) or man-made barriers (weirs, culverts, tunnels, shallow concrete channels etc.) to fish passage restricting up or downstream movement. At least five of the catchments where congolli had a restricted distribution had man-made barriers less than a kilometre upstream of the site they were last recorded (Patawalonga, Field, Pedler, Myponga and Bungala) and a large proportion of other catchments have barriers further upstream. Congolli migration and dispersal appears to increase in response to the removal of barriers (Ryan *et al*. 2018), the provision of fish passage (Zampatti *et al*. 2012, Bice *et al.* 2016), and the delivery of environmental flows (Webb *et al*. 2018). Aspects of congolli life-history (semelparous catadromy) enable the species to disperse in the marine habitat and potentially access nearby catchments (Schmidt *et al*. 2014).

Management actions should be directed at removal or bypass of instream barriers and restoration of estuarine linkages, restoration of timely flow for female passage to upstream habitats and restoration of lowland reaches.

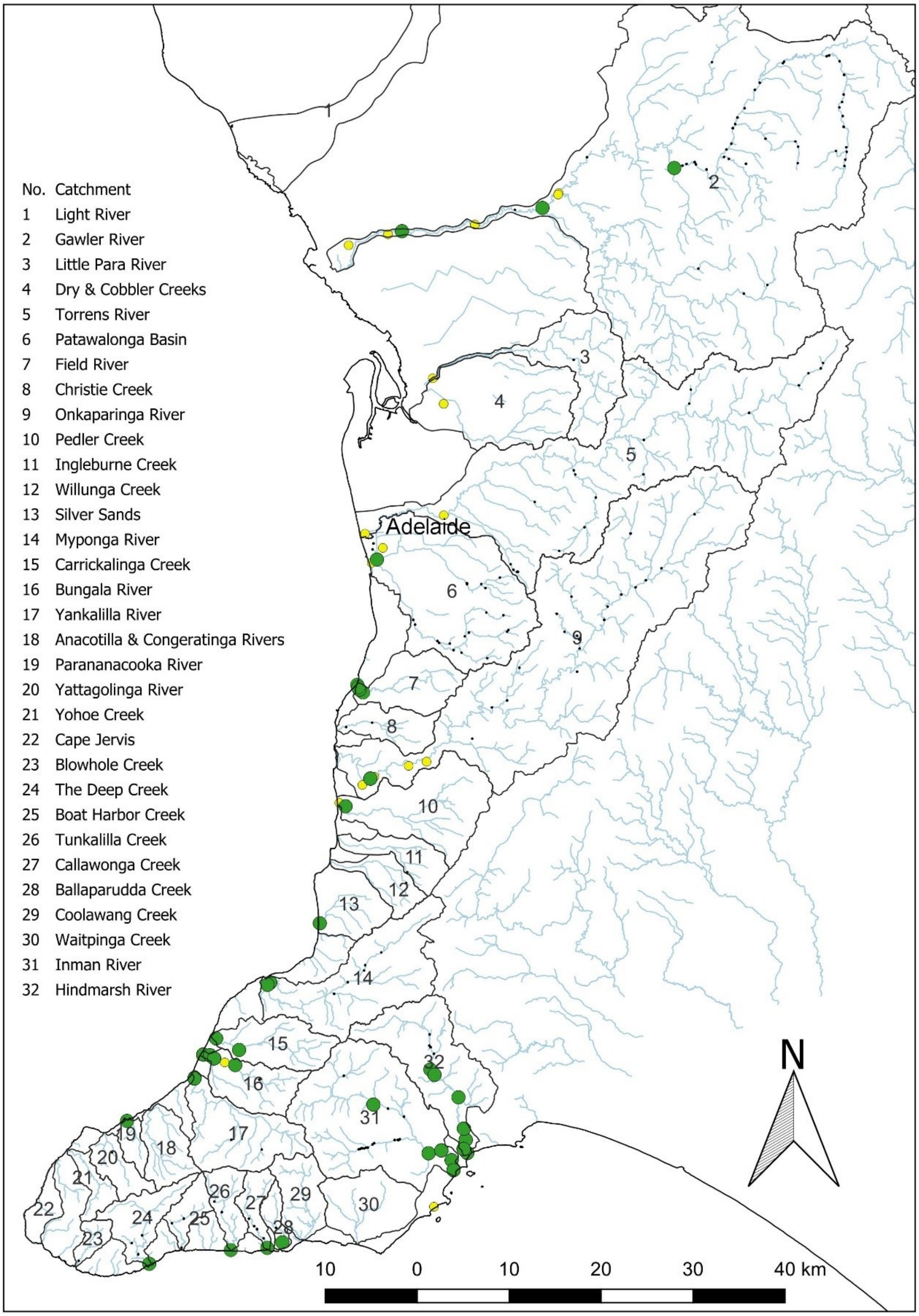

Figure 15. Congolli distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Western bluespot goby (Pseudogobius olorum)

Recent molecular phylogenetic studies demonstrated that western bluespot goby (*Pseudogobius olorum)* is a species complex with western (*P. olorum*) and eastern (*P.* sp.9) lineages divided by the Fleurieu Peninsula with further evidence of hybridisation centring around the Inman, Hindmarsh and Finniss Rivers (Hammer *et al*. 2021). As the morphological taxonomy of these species is yet to be determined, *P. olorum* will be discussed as a single species.

Monitoring from 2007–2021 detected western bluespot goby in lowland reaches and estuarine habitat across the WMLR. The species was recorded in eight of the 12 catchments previously recorded prior to 2007 (Figure 16). It was not captured on the Southern Fleurieu from Inman River to Bungala River, although records prior to 2007 indicate small populations in Waitpinga Creek and Yattagolinga River. The species was absent from 2007–2021 surveys conducted in the Little Para River. On the contrary, western bluespot goby were recorded at sites inland and upstream of barriers in the North Para River. This species has no IUCN Red List conservation rating but was listed as “Rare” under the regional conservation status (Hammer *et al*. 2009, Gillam and Urban 2014).

Western bluespot goby is tolerant to a broad range of salinities but is commonly found in lower salinities of upper estuarine habitats (Gill and Potter 1993). This may explain the higher presence of the species in the slightly saline waters often encountered in the North Para River. Indeed, Morgan *et al.* (2014) reported that bluespot goby will colonise upstream reaches as a result of secondary salinisation and Hallett (2016) reported that bluespot goby abundance increases in response to degradation. McNeil *et al.* (2011b) observed that adult western bluespot goby aggregate to spawn in estuaries in response to freshwater flows. The main threat to this species is reduced freshwater flows leading to hypersaline, hypoxic and eutrophic estuarine conditions that may result in failure to trigger spawning aggregations (McNeil *et al.* 2011b). In addition to protecting freshwater flows, this species would benefit from protection and restoration of estuarine habitats, especially in several urban estuaries where it was absent. Restoration of fish passages using constructed fish-ways and bypass structures have been shown to be effective for improving estuary connectivity to lower catchment reaches for the western bluespot goby and other diadromous species (McNeil *et al*. 2011b, Beatty *et al*. 2014). The constructed fishway in Breakout Creek for example, has restored western bluespot goby to the lower reaches of the Torrens River (McNeil *et al.* 2011b).

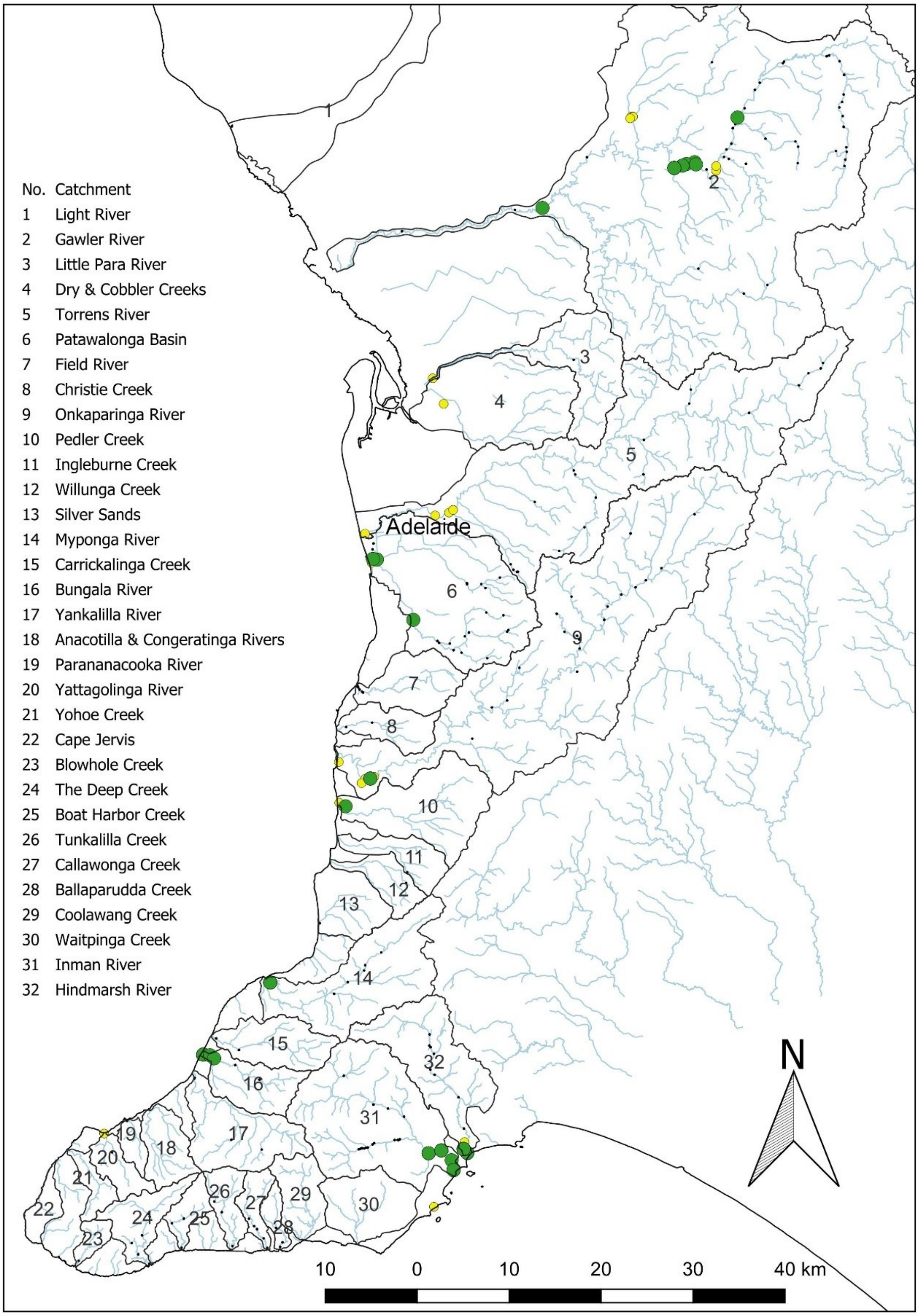

Figure 16. Western bluespot goby distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Freshwater catfish (Tandanus tandanus)

Monitoring from 2007–2021 detected freshwater catfish in two more catchments than recorded prior to 2007 (Patawalonga and Field Rivers, Figure 17). The species was captured at one site in the Patawalonga and three sites in the lower reaches of the Field River where its distribution has not been previously recorded. This species is listed as “Least Concern” on the IUCN Red List (Gilligan & Clunie 2019), and “Endangered” in both the state and regional conservation status (Hammer *et al.* 2009, Gillam and Urban 2014). The state and regional endangered status was due to the decline in the freshwater catfish in the Murray-Darling Basin while IUCN status was determined by the total population across eastern Australia (Gilligan & Clunie 2019).

Freshwater catfish populations in the Torrens, Patawalonga and Field Rivers are most probably translocations from the Murray River population (McNeil and Hammer 2007). The population associated with the Torrens River may have established as a result of historical inter-basin water transfers. Alternatively, individuals from all sites may have been deliberately translocated into these catchments. Indeed, there is a complicated history of translocations in an effort to conserve this species (Clunie and Koehn 2001). The complex phylogenetic and phylogeographic structure observed in this species has implications for future stocking or translocation from the local populations (Jerry 2008, Rourke and Gilligan 2015) as well as broodstock management and captive breeding programs (Hill *et al*. 2015). This may be particularly plausible for the Field River and Patawalonga, as catfish have not been observed in watercourses adjacent to these catchments. Translocated catfish represent a potential threat to native fish from predation and competition for habitat and food resources by (Gillanders *et al*. 2006). Within their natural range, aspects of this species’ biology such as their breeding lifecycle are susceptible to anthropogenic threats including changes in flow regimes and regulation, habitat degradation and predation and competition with invasive species (Ye *et al*. 2015, Koster *et al*. 2015). Despite being non-endemic to the WMLR, this species could still be used as an indicator of aquatic health.

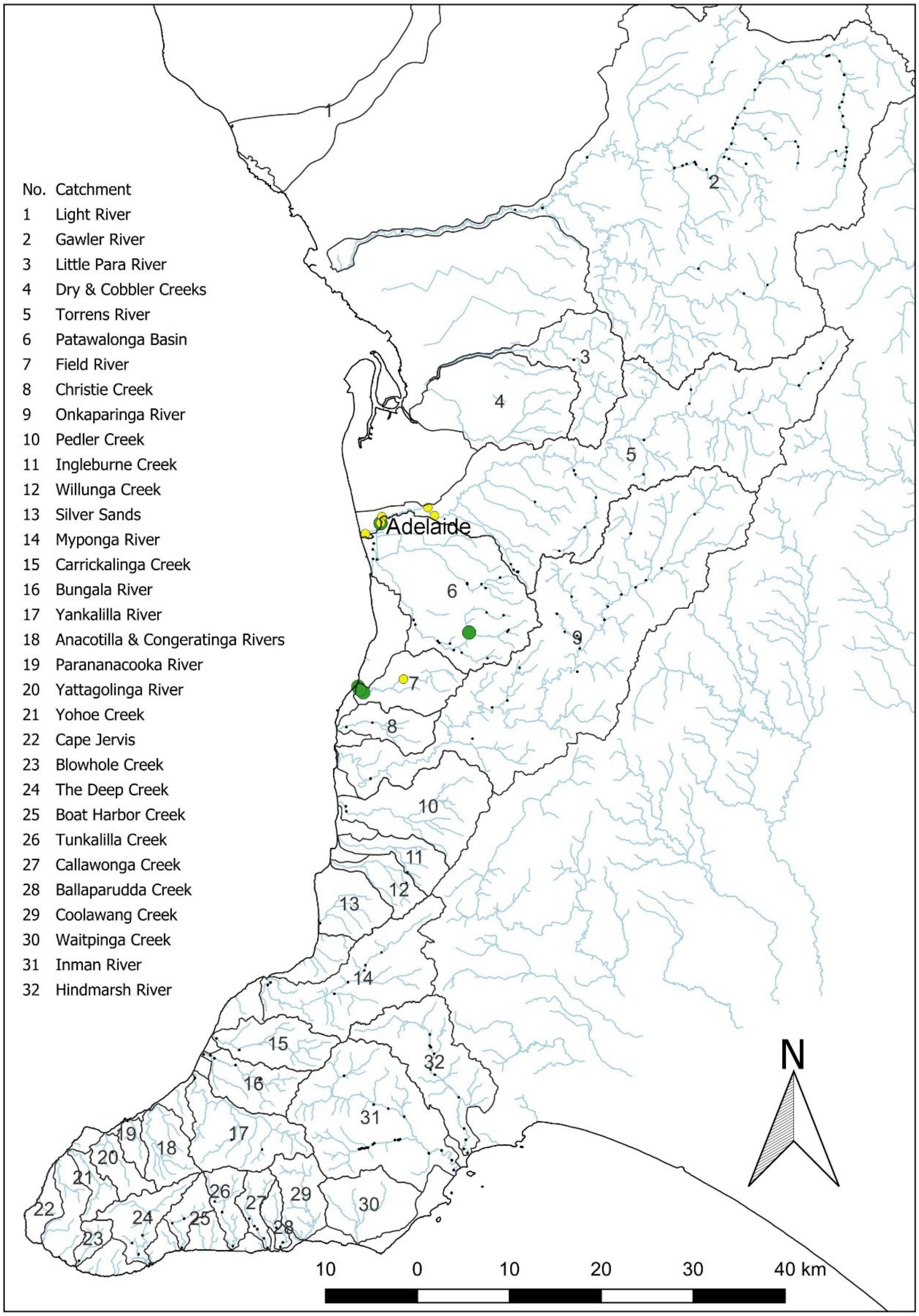

Figure 17. Freshwater catfish distribution in the WMLR. Yellow = 2007 biological review species distribution, green = 2007–2021 species distribution and black = all 2007–2021 sample sites.

4.2. Invasive fish

Goldfish (Carassius auratus)

Monitoring from 2007–2021 detected goldfish in three of the catchments that they had been reported in prior to 2007 (Gawler, Torrens and Patawalonga) but not in the Little Para and Onkaparinga although catch data from concurrent research programs showed that they were detected in the Onkaparinga during this time (Figure 18) (McNeil *et al*. 2011b). A small number were also detected in Christies Creek and Pedler Creek catchments.

Goldfish had a similar distribution to common carp *(C. carpio)* (i.e. present in lowland urban areas and mainly absent in upstream reaches and southern Fleurieu streams) but were absent from the Inman River. In reviewing the work of others, Conallin *et al*. (2012) found that while goldfish are considered to be a relatively 'benign' introduced species, high abundance coupled with biological characteristics such as high fecundity, rapid growth, early maturity, broad diet and tolerance of poor water quality suggests that, like carp, they could have detrimental effects on aquatic ecosystem health. Indeed, Beatty *et al*. (2017) state that goldfish is now considered one of the world's worst invasive species. Rowe (2007) and Schallenberg and Sorell (2009) reported that goldfish, amongst other invasive species, were associated with a regime shift that included devegetation and increased turbidity. The vigorous feeding behaviour resuspends nutrients making them available to algae, whilst passage through the intestines of goldfish has been suggested to increase the growth of ingested cyanobacteria (Morgan and Beatty 2007). Thus, the increase in goldfish biomass could become a major factor contributing to algal blooms, particularly within nutrient rich environments. In reviewing the work of others, Morgan and Beatty (2007) report that goldfish can prey on the eggs, larvae and adults of native fishes, compete with them for food and habitat, and have been shown to cause turbidity and deplete aquatic vegetation.

Potential for ongoing release of this species from domestic aquaria makes it a likely species to appear regularly in new reaches and catchments despite best management practice for environmental issues. Goldfish is a declared exotic species under the South Australian Fisheries Management Act (2007). Under the Act, it may not be deposited, released or allowed to escape into any waters in South Australia without specific authorisation. Given their similar biological attributes, management actions that aim to disadvantage carp are likely to also disadvantage goldfish. Goldfish can be relatively sedentary with a high degree of residency, but can also be reasonably mobile, travelling hundreds of kilometres each year and also undertake seasonal spawning migration into lentic habitats (Beatty *et al.* 2017). This attribute could potentially be exploited for control purposes, similar to techniques used to trap migrating carp.

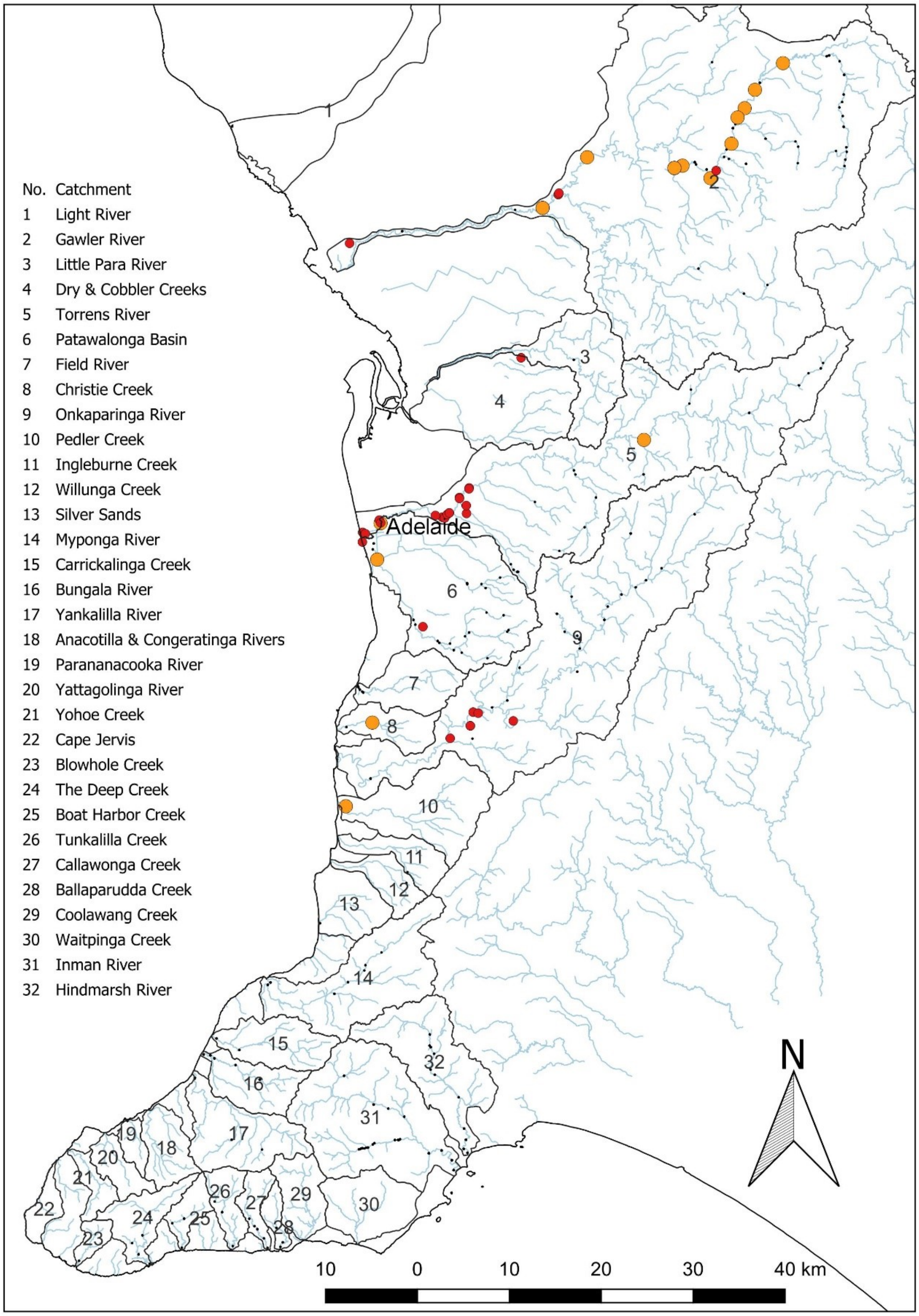

Figure 18. Goldfish distribution in the WMLR. Red = 2007 biological review species distribution, orange = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Common or European carp (Cyprinus carpio)

Monitoring from 2007–2021 detected European carp in three of the catchments that they had been reported in prior to 2007 (Gawler, Torrens and Patawalonga) but not in the Little Para and Onkaparinga, although catch data from concurrent research programs showed that they were detected in the Onkaparinga during this time (McNeil *et al*. 2011b). In addition, the patchy distribution of carp has increased in WMLR having new records in the Field River, Pedler Creek and Inman River catchments. Of note, carp appear to have spread throughout the main channel of the Inman River in the last 15 years posing potential threats to native taxa and habitat quality for tributaries in the Inman catchment. The single large individual recorded in the Field River catchment in May 2021 suggests it may have been recently translocated as survey data from long-term monitoring in the catchment has not previously detected carp.

Carp have an intermediate life history strategy (opportunistic/periodic), high fecundity (100,000 eggs kg^{-1}; up to 1 million eggs y^{-1}), longevity (28+ years), ability to occupy a broad range of habitats and tolerance to extreme environmental conditions (Winemiller and Rose 1992; Brown *et al*. 2003; Koehn 2004; Smith 2005). Carp are "ecosystem engineers" and when in high abundance, cause detrimental changes to benthic habitats, water quality and the distribution and abundance of native flora and fauna (Gehrke and Harris 1994; Miller and Crowl 2006; Matsuzaki *et al.* 2009). These impacts stem largely from carp's bottom-feeding behaviour and are most commonly reported in shallow off-stream wetland habitats (Parkos *et al.* 2003; Sibbing *et al.* 1986). Carp are declared noxious under the South Australian Fisheries Management Act (2007). Noxious species are regarded as a severe threat to the natural environment and industries. Under the Act, they cannot be held or traded in South Australia without specific authorisation and must not be returned to the water if caught.

The population of carp in the Torrens River has remained persistent throughout the 2007–2021 period (McNeil *et al*. 2011a, Thwaites and Schmarr 2019). Carp have been also recorded in urban wetlands (2007–2021) in the Patawalonga and Pedler Creek catchments (Figure 19), where water levels and dense emergent vegetation remain stable. Whilst carp populations within invaded catchments are persistent, their abundance never reaches that of the Murray River. In contrast to the Murray River, the WMLR is characterised by streams with fewer barriers to fish passage, limited low head weirs and associated weir pools, and a high level of within channel diversity (i.e. pools, runs, riffles). Most streams contain abundant physical habitat (i.e. snags, diverse vegetation, rock outcrops), limited off-channel carp breeding sites (i.e. wetlands, marshes; Koehn and Nichol 1998) and relatively natural hydrology. The limited spawning/nursery sites coupled with the overall condition of the catchments may be disadvantaging carp and limiting recruitment within the WMLR. Indeed, sites with increased carp numbers are correlated with the increasing levels of environmental disturbance (Gehrke 1997). Management of aquatic ecosystems should aim to promote and maintain flow and habitat that not only disadvantages carp but are advantageous for native species.

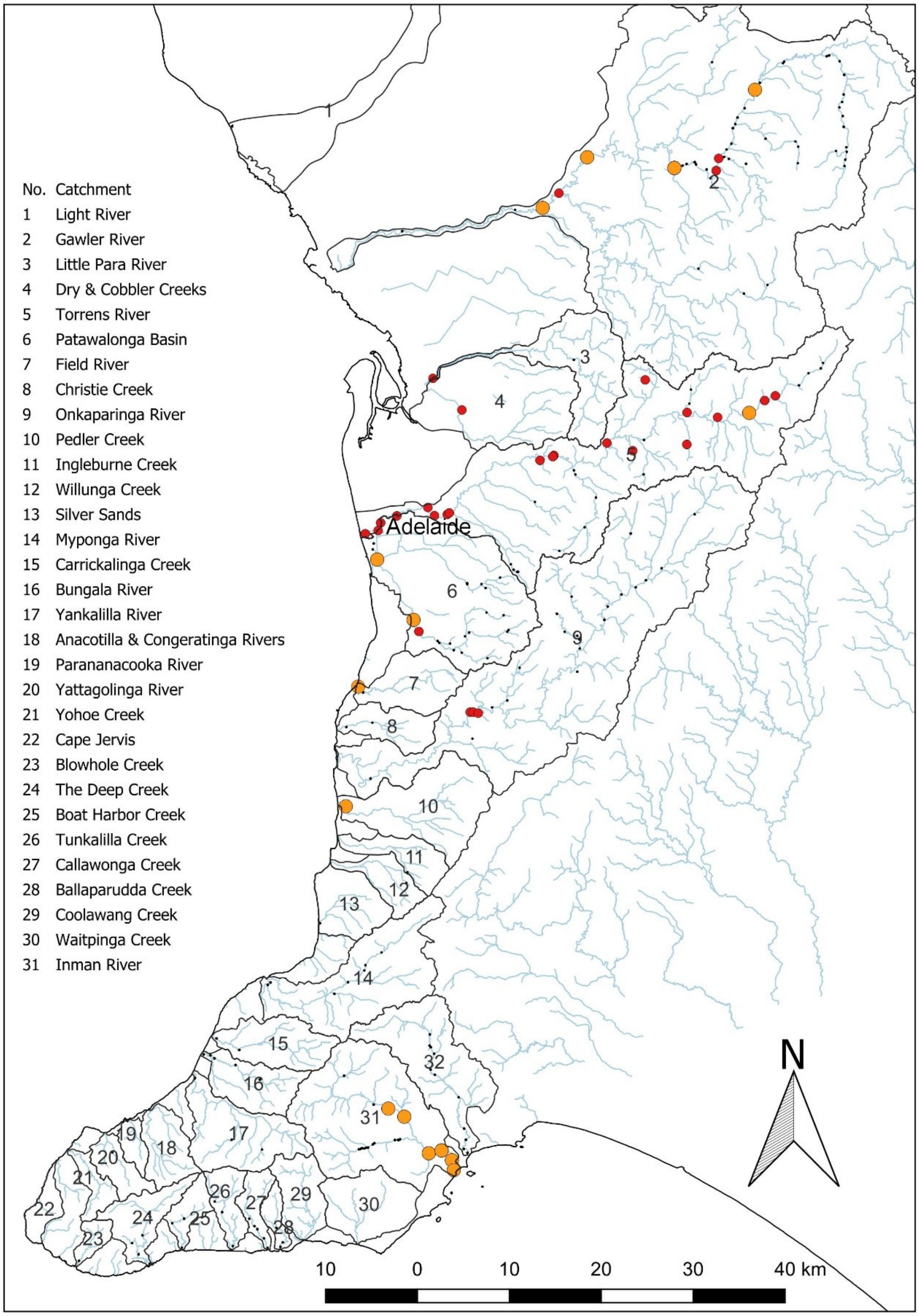

Figure 19. Common carp distribution in the WMLR. Red = 2007 biological review species distribution, orange = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Gambusia (Gambusia holbrooki)

Gambusia are widely distributed in the WMLR. Monitoring from 2007–2021 detected gambusia in all of the catchments that they had been reported prior to 2007 (Figure 20). The extent of gambusia from surveys conducted over the past 15 years indicate their range has expanded with five new records in the Bungala, Myponga, Pedler, Christies and Hindmarsh catchments. Increased survey effort in the North Para River revealed that Gambusia were widespread in this catchment (Figure 20).

Gambusia is a well-established pest species. They are declared noxious under the South Australian Fisheries Management Act (2007). It is recognised as an aggressive competitor with sympatric native taxa and commonly dominates shallow, low flow or still-water habitats found in wetlands, lakes and slow flowing streams (Lintermans 2007, Pyke 2008, Rowe *et al*. 2008). Larval predation, juvenile fin-nipping, interspecific aggression and resource competition all contribute to reduced densities or altered distribution of native species (Ivantsoff and Aarn 1999, Rowe *et al.* 2008). While the species is reasonably adaptive, existing across a range of habitats and conditions in the WMLR, it can be limited by extreme flow variability and river ephemerality (McNeil 2004, Pyke 2008). Native species with flexible, generalist life-history strategies (e.g. carp gudgeon , flathead gudgeon) may co-exist with gambusia in resource-limited, environmentally harsh habitats but some specialist species (e.g. southern pygmy perch, Murray rainbowfish) are likely to be fragmented and decline in abundance (McDonald *et al.* 2012). While pest management strategies to control and eradicate gambusia remain difficult, promoting watercourse conditions that favour evolutionary adaptations for native fish species (e.g. galaxiids, gudgeons and pygmy perch) may present one way to limit gambusia distribution and impact on native species (Ho *et al.* 2013, Coleman *et al.* 2016).

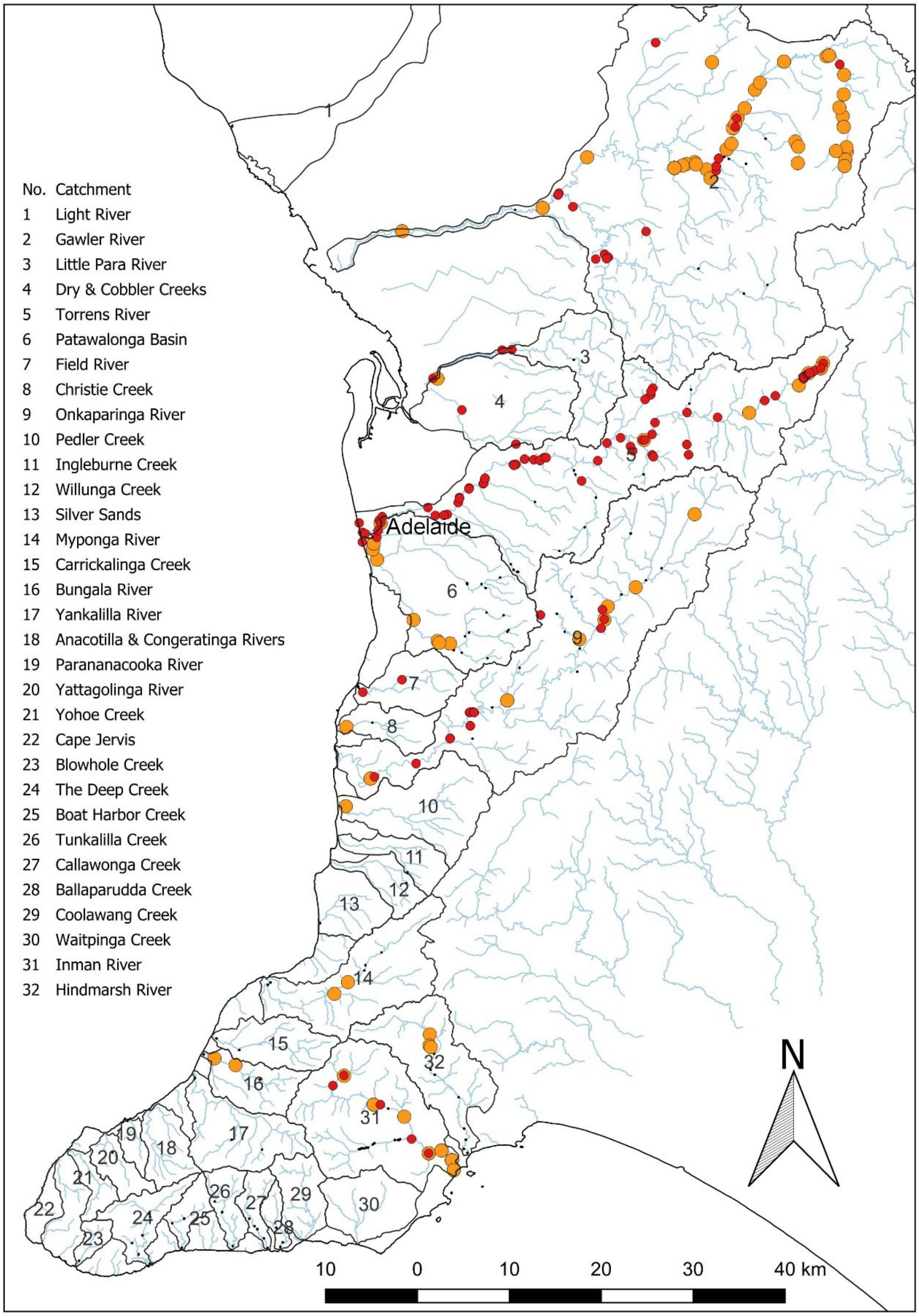

Figure 20. Gambusia distribution in the WMLR. Red = 2007 biological review species distribution, orange = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Redfin perch (Perca fluviatilis)

Redfin perch (*Perca fluviatilis*) were a common component of fish assemblages across the WMLR. Monitoring from 2007–2021 detected redfin perch in all the catchments (*n* = 7) that they had been reported prior to 2007 (Figure 21). Although redfin perch were found at some sites in the major catchments of the Southern Fleurieu prior to 2007 (e.g. Hindmarsh, Inman), occurrences for the species appear low. Records 2007–2021 show their distribution now includes the Bungala catchment on the Southern Fleurieu. While the overall range does not appear to have expanded since 2007, distribution within that range has expanded. Specifically, it appears the species has expanded to the upper reaches of the North Para River where they are particularly dominant compared to native taxa. Expansion in distribution is also at many sites that were previously surveyed in years prior to 2007. This was particularly evident in the Inman, Myponga and South Para Rivers where their occurrence is extensive.

Redfin perch are declared noxious under the South Australian Fisheries Management Act (2007). The species is a significant predator and threat to native fish populations (McDowall 1996, Rowe *et al*. 2008). In the WMLR, redfin perch populations vary in their age structure, but typically comprise a small number of large individuals or populations dominated by a cohort of juveniles outnumbering large adult fish (SARDI unpublished data). They predate upon a wide range of taxa, can be cannibalistic, but primarily compete for prey with other native piscivorous species (Wedderburn *et al.* 2014). The feeding behaviour and life history strategy of red fin perch supports early onset predatory behaviour compared to the age dependent predatory structure observed in other native taxa (Wedderburn and Barnes 2016). Young cohorts also appear to exclude native species at an early age (e.g. galaxiids), resulting in lower native species diversity and range particularly in larger permanent water sinks such as refuge pools. Poor water quality and watercourse drying are known to limit the distribution and potential impact of redfin perch (Wilson *et al.* 2008), however, even in drought conditions, the species is tolerant and resilient to a wide range of salinities (and temperatures) as has been observed in Murray River channel habitats (Wedderburn *et al.* 2012). Consideration of flow regime, timing and location as well as maintaining or improving instream habitat should be considered to limit further distribution and competition with native fish species in WMLR.

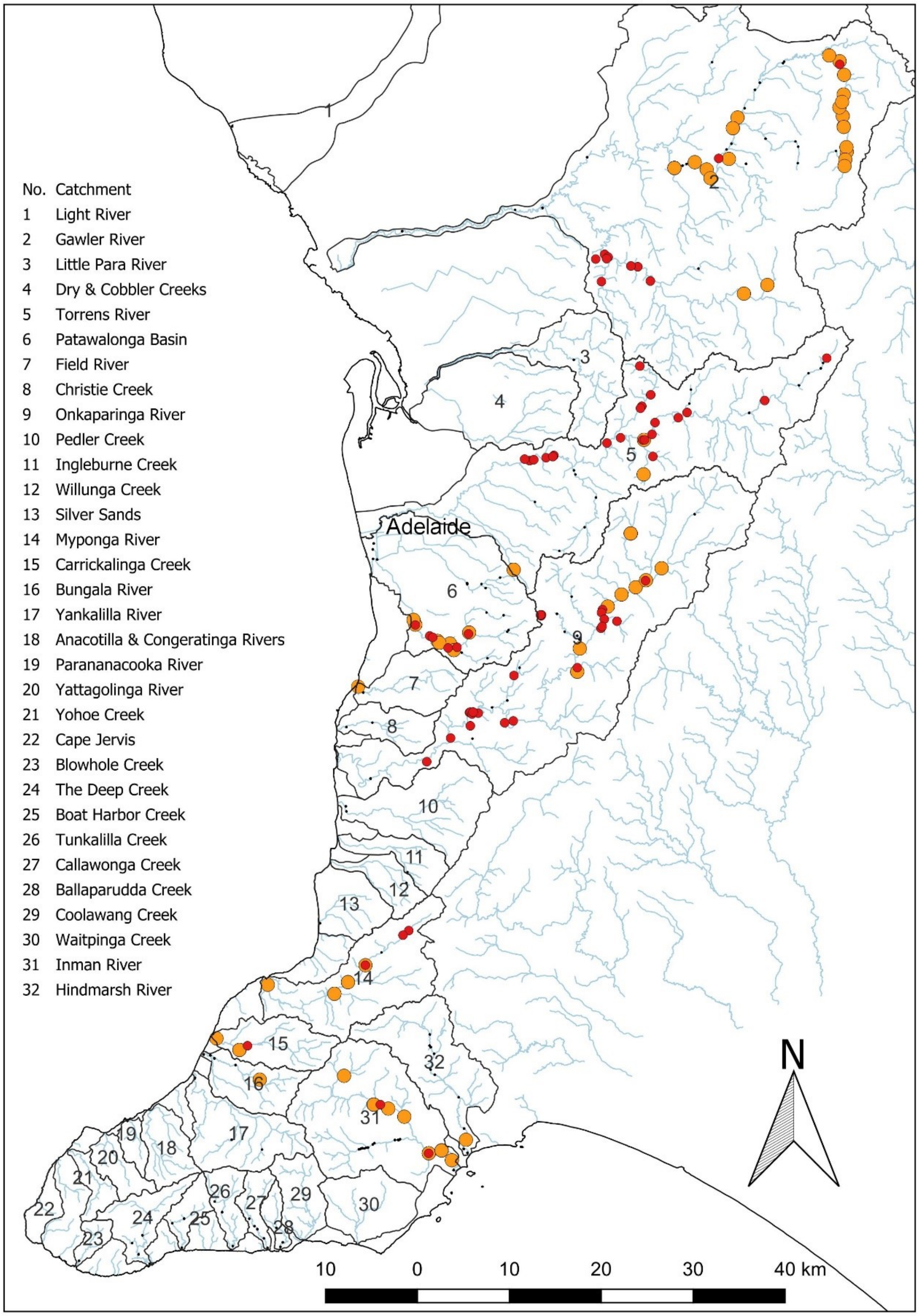

Figure 21. Redfin perch distribution in the WMLR. Red = 2007 biological review species distribution, orange = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Speckled livebearer (Phalloceros caudimaculatus)

Speckled livebearer are declared noxious under the South Australian Fisheries Management Act (2007). The population in Willunga Creek represents a new invasive species in the WMLR region. In 2008, a large isolated population of speckled livebearer was discovered in Willunga Creek, SA (McNeil and Wilson 2008). After preliminary trials to determine the most effective eradication strategies during 2009, this isolated population was treated using rotenone in winter 2010. Treatment occurred along a 3–4 km reach and post treatment netting surveys throughout did not detect any remaining livebearers or other fish. However, subsequent surveys during spring 2010 discovered small pockets of livebearer and a second treatment of rotenone was applied. Follow-up monitoring during autumn 2011 did not capture any livebearer and, as part of a broader restoration goal, mountain galaxias from a neighbouring stream were released into the reach during spring 2011. Follow-up monitoring during spring 2012 provided further confirmation of the success of the eradication program and also the first confirmation of the success of the restoration program with the capture of several mountain galaxias. However, in 2017 speckled livebearer were captured again at one of two sites sampled in Willunga Creek (Figure 22)(Schmarr *et al.* 2018).

Little is known about the potential impact of speckled livebearer on native fish species in Australia. However, it has been reported that they can displace gambusia (Maddern 2008) and it has been speculated that they may impact species through aggressive behaviour, competition for resources and transmission of disease (Biosecurity SA). It is recommended that control efforts are recommenced in an attempt to eradicate the species and to prevent further range expansion into adjacent catchments. Concurrent research should be conducted into the impacts that this species poses to native species.

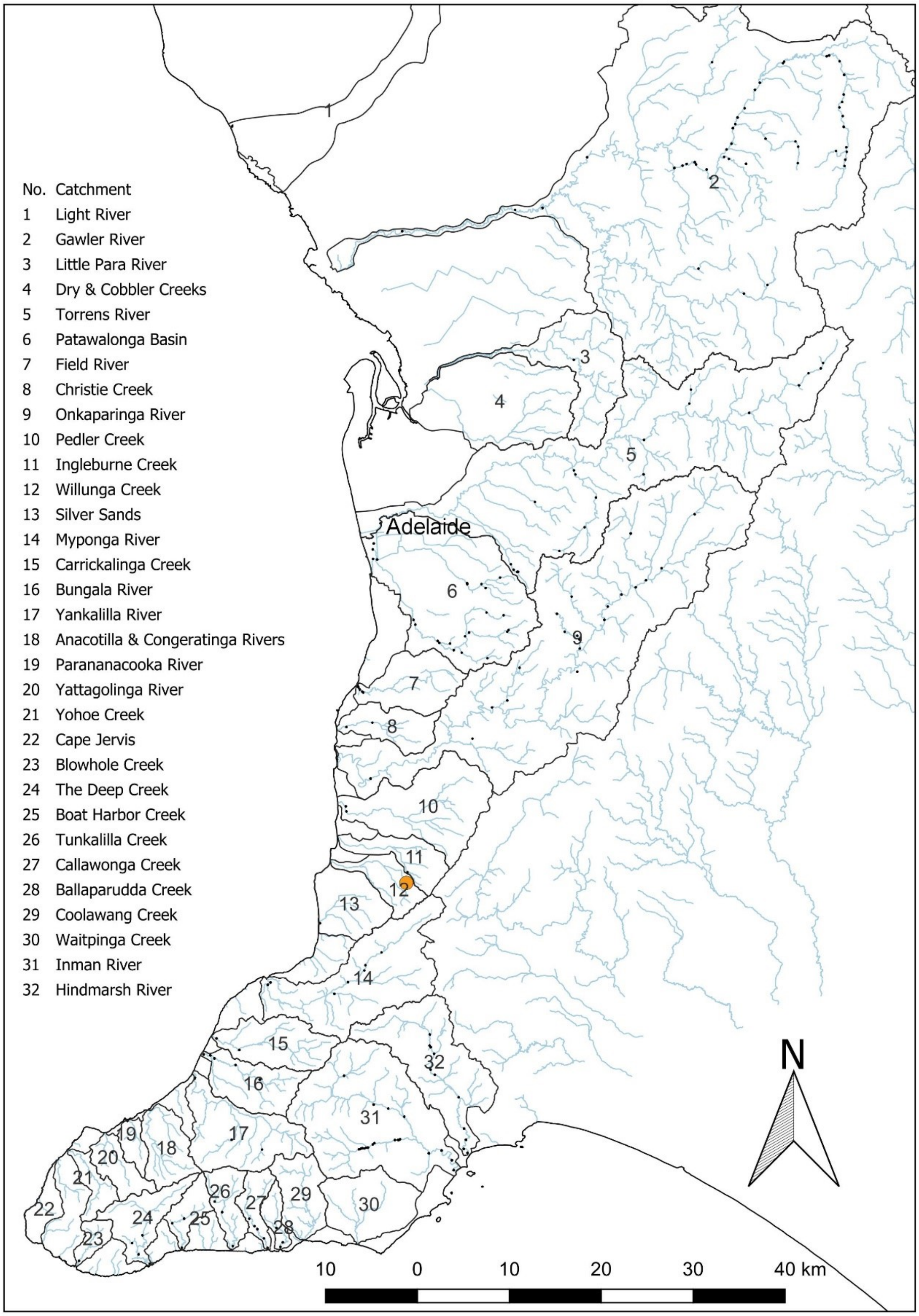

Figure 22. Speckled livebearer distribution in the WMLR. Red = 2007 biological review species distribution, orange = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Brown trout (Salmo trutta) and rainbow trout (Oncorhynchus mykiss)

Monitoring from 2007–2021 detected rainbow trout in two (Torrens and Patawalonga) out of the four catchments (Torrens, Patawalonga, Yankalilla and Inman) where they had been detected prior to 2007 (Figure 23). Rainbow trout were not detected in the Inman and Yankalilla catchments where they had been reported prior to 2007. They were additionally detected in the Field and Hindmarsh catchments for the first time from 2007–2021.

Brown trout were detected in seven (Torrens, Patawalonga, Onkaparinga, Hindmarsh, Yankalilla, Callawonga and Deep Creek) out of the eight catchments that they had been reported prior to 2007 (Figure 24). The Inman was the only catchment where they were not detected after 2007. They were detected in the Deep Creek Conservation Park at Boat Harbour Creek for the first time from 2007–2021. Both species were present predominantly in upland reaches characterised by cool permanently flowing water.

The impacts of invasive trout primarily relate to predation and competition for habitat and food resources (Closs and Lake 1996, Fulton 2004, McDowall 2006, Shelton *et al.* 2015, Jones and Closs 2017). Their aggressive feeding behaviour is known to impact the distribution and abundance of native invertebrate and fish species (McDowall 2006) leading to the establishment of source-sink metapopulations (Woodford and McIntosh 2010) with increasing isolation (Woodford and McIntosh 2013). Impacts are greater for smaller size classes (McIntosh *et al.* 2010, Shelton *et al.* 2015), non-migratory species (Jones and Closs 2017) and in the absence of instream shelter such as complex cobble structure (Sowersby *et al.* 2016). The combined impacts can result in native fish populations up to 97% lower in invaded streams than in streams where trout are absent (Shelton *et al.* 2015).

Routine gut content analyses across a range of SARDI studies (2007–2021) indicate trout diets comprise high numbers of native shrimp, fish (native and non-native) and the common yabby (*Cherax destructor*). Trout were frequently captured in pools where native species were either absent or limited in number supporting the notion that predation on native galaxiids as primary food sources can limit the distribution of native taxa in the presence of trout. The Callawonga catchment is the only known current location where trout appear to have developed a persistent population with different age cohorts suggesting successful natural recruitment is occurring (McDowall 2006, Schmarr and Thwaites 2019). Intentional legal and illegal stocking of trout, and translocation of this recreational species is a threat to native fishes throughout the WMLR. A recent review of the impact of trout on native fish species in the WMLR (2020) has led to changes in stocking of trout in streams and rivers on the Southern Fleurieu Peninsula. It is now currently illegal for the release of trout in all but the Hindmarsh River (which has recently ceased to assess the impact of trout on native species). Repeat surveys in trout populated streams will determine where self-sustaining populations have established and to determine the long-term impacts on native fish and invertebrate populations.

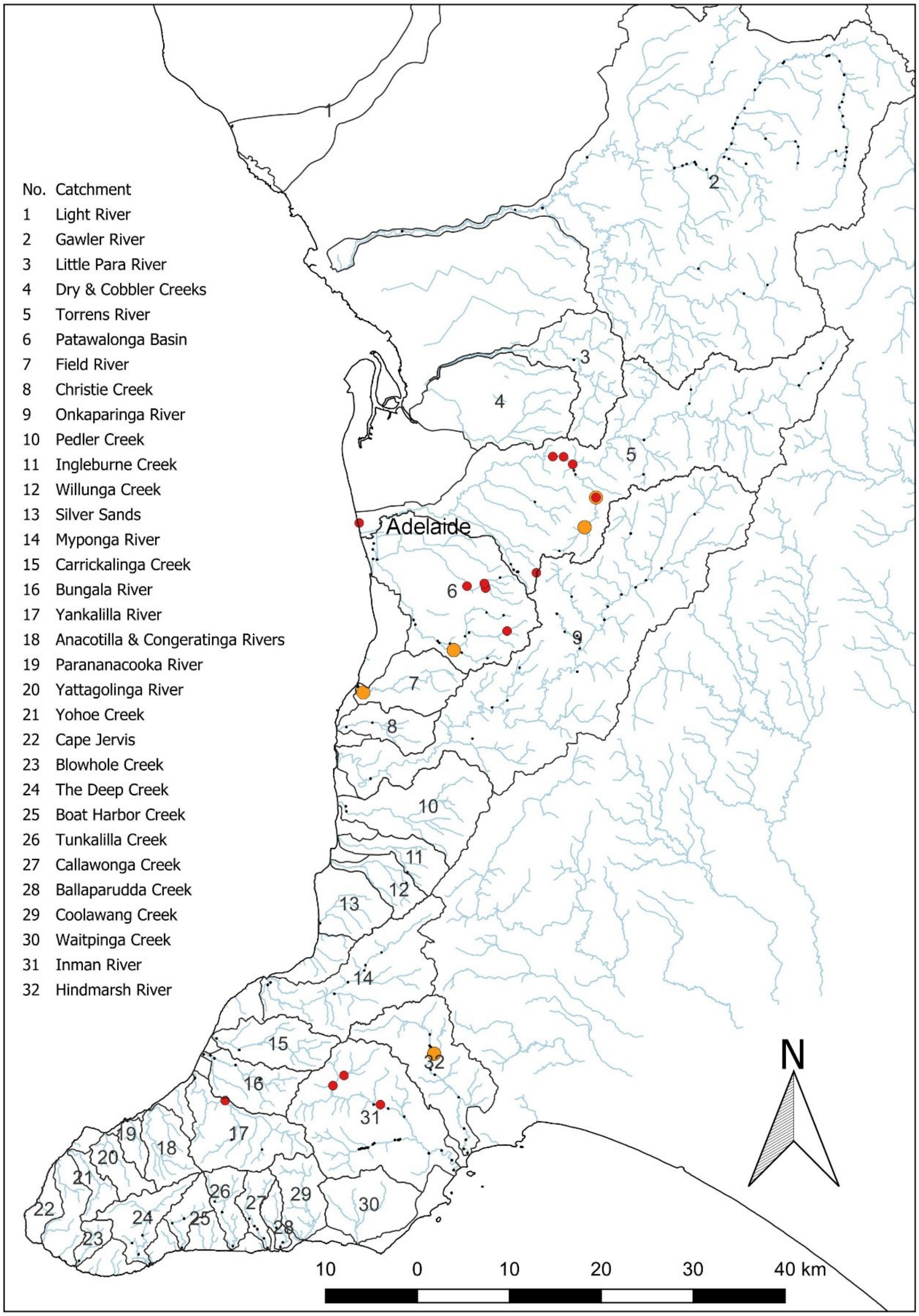

Figure 23. Rainbow trout distribution in the WMLR. Red = 2007 biological review species distribution, orange = 2007–2021 species distribution and black = all 2007–2021 sample sites.

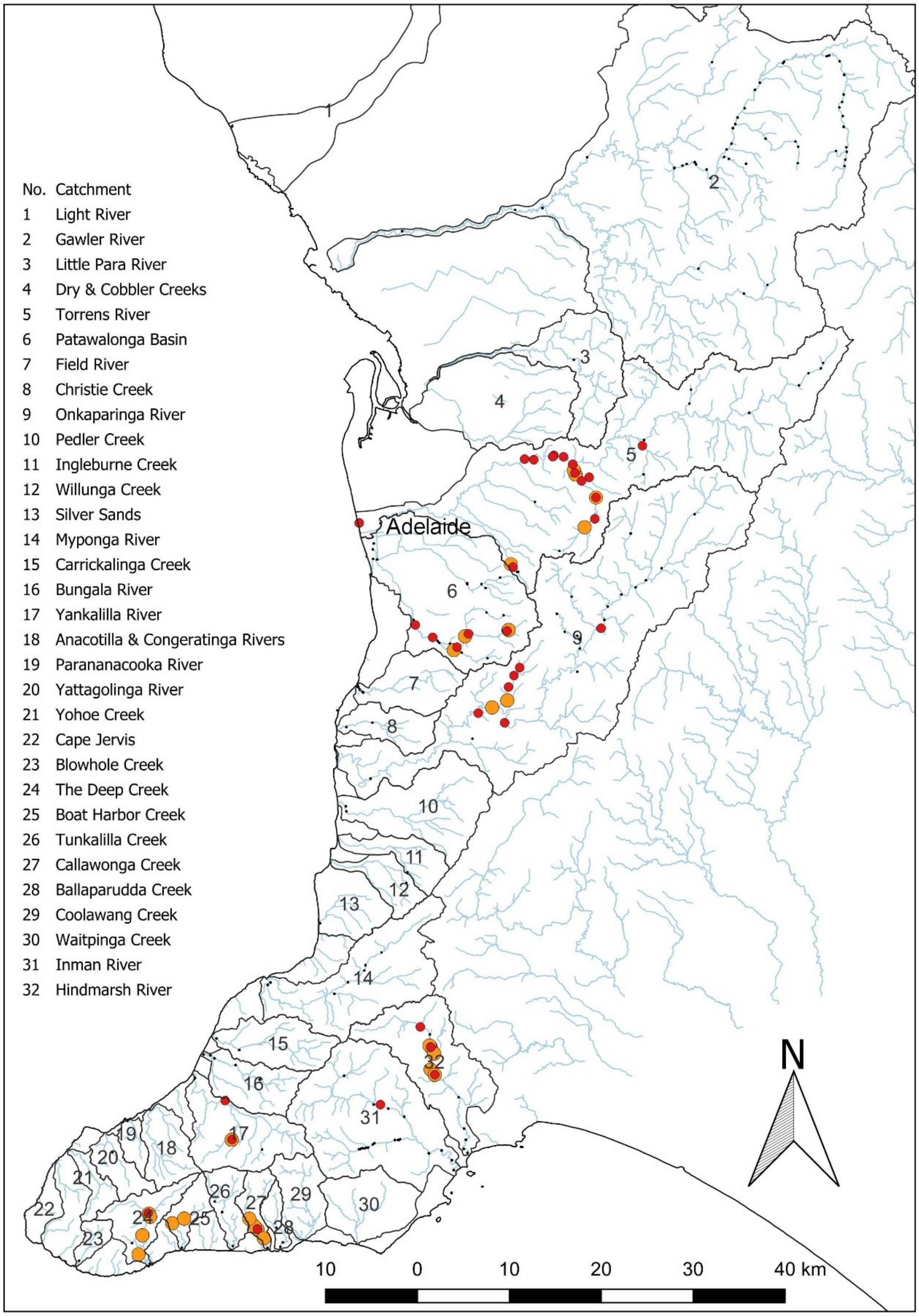

Figure 24. Brown trout distribution in the WMLR. Red = 2007 biological review species distribution, orange = 2007–2021 species distribution and black = all 2007–2021 sample sites.

Tench (Tinca tinca)

Tench have a limited distribution in the WMLR. Monitoring from 2007–2021 detected tench in two catchments, the North Para where they were also detected prior to 2007 and the Patawalonga where they were detected for the first time (Figure 25). They were not detected in the Onkaparinga where they had been reported prior to 2007, however catch data from concurrent research programs showed that they were detected in the Onkaparinga during this time (McNeil *et al*. 2011). Extensive monitoring from 2007–2021 indicate that tench are established and distributed across a larger number of sites in the North Para River compared to other catchments of the WMLR though abundances appear to be small.

Tench are declared noxious under the South Australian Fisheries Management Act (2007). The species is reported to have broad environmental tolerances with preference for shallow, low flow velocity, benthic habitat with muddy substrate, and avoid areas of high flow and fluctuating water levels (Cudmore and Mandrak 2011). Tench are an adaptable species successfully occurring in a range of water qualities and environmental conditions (Avlijaš *et al.* 2022). The impact of tench populations in Australian waters is not well documented. However, in reviewing the work of others, Rowe *et al*. (2008) report that tench interactions with other species are relatively minor but may have density dependent effects on macrophytes and water quality, leading to impacts on habitat for other species. In reviewing other research, Avlijaš *et al.* (2022) reported tench impacts of high predation pressure on invertebrate prey and reduced abundances of native fishes through resource competition. Although tench were previously thought to be somewhat sedentary, they have been found to be capable of large-scale migrations up to 250 km (Morissette *et al.* 2021). Similar to carp, tench are known to increase turbidity and eutrophication as a result of their bottom-feeding behaviour (Avlijaš *et al.* 2018).

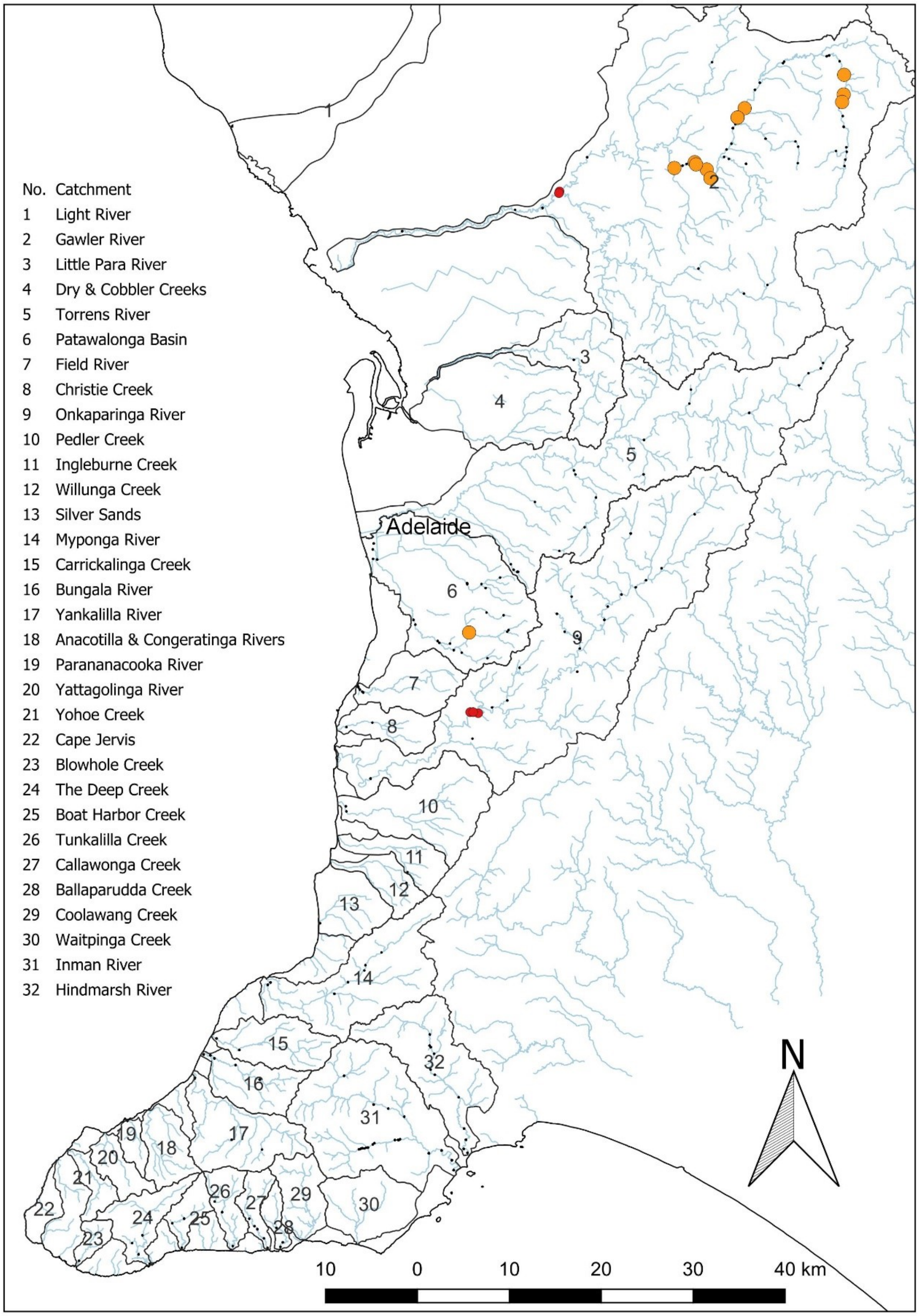

Figure 25. Tench distribution in the WMLR. Red = 2007 biological review species distribution, orange = 2007–2021 species distribution and black = all 2007–2021 sample sites.

4.3. Section summary

The sampling strategies and methodology implemented to assess fish biodiversity and population health in the WMLR has dramatically improved since 2007. Extensive investment in temporal and spatial fish monitoring and improvements in survey design and efficacy has expanded the knowledge of species distributions, community structure and population condition including documented pressures that are critical to understand aquatic ecosystem function and change. This biological review provides a unique and most current repository of biological information for freshwater fishes of the WMLR.

Monitoring was conducted at 237 sites over 467 sampling events (spring/autumn seasons) in 24 catchments (Figure 3 & Figure 4). A total of 212 sites contained fish while no fish were detected in the remaining 25 sites. Ten of these 25 sites contained fish prior to 2007. There has been no loss of native freshwater fish species across the WMLR region since 2007. The monitoring program recorded 12 native species (11 repeated from the 2007 report and one new species), four of the five previously known translocated species, and eight invasive species including seven repeated from 2007 and one new species (Figure 4). The new native species was bony herring (*Nematalosa erebi*) which was detected for the first time in the WMLR in the Inman River (Figure 12). The new invasive species was speckled livebearer (*Phalloceros caudimaculatus*) which were detected in upper Willunga Creek (Figure 22). Short-headed lamprey (*Mordacia mordax*) and southern purple-spotted gudgeon (*Mogurnda adspersa*) were not detected post 2007. Shortheaded lamprey were rare prior to 2007 and impacts from flow regulating structures and altered flow regimes may have further reduced the likelihood of capturing this species (Bice *et al.* 2019). Southern purple-spotted gudgeon were believed to be extinct in the WMLR long before 2007 (McNeil and Hammer 2007).

The conservation status of native freshwater fish is commonly categorised at four different scales (international, national, state and regional) based on criteria assessed at different spatial extents. The international standard for classifying species is the International Union for Conservation Nature (IUCN), the Australian National standard is the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), the State standards are the National Parks and Wildlife Act 1972 (NPW Act) and Fisheries Management Act 2007, with regional assessments based on data developed through SA regional species projects and also the biogeographic regionalisation for Australia commonly referred to as Australia's bioregions (IBRA).

There were some changes in the state and regional conservation status of endemic fish species since 2007. Based on the criteria for South Australia, mountain galaxias and congolli were reclassified from rare to vulnerable. The state conservation status of climbing galaxias were reclassified from vulnerable to rare, but they are classified as vulnerable at the regional level. Despite not being captured in the WMLR for several decades, the conservation status of the southern purple-spotted gudgeon was reclassified from endangered to critically endangered. Murray rainbowfish were previously listed as rare at a state level but removed from conservation listings. The conservation status of all other fish species reported as part of this biological review have remained unchanged at the state level. Since 2007, international and regional conservation assessments have been implemented to highlight the risk of species extinction and provide potential guidance for future conservation management actions. However, differences in the spatial scales highlights disparities between ratings (e.g. downscaled or upscaled depending on spatial extent) which need to be taken into consideration. This was notably apparent in this study especially between international ratings and assessments established at regional scales. For instance, some species are listed as least concern internationally but are vulnerable (climbing galaxias, congolli and mountain galaxias), critically endangered (southern purple-spotted gudgeon) or extinct (shortheaded lamprey) at a regional level. While the listing of a species conservation status at the international level is important to identify broadscale environmental degradation, it is critical that regional conservation assessments using updated species distribution and abundance data are conducted at regular intervals to ensure currency of conservation effort and management interventions are prioritised through contemporary development of regional and local level strategic plans and their objectives.

5. REGIONAL CONDITION ASSESSMENT

The BCG model successfully quantified the biological condition of sites surveyed between 2007 and 2021 with results verified and consistent with observations from qualitative field surveys. A total of 237 sites across the WMLR were scored on 467 occasions (incorporating seasonal and repeat survey replicates) using the BCG model (Figure 27). This is the first time fish health scores have been spatially and temporally consolidated at both broad landscape, catchment and finer scales for most of the WMLRs rivers, streams and creeks. The scores indicate that ecosystem health is highly variable. Scores range from 1.2 (good) to 5.6 (poor) with notable intra and inter-stream variation and a broad spatial gradient in condition particularly evident in the north – south longitudinal direction (northern WMLR to Southern WMLR). (Appendix 2).

Good BCG scores (1–2.7) were generally associated with the presence of all expected native species in high abundance with broad size distribution (except for tolerant species), the absence of invasive species, and good connectivity and land use. For example, Deep Creek Estuary recorded a score of 1.6 due to the presence of all expected species in good abundance including climbing galaxias, congolli (BCG Attribute 2 score = 2), and common galaxias (Attribute 3 = 1.5). All native species were well represented in size structures (Attribute 7 = 2), no tolerant or invasive species were recorded (Attribute 5 = NA, Attribute 6 = 1), there were good land use scores across all scales (Attribute 9: 100 m = 1, 400 m = 1, catchment = 1) and good connectivity (Attribute 10 = 2) (Appendix 2). Poor BCG scores (4.3–6) were generally associated with absence of expected native species, a low abundance and limited size distribution of native species, a high abundance of tolerant native species, the presence of predatory and/or non-predatory invasive species, poor connectivity and poor land use practices. For example, Old Moculta Bridge (North Para River, Gawler catchment) scored 5.2 overall due to the absence of bluespot goby, congolli and common galaxias (Attribute 2 = 6, Attribute 3 = 6), a high abundance of tolerant flathead gudgeon (Attribute 5 = 6), with a broad size distribution (Attribute 7 = 2), and high abundance of predatory redfin perch (Attribute 6 = 6). Land use scores were poor at all spatial scales (Attribute 9: 100 m = 6, 400 m = 6, catchment = 5) and connectivity was also poor (Attribute 10 = 5) (Appendix 2). Intermediate BCG scores (2.7–4.3) were a mixture of good and poor scores across attribute groups. For example, Field River scored well for native fish attributes (2–2.5) relatively good for invasive species and connectivity but poorly for size distribution and land use (Appendix 2).

The BCG model was also sensitive to changes in fish community. For example, Hindmarsh Falls recorded an invasion and a subsequent increase in the abundance of brown trout which corresponded with a decrease in the abundance of climbing galaxias and a decrease and then apparent extirpation of mountain galaxias. This led to a downgrade in scores from 1.7 in 2011 to 3.9 in 2019. Over this period, scores for land use and connectivity remained unchanged (Appendix 2).

There were notable differences when BCG scores were apportioned by the WMLR regional landscape administration boundaries (Northern and Yorke, Green Adelaide, and Hills and Fleurieu landscape regions). “Good” BCG scores (ranging from 1–2.7) were recorded at 29.2% of sites in the Hills and Fleurieu region, followed by 13.9% of sites in Green Adelaide and 3% of sites in Northern and Yorke (Table 4). Intermediate BCG scores (2.7–4.3) were recorded at 56.3%, 58.3% and 32% of sites in Hills and Fleurieu, Green Adelaide and Northern and Yorke, respectively (Table 4). Poor scores (4.3–6) were recorded at 14.6%, 27.8% and 65% of sites in Hills and Fleurieu, Green Adelaide and Northern and Yorke, respectively (Table 4). All landscape regions comprised a high percentage of sites with intermediate BCG scores which resulted in overall intermediate mean BCG scores of 3.3 for Hills and Fleurieu, 3.7 for Green Adelaide and 4.3 for Northern and York (Figure 26).

Table 4. Percentage of sites across WMLR landscape regions recording good, intermediate and poor scores.

	% Good	% Intermediate	% Poor
Hills and Fleurieu (*n*=295)	29.2	56.3	14.6
Green Adelaide (*n*=72)	13.9	58.3	27.8
Northern and Yorke (*n*=100)	3	32	65

There were significant differences in aquatic health across landscape regions resulting in a condition gradient of good to poor from south to north (Figure 27). The Hills and Fleurieu landscape region recorded significantly better mean BCG scores than Green Adelaide ($p=0.0003$) and Northern and Yorke ($p<0.0001$) while Green Adelaide recorded significantly better scores than Northern and Yorke ($p<0.0001$) (Figure 26). Given the spatial extent of the Hills and Fleurieu region, we divided it into two separate management units (Hills and Fleurieu South and North) delimited by the southern-most extent of the Green Adelaide region (Figure 27) and repeated the beta regression with the new sub-regions. This resulted in Hills and Fleurieu South recording significantly better mean BCG scores than Hills and Fleurieu North ($p=0.0038$), Green Adelaide ($p<0.0001$) and Northern and Yorke ($p<0.0001$) (Figure 26). Interestingly, Hills and Fleurieu North was not significantly different to Green Adelaide ($p=0.9402$) but was still significantly different to Northern and Yorke ($p<0.0001$). Similar to the previous regression, Green Adelaide recorded significantly better scores than Northern and Yorke ($p<0.0001$). No significant differences in BCG scores were detected between years across all four regions indicating that broader biological condition has remained relatively stable. This does not imply that some sites within some catchments have not improved or degraded over time, but that overall changes in ecosystem health across regions were not enough to signal widespread contemporary impacts.

The north–south condition gradient was associated with a shift from predominantly poor scores (4.3–6) across the majority of attribute groups in the northern catchments to a high proportion of intermediate (2.7–4.3) and good scores (1–2.7) across all attribute groups in the southern catchments. Northern and Yorke recorded poor mean scores for land use and connectivity and intermediate mean scores for invasive species. The combined impacts are likely to have contributed to the intermediate mean score for tolerant species and poor mean scores for native species (Attributes 1–3) within this region. Green Adelaide recorded poor mean scores for land use and intermediate mean scores for connectivity which may have influenced the poor mean score for some native species (Attribute 2), and intermediate mean scores for all other native species (Attributes 1, 3 and 5). Invasive species are likely to have had minimal impact in Green Adelaide as they recorded good mean scores. Hills and Fleurieu recorded better scores for all attribute groups. The intermediate mean land use and connectivity scores and good mean invasive species scores are likely to have contributed to the intermediate mean native species scores across Attributes 2 and 3 for the Hills and Fleurieu. BCG scores across catchments were also highly variable but follow the regional trends described above (Appendix 3).

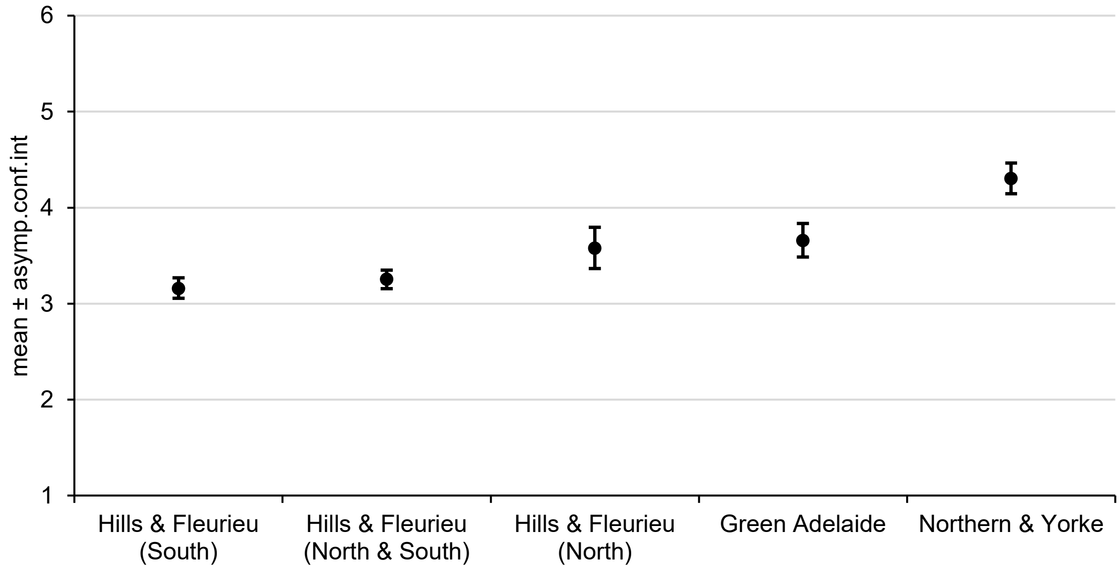

Figure 26. Plot displaying estimated marginal means scores calculated from transformed BCG scores with asymptotic confidence intervals by landscape region in the WMLR from 2007–2021 (Good scores = 1–2.7, Intermediate = 2.7–4.3, Poor = 4.3–6). Hills and Fleurieu (n = 295 sites/scores, Green Adelaide n = 72 sites/scores and Northern and Yorke (WMLR only) (n = 100 sites /scores). For map of management regions see Figure 27.

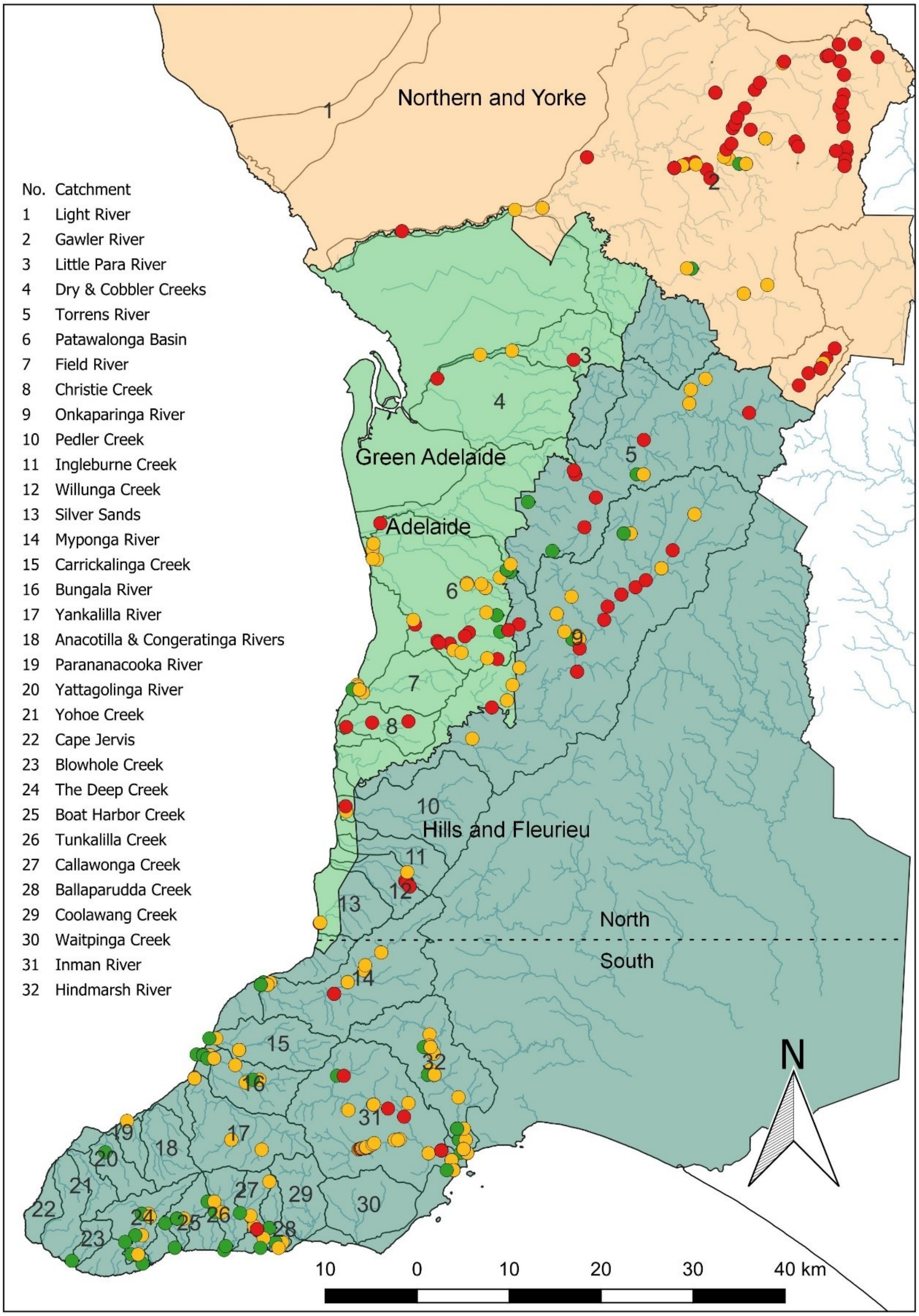

Figure 27. Distribution of BCG scores across the WMLR (n=467). Good (green circles) 1 to 2.7, intermediate (amber circles) 2.7 to 4.3 and poor (red circles) 4.3 to 6. The most recent 267 scores are visible due to stacking.

The BCG provides the most current quantitative evaluation of aquatic health across the WMLR at different management scales (e.g. regional, subregional, catchment and site). It provides a framework to identify, prioritise and quantify the impact of management interventions that aim to maintain or improve individual attribute scores and overall ecosystem health. Depending upon the condition of the site, this may involve:

- Protecting and maintaining sites that are in good condition and mitigating any further degradation of poor sites. Legislation, policies and education should be applied to prevent land use changes, mitigate the introduction of invasive species or to maintain connectivity. For example, sites in First Creek above Waterfall Gully (BCG score 1.4) have legislation protecting land use (National Parks and Wildlife Act 1972, National Parks and Wildlife (National Parks) Regulations 2016), legislation and policies aimed at mitigating the incursion of invasive species (Fisheries Management Act 2007) and policies for maintaining connectivity through controlling water affecting activities (Landscape South Australia Act 2019). This form of protection is particularly important as it requires significantly less resources than any form of remediation. In addition, it will assist in maintaining poor and degraded sites whilst appropriate remediation interventions are prioritised.
- Restoration of riparian and catchment vegetation to minimise or mitigate impacts associated with poor land use practices (i.e. erosion, sedimentation, nutrient loading) (Brooks and Lake 2007). This should be considered the first intervention as it is likely to facilitate improvements across other attributes. For example, the Hastings site within Back Valley tributary of Inman River in 2020 recorded poor overall scores for the site (BCG score 3.7) due to the absence of expected native species and poor land use scores particularly at the 100 m and 400 m levels. Restoration of riparian and localised catchment vegetation will result in an improvement in land use scores and is likely to promote recolonisation of expected native species, which will also improve the overall score. This site is a particularly good candidate for remediation as the absent native species are present elsewhere in the tributary and there are no invasive species nearby. Strategies that seek to restore riparian vegetation should also implement programs to manage stock access and control exotic weeds (Robertson and Rowling 2000, Jansen and Robertson 2001).
- Removal of barriers and/or the provision of fish passage should result in a significant improvement in fish movement and therefore connectivity scores, particularly if native

taxa are available to recolonise as this will also improve native species attributes (Zampatti *et al*. 2012, Beatty *et al*. 2013, Beatty *et al*. 2014, Mathwin *et al*. 2015, Bice *et al.* 2016, Harris *et al.* 2016, Ryan *et al*. 2018). For example, Washpool site in Silver Sands catchment had a poor score (BCG score 4.5) due to the presence of a significant barrier downstream of the site and the absence of two expected diadromous native species (congolli and common galaxias) and one tolerant native species (flathead gudgeon). As the expected native species are present immediately downstream, the removal of the barrier or provision of fish passage will see a significant improvement in scores at this site, particularly if there is adequate flow and suitable microhabitat. The absence of invasive species and relatively good land use scores make this an ideal site for remediation. It is important to note that even if some species aren't present or able to recolonise from within the catchment, further actions such as restocking via translocation or captive breeding may be considered (Cottingham *et al*. 2020). Addressing barriers to fish passage in the WMLR is particularly important as 31% of sites are impacted by barriers causing significant loss of connectivity such as dam walls, large weirs and regulators (BCG score 4.3–6) with a further 35% having some loss of connectivity due to barriers such as seasonally impassable weirs and culverts (BCG score 2.7–4.3).

- Control of invasive species to minimise predation and competition. The control or eradication of invasive species requires a deep understanding of the target species as well as sufficient resources to support what may require long-term effort (Thwaites *et al*. 2016, Stuart *et al*. 2021, Yick *et al*. 2021). Notwithstanding, management interventions that seek to control or eradicate invasive species will result in an improvement in invasive species scores and a concurrent improvement in native species scores (Lintermans 2000, Lintermans and Raadik 2001). For example, Hindmarsh Falls transitioned to an intermediate score (BCG score 3.9) following an invasion of brown trout and corresponding decrease in native species. Control or eradication of brown trout from this site via cessation of stocking and physical removal will see an improvement in both invasive and native species scores. As both land use and connectivity are relatively good within this reach, the control of one attribute (invasive species) should result in a significant improvement to the overall score. If native fish recovery is not observed after control/eradication efforts, then restocking could be considered (Cottingham *et al*. 2020).

The intention of the BCG is to quantify the ecological health of systems which can then be used to prioritise, implement and evaluate management actions with the aim of maintaining or restoring habitat to support native fish populations. Ideally, by implementing management interventions similar to those outlined above, native fish populations will be maintained or returned to natural levels with the minimum investment required and without any further intervention. This is especially important given that changes in fish and catchment health are likely to worsen due to climate change, increased urbanisation and agricultural development particularly in catchments that are already impacted and are transitioning in condition from good to poor (Balcombe *et al*. 2011, Morrongiello *et al.* 2011).

6. FUTURE DIRECTIONS AND OPPORTUNITIES

Monitoring and Biological Condition Gradient

Future monitoring utilising the methods described above should involve resampling at previous sites to capture long-term fish community trends and at new sites to expand the coverage of species distribution data (i.e. reservoirs, urban areas, estuaries). Continued monitoring in new and previously surveyed locations is particularly important as it may detect changes in the distribution of species similar to those recorded between 2007 and 2021.

Targeted monitoring programs should provide routine evaluation of areas with high ecological value (including areas with species of conservation concern) in order to provide early detection and mitigation of potentially detrimental impacts (i.e. rapid response to new invasive species incursion in Back Valley southern pygmy perch population). The frequency and intensity of monitoring will vary depending upon the nature of the impact and the sensitivity of the species present. For example, a species of conservation concern under imminent threat of a nearby invasive predator population will require more frequent monitoring (i.e. at least annually) than a common species under threat from a predator population located below a barrier.

Intervention specific monitoring programs should be designed to evaluate management actions such as the removal of barriers, provision of fish passage, control/eradication of invasive species and changes in land use such as clearing or replanting riparian habitat. This is particularly important if annual monitoring does not have the resolution to detect changes associated with these interventions. The BCG should be used to evaluate outcomes of management interventions in order to provide feedback to support adaptive management.

Invasive/non-endemic species

The design of a research program to collect information to support the development of an invasive species management strategy would be beneficial for future management of pest fish and other noxious species identified for the WMLR. This program should seek to understand the impacts for all invasive species (i.e. predation, competition, exclusion/overlap with native species) within the WMLR and prioritise control efforts on high impact species. The program should consider traditional monitoring coupled with targeted surveillance utilising genetic methods (Rourke *et al*. 2022) as well as acoustic tracking to identify movement patterns and habitat preferences (Thwaites *et al*. 2016). The program should map the spatial extent of priority invasive species and impacted native species within invaded systems (e.g. speckled livebearer and mountain galaxias in the Willunga catchment, trout and galaxiid species in Hindmarsh River).

The program should aim to identify exploitable behaviours such as seasonal migration and aggregation points in order to develop effective control techniques (Thwaites *et al*. 2016, Stuart *et al*. 2021, Yick *et al*. 2021). In addition, it should quantify any morphological and physiological differences between invasive and native species that may assist in developing control techniques such as physical traps that rely on size or behavioural differences (Thwaites *et al*. 2010, Thwaites 2011). Chemical control techniques (i.e. rotenone) may apply, but only if the treatment can be contained to specific reaches and recolonisation can occur either naturally or via translocation from neighbouring catchments (Lintermans 2000, Lintermans and Raadik 2001, Cottingham *et al*. 2020). Whilst the control and eradication of invasive species can be resource intensive, it is an important prerequisite to facilitate the recovery of native fish populations.

Finally, while the program is aimed at invasive species, surveys of non-endemic (i.e. stocked or translocated) fish within reaches adjacent to stocked reservoirs should be used to understand potential impacts of these species in WMLR catchments and to inform management strategies if required. This is important as non-endemic species can also have devastating impacts on endemic fish populations.

Barriers

A collaborative research program should be designed and implemented to document an inventory of in-stream barriers that may impact fish distribution and movement in the WMLR. The program should interrogate existing datasets held by relevant stakeholders (i.e. government agencies and landholders) in order to develop a comprehensive spatial layer of barriers. Remote sensing (satellite and drone) and on-ground surveys like those conducted by Schmarr *et al*. (2011) should be used to ground truth results and identify barriers that are not currently recorded. To ensure the quality and utility of the spatial layer, it should be reviewed by stakeholders and published to the SA Government open data portal (data.sa.gov.au). The addition of a spatial layer will facilitate the development of a data-driven quantitative approach to scoring Attribute 10 in the BCG. In addition, it will aid in confirming the absence of barriers which will result in BCG scores of 1 being introduced to the attribute. Currently Attribute 10 scoring assumes some form of barrier is affecting every site and therefore can only be assigned a minimum score of 2 (see methods above).

Where the presence of potential barriers is identified, the impact of the barrier should be assessed with an analysis of fish distribution above and below the barrier as well as an evaluation of fish movement and behaviour in relation to the barrier (e.g. acoustic telemetry; Bice *et al*. 2018). This work should consider the impact of barriers under variable hydrology and be used to refine the definition of what constitutes a barrier to the species present within the WMLR. The results of this work will directly inform management decisions regarding the identified barriers which may include removal, modification, construction of fishways, provision of flow or “do nothing”. If removal or provision of fish passage is impractical (i.e. dam, large weir, natural waterfall) and it is understood that fish species were extirpated from above the barrier via anthropogenic pressure (i.e. invasive species, flow disturbance etc), then restocking programs should be considered to expand fish species distribution to their original range. Distribution, movement and behaviour should be re-evaluated following any management intervention.

Estuaries

Estuaries play a pivotal role in supporting commercially and recreationally important freshwater and marine fish and crustacean stocks and are a critical conduit for many native diadromous species to complete their lifecycles (Creighton 2013). It is estimated that almost all recreationally targeted fish species and the vast majority of commercially targeted species are dependent on a life-cycle phase within estuarine environments (Creighton 2013). South Australia has 102 recognised estuaries and of these, there are approximately 35 known estuaries in the WMLR between Light River on the northern Adelaide Plains and the Murray River (Rumbelow 2010). These estuaries range in spatial extent from several kilometres (e.g. Onkaparinga) to less than 100 metres (e.g. Parananacooka)

To date, the emphasis of sampling estuarine habitats has focussed on diadromous and obligate freshwater species that utilise estuaries either for refuge and food resources or as conduits for accessing freshwater habitats upstream. True estuarine species and marine species with estuarine dependent life-history phases are critically important but remain largely overlooked in the WMLR (cf. McNeil and Hammer 2007, Rumbelow 2010). In order to provide a more comprehensive understanding of the role estuaries play in the life cycles of a range of fish species monitoring should aim to fill this considerable knowledge gap. Fundamental to this would be to establish a long-term temporal and spatial monitoring program to record species distribution and to evaluate the biological condition of estuaries across the WMLR using an estuarine specific condition assessment tool (ECAT) (e.g. BCG adapted for estuaries). While a review of historical literature and preliminary surveys to inform an inventory of estuarine fish taxa in the WMLR has commenced (Green Adelaide, 2022), future development and implementation of the ECAT necessitates seasonal information to capture the breath of community structure and environmental conditions that may drive population success. This would complement the BCG used to assess upstream condition by objectively assessing the health and therefore the relative importance of estuaries for production and conservation of marine, estuarine and freshwater species. An ECAT will help managers set priority targets for maintaining or restoring health and prioritise investment with the aim of supporting the State's fisheries by increasing productivity within estuarine nursery habitats.

Biological Condition Gradient (BCG)

The quantitative BCG model provided a rapid, reproducible data-driven approach and should continue to be used to quantify ecosystem health and evaluate the results of long-term and targeted monitoring, and management interventions across the WMLR.

REFERENCES

Amtstaetter F., Tonkin Z., O'Connor J., Stuart I. & Koster W. M. (2021) Environmental flows stimulate the upstream movement of juvenile diadromous fishes. *Marine and Freshwater Research* 72, 1019–1026.

Amtstaetter, F., Yen, J.D., Hale, R., Koster, W., O'Connor, J., Stuart, I. & Tonkin, Z., (2021). Elevated river discharge enhances the immigration of juvenile catadromous and amphidromous fishes into temperate coastal rivers. *Journal of Fish Biology*, 99(1), 61-72.

Armstrong, D. M., Croft S. J., & Foulkes J. N. (2003). A Biological Survey of the Southern Mount Lofty Ranges, South Australia, 2000-2001. (Department for Environment and Heritage, South Australia).

Arthington, A. H., Olden, J. D., Balcombe, S. R. & Thoms, M. C. (2010). Multi-scale environmental factors explain fish losses and refuge quality in drying waterholes of Cooper Creek, an Australian arid-zone river. *Marine and Freshwater Research*, 61, 842–856.

August, S. M., & Hicks, B. J. (2008). Water temperature and upstream migration of glass eels in New Zealand: implications of climate change. *Environmental Biology of Fishes*, 81(2), 195-205.

Avlijaš, S., Ricciardi, A., & Mandrak, N. E. (2018). Eurasian tench (*Tinca tinca*): the next Great Lakes invader. *Canadian Journal of Fisheries and Aquatic Sciences*, 75(2), 169-179.

Avlijaš, S., Mandrak, N.E. & Ricciardi, A., 2022. Effects of substrate and elevated temperature on the growth and feeding efficiency of an invasive cyprinid fish, Tench (*Tinca tinca*). *Biological Invasions*, 1-15.

Balcombe, S. R., Sheldon, F., Capon, S. J., Bond, N. R., Hadwen, W. L., Marsh, N., & Bernays, S. J. (2011). Climate-change threats to native fish in degraded rivers and floodplains of the Murray–Darling Basin, Australia. *Marine and Freshwater Research*, 62(9), 1099-1114.

Barbee, N. C., Hale, R., Morrongiello, J., Hicks, A., Semmens, D., Downes, B. J., & Swearer, S. E. (2011). Large-scale variation in life history traits of the widespread diadromous fish, *Galaxias maculatus*, reflects geographic differences in local environmental conditions. *Marine and Freshwater Research*, 62(7), 790-800.

Barriga, J. P., Battini, M. A., García-Asorey, M., Carrea, C., Macchi, P. J., & Cussac, V. E. (2012). Intraspecific variation in diet, growth, and morphology of landlocked *Galaxias maculatus* during its larval period: the role of food availability and predation risk. *Hydrobiologia*, 679(1), 27-41.

Beatty, S, Allen, M, Lymbery, A, Storer, T, White, G, Morgan, D & Ryan, T (2013). Novel methods for managing freshwater refuges against climate change in southern Australia: Evaluating small barrier removal to improve refuge connectivity - a global review of barrier decommissioning and a process for southern Australia in a drying climate, National Climate Change Adaptation Research Facility, Gold Coast, 73 pp

Beatty, S.J., Seewraj, K., Allen, M. & Keleher, J. (2014) Enhancing fish passage over large on-stream dams in south-western Australia: a case study. *Journal of the Royal Society of Western Australia*, 97 (2). 313-330.

Beatty, S.J., Allen, M.G., Whitty, J.M., Lymbery, A.J., Keleher, J.J., Tweedley, J.R., Ebner, B.C. & Morgan, D.L. (2017). First evidence of spawning migration by goldfish (*Carassius auratus*); implications for control of a globally invasive species. *Ecology of Freshwater Fish*, 26(3), 444-455.

Bertozzi, T., Adams, M. & Walker, K.F. (2000) Species boundaries in carp gudgeons (Eleotrididae: *Hypseleotris*) from the River Murray, South Australia: evidence for multiple species and extensive hybridization. *Marine and Freshwater Research* 51, 805–815.

Bice, C.M., Gehrig, S.L., Zampatti, B.P., Nicol, J.M., Wilson, P., Leigh, S.L. & Marsland, K., (2014). Flow-induced alterations to fish assemblages, habitat and fish–habitat associations in a regulated lowland river. *Hydrobiologia*, 722(1), 205-222.

Bice, C. M., Zampatti, B. P. & Fredberg, J. (2016). Assessment of the biological effectiveness of newly constructed fishways on the Murray Barrages, South Australia: Progress Report 2016. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2016/000452-1. SARDI Research Report Series No. 923. 55pp.

Bice, C., Gilligan, D. & Koehn, J. (2019). *Pseudaphritis urvillii. The IUCN Red List of Threatened Species* 2019: e.T122913501A123382361.

Bice, C., Gilligan, D., Raadik, T. & Unmack, P. (2019). *Mogurnda adspersa. The IUCN Red List of Threatened Species* 2019: e.T13609A123378372.

Bice, C. & Hammer, M. (2019). *Philypnodon grandiceps. The IUCN Red List of Threatened Species* 2019: e.T123359847A123382886.

Bice, C., Gilligan, D., Tonkin, Z. & Unmack, P. (2019). *Melanotaenia fluviatilis. The IUCN Red List of Threatened Species* 2019: e.T122905924A123382241.

Bice, C., Raadik, T., David, B., West, D, Franklin, P., Allibone, R, Ling, N., Hitchmough, R. & Crow, S. (2019). *Galaxias maculatus. The IUCN Red List of Threatened Species* 2019: e.T197279A129040788.

Bice, C.M., Zampatti, B.P., & Morrongiello, J.R. (2018). Connectivity, migration and recruitment in a catadromous fish. *Marine and Freshwater Research*, 69, 1733–1745

Bice, C. M., Zampatti, B. P., & Koster, W. (2019). Tracking lamprey spawning migrations in the River Murray. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2019/000190–1. SARDI Research Report Series No. 1027. 36pp.

Biosecurity SA (2022). Speckled livebearer (*Phalloceros caudimaculatus*) brochure. https://pir.sa.gov.au/__data/assets/pdf_file/0020/214661/PIR-012_Livebearer_print.pdf accessed 2/06/2022.

Booker, D. J., & Graynoth, E. (2013). Relative influence of local and landscape-scale features on the density and habitat preferences of longfin and shortfin eels. *New Zealand Journal of Marine and Freshwater Research*, 47(1), 1-20.

Brooks, S. S., & Lake, P. S. (2007). River restoration in Victoria, Australia: change is in the wind, and none too soon. *Restoration Ecology*, 15(3), 584-591.

Brown, P., Sivakumaran, K.P., Stoessel, D., Giles, A., Green, C., Walker, T. (2003). Carp Population Biology in Victoria. Marine and Freshwater Resources Institute, Department of Primary Industries, Snobs Creek, Victoria.

Closs, G.E., Lake, P.S. (1996) Drought, differential mortality and the coexistence of a native and an introduced fish species in a south east Australian intermittent stream. *Environmental Biology of Fishes,* 47, 17–26.

Clunie, P., & Koehn, J. (2001). Freshwater catfish: a recovery plan. Freshwater Ecology, Arthur Rylah Institute for Environmental Research, Department of Natural Resources and Environment.

Cole, T., Hammer, M., Unmack, P., Teske, P., Brauer, C., Adams, M., & Beheregaray, L. (2016). Range-wide fragmentation in a threatened fish associated with post-European settlement modification in the Murray–Darling Basin, Australia. *Conservation Genetics,* 17, 1377–1391.

Coleman, R., Raadik, T., Pettigrove, V. & Hoffmann, A. (2016). Taking advantage of adaptations when managing threatened species within variable environments: The case of the dwarf galaxias, *Galaxiella pusilla* (Teleostei, Galaxiidae). *Marine and Freshwater Research*, 68.

Conallin, A., Smith, B., Thwaites, L. Walker, K. & Gillanders, B. (2012). Environmental water allocations in regulated lowland rivers may encourage offstream movements and spawning by common carp, *Cyprinus carpio*: implications for wetland rehabilitation. *Marine and Freshwater Research*, 63, 865–877.

Cook, B. D., Bunn, S. E., & Hughes, J. M. (2007). Molecular genetic and stable isotope signatures reveal complementary patterns of population connectivity in the regionally vulnerable southern pygmy perch (*Nannoperca australis*). *Biological Conservation*, 138(1-2), 60-72.

Cook, B. D., Kennard, M. J., Adams, M., Raadik, T. A., Real, K., Bunn, S. E., & Hughes, J. M. (2019). Hydrographic correlates of within-river distribution and population genetic structure in two widespread species of mountain galaxias (Teleostei, Galaxiidae) in southern Australia. *Freshwater Biology*, 64(3), 506-519.

Cottingham, A., Hall, N. G., Loneragan, N. R., Jenkins, G. I., & Potter, I. C. (2020). Efficacy of restocking an estuarine-resident species demonstrated by long-term monitoring of cultured fish with alizarin complexone-stained otoliths. A case study. *Fisheries Research*, 227, 105556.

Creighton, C. (2013). Revitalising Australia's estuaries. FRDC 2013 Fisheries Research and Development Corporation, 1-165.

Cribari-Neto, F. & Zeilis, A. (2010). Beta Regression in R. *Journal of Statistical Software*, 34, 1–24.

Crook, D. A., Koster, W. M., Macdonald, J. I., Nicol, S. J., Belcher, C. A., Dawson, D. R., O'Mahony, D. J., Lovett, D., Walker, A., & Bannam, L. (2010). Catadromous migrations by female tupong (*Pseudaphritis urvillii*) in coastal streams in Victoria, Australia. *Marine and Freshwater Research*, 61: 474–483.

Crook, D. A., Macdonald, J. I., Morrongiello, J. R., Belcher, C. A., Lovett, D., Walker, A., & Nicol, S. J. (2014). Environmental cues and extended estuarine residence in seaward migrating eels (*Anguilla australis*). *Freshwater Biology*, 59(8), 1710–1720.

Cudmore, B. & Mandrak, N. E. (2011). Biological synopsis of tench (*Tinca tinca*). *Canadian manuscript report of fisheries and aquatic sciences/Rapport manuscrit canadien des sciences halieutiques et aquatiques*, 2948.

Davies, S.P. & Jackson, S.K. (2006). The biological condition gradient: A descriptive model for interpreting change in aquatic ecosystems. *Ecological Applications,* 16(4): 1251–1266.

Davies, P. E., Harris, J. H., Hillman, T. J., & Walker, K. F. (2010). The sustainable rivers audit: assessing river ecosystem health in the Murray–Darling Basin, Australia. *Marine and Freshwater Research*, 61(7), 764-777.

Dexter, T., Bond, N., Hale, R., & Reich, P. (2014). Dispersal and recruitment of fish in an intermittent stream network. *Austral Ecology*, 39(2), 225-235.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.-H., Soto, D., Stiassny, M.L.J. & Sullivan, C.A. (2006), Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81: 163–182.

Ebner, B., Brooks, S. & Butler, G. (2019). *Nematalosa erebi*. *The IUCN Red List of Threatened Species* 2019: e.T98807658A145096515.

Ehrlich, P. R., & Pringle, R. M. (2008). Where does biodiversity go from here? A grim business-as-usual forecast and a hopeful portfolio of partial solutions. *Proceedings of the National Academy of Sciences*, 105(supplement_1), 11579-11586.

Ellis, I., Cheshire, K., Townsend, A., Copeland, C. Danaher, K. & Webb, L. (2016). Fish and Flows in the Murray River Catchment - A review of environmental water requirements for native fish in the Murray River Catchment. NSW Department of Primary Industries, Queanbeyan.

Feio, M.J., Hughes, R.M., Callisto, M., Nichols, S.J., Odume, O.N., Quintella, B.R., Kuemmerlen, M., Aguiar, F.C., Almeida, S.F.P., Alonso-EguíaLis, P., *et al.* (2021). The Biological Assessment and Rehabilitation of the World's Rivers: An Overview. *Water*, 13, 371.

Ferguson, G. J., Ward, T. M., Ye, Q., Geddes, M. C., & Gillanders, B. M. (2013). Impacts of drought, flow regime, and fishing on the fish assemblage in southern Australia's largest temperate estuary. *Estuaries and Coasts*, 36(4), 737-753.

Ferrari, S.L.P. & Cribari-Neto, F. (2004). Beta Regression for Modelling Rates and Proportions. *Journal of Applied Statistics*, 31(7), 799–815.

Fulton, W. (2004). Review of trout stocking in South Australia: South Australian Fisheries Management Series No. 41. Adelaide: Primary Industries and Resources SA.

Gehrke, P.C., & Harris, J.H. (1994). The role of fish in cyanobacterial blooms in Australia. *Australian Journal of Marine and Freshwater Research,* 45: 905–915.

Gehrke, P.C. (1997). Differences in composition and structure of fish communities associated with flow regulation in New South Wales Rivers. In: *Fish and Rivers in Stress: the NSW Rivers Survey* (Eds. Harris, J.H. & Gehrke, P.C.). NSW Fisheries Office of Conservation and Cooperative Research Centre for Freshwater Ecology, pp 169–200.

Gill, H.S., Potter, I.C. (1993) Spatial segregation amongst goby species within an Australian estuary, with a comparison of the diets and salinity tolerance of the two most abundant species. *Marine Biology,* 117, 515–526

Gillam, S. & Urban, R. (2014) Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments, Adelaide and Mount Lofty Ranges NRM Region. Department of Environment, Water and Natural Resources, South Australia.

Gillanders, B., Elsdon, T. & Munro, A. (2006). Impacts of Native Fish Stocking on Fish in the Murray-Darling Basin.

Gilligan, D. & Clunie, P. (2019). *Tandanus tandanus. The IUCN Red List of Threatened Species* 2019: e.T122902003A123382071.

Goonan, P., Gaylard, S., Jenkins, C., Thomas, S., Nelson, M., Corbin, T., Kleinig, T., Hill, R., Noble, W. & Solomon, A. (2012). The South Australian monitoring, evaluation and reporting program for aquatic ecosystems: context and overview. South Australian Environment Protection Authority, Adelaide.

Gomon, M.F. & Bray, D.J. (2021). *Nematalosa erebi* in Fishes of Australia, accessed 06 Jul 2022, https://fishesofaustralia.net.au/home/species/2061

Green, K. (2008). Fragmented distribution of a rock climbing fish, the Mountain Galaxias *Galaxias olidus*, in the snowy mountains. *Proceedings of the Linnean Society of New South Wales*, 129, 175-182.

Hallett, C.S. (2016). Assessment of the condition of the Swan Canning Estuary in 2016, based on the Fish Community Index of estuarine condition. Final report to the Department of Parks and Wildlife. Murdoch University, Western Australia, 35 pp.

Hammer, M. P., & Walker, K. F. (2004). A catalogue of South Australian freshwater fishes including new records, range extensions and translocations. *Transactions of the Royal Society of South Australia,* 128, 85–97.

Hammer, M. (2005). Adelaide Hills Fish Inventory: distribution and conservation of freshwater fishes in the Torrens and Patawalonga catchments, South Australia. Report to Torrens and Patawalonga Catchment Water Management boards. Native Fish Australia (SA) Inc., Adelaide. p. 68.

Hammer, M.P. (2009). Freshwater fish monitoring in the Eastern Mount Lofty Ranges: environmental water requirements and tributary condition reporting for 2008 and 2009. Report to the SAMDB NRM Board. Aquasave Consultants, Adelaide.

Hammer, M.P., Wedderburn, S. & van Weenen, J. (2009). Action Plan for South Australian Freshwater Fishes.

Hammer, M., Adams, M. & Foster, R. (2012). Update to the catalogue of South Australian freshwater fishes (Petromyzontida & Actinopterygii). *Zootaxa*, 3593, 59–74.

Hammer, M.P., Adams, M., Thacker, C.E., Johnson, J.B., Unmack, P.J., 2019. Comparison of genetic structure in co-occurring freshwater eleotrids (Actinopterygii: *Philypnodon*) reveals cryptic species, likely translocation and regional conservation hotspots. *Molecular Phylogenetics and Evolution*. 139, 106556.

Hammer, M. P., Adams, M., Unmack, P. J., Hassell, K. L. & Bertozzi, T. (2021). Surprising *Pseudogobius*: Molecular systematics of benthic gobies reveals new insights into estuarine biodiversity (Teleostei: Gobiiformes). *Molecular Phylogenetics and Evolution*, 160, 107140.

Harris, J. H. (1995). The use of fish in ecological assessments. *Australian Journal of Ecology*, 20, 65–80.

Harris, J. H., Kingsford, R. T., Peirson, W., & Baumgartner, L. J. (2016). Mitigating the effects of barriers to freshwater fish migrations: the Australian experience. *Marine and Freshwater Research*, 68(4), 614-628.

Hickford, M.J., Cagnon, M. & Schiel, D.R., 2010. Predation, vegetation and habitat-specific survival of terrestrial eggs of a diadromous fish, *Galaxias maculatus* (Jenyns, 1842). *Journal of Experimental Marine Biology and Ecology*, 385(1-2), pp.66-72.

Hickford, M.J. & Schiel, D.R., 2014. Experimental rehabilitation of degraded spawning habitat of a diadromous fish, *Galaxias maculatus* (Jenyns, 1842) in rural and urban streams. *Restoration Ecology*, 22(3), 319-326.

Hill, E., Ingram, B. A., Rourke, M., Mitchell, J., & Strugnell, J. M. (2015). Genetic diversity and population structure of the threatened freshwater catfish, *Tandanus tandanus*, in Victoria, Australia. *Conservation Genetics*, 16(2), 317-329.

Ho, S., Bond, N. & Thompson, R. (2013). Does seasonal flooding give a native species an edge over a global invader? *Freshwater Biology*, 58, 159–170.

Humphries, P., King, A. J. & Koehn, J. D. (1999). Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental biology of fishes*, 56, 129–151.

Ivantsoff, W. & Aarn (1999). Detection of predation on Australian native fishes by G*ambusia holbrooki*. *Marine and Freshwater Research*, 50, 467–468.

Jackson, D. A., Peres-Neto, P. R. & Olden, J. D. 2001. What controls who is where in freshwater fish communities the roles of biotic, abiotic, and spatial factors. *Canadian Journal of Fisheries and Aquatic Sciences*, 58, 157–170.

Jansen, A. M. Y., & Robertson, A. I. (2001). Relationships between livestock management and the ecological condition of riparian habitats along an Australian floodplain river. *Journal of applied ecology*, 63-75.

Jerry, D. R. (2008). Phylogeography of the freshwater catfish *Tandanus tandanus* (Plotosidae): a model species to understand evolution of the eastern Australian freshwater fish fauna. *Marine and Freshwater Research*, 59(4), 351-360.

Jones, P. & Closs, G.E. (2017). The Introduction of Brown Trout to New Zealand and their Impact on Native Fish Communities: Biology, Ecology and Management. 10.1002/9781119268352.ch21.

Jung, C. A., Barbee, N. C., & Swearer, S. E. (2009). Post-settlement migratory behaviour and growth-related costs in two diadromous fish species, *Galaxias maculatus* and *Galaxias brevipinnis. Journal of Fish Biology*, 75(3), 503-515.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. *Fisheries*, 6, 21–27.

Kilsby, N. N., & Walker, K. F. (2012). Behaviour of two small pelagic and demersal fish species in diverse hydraulic environments. *River Research and Applications*, 28(5), 543-553.

King, A., Humphries, P. & Lake, P. (2003). Fish recruitment on floodplains: the roles of patterns of flooding and life history characteristics. *Canadian Journal of Fisheries and Aquatic Sciences*, 60, 773–786.

Koehn, J.D. (2004). Carp (*Cyprinus carpio*) as a powerful invader in Australian waterways. *Freshwater Biology,* 49: 882–894.

Koehn, J.D. & Nichol, S.J. (1998). Habitat and movement requirements of fish. In proc. *1996 Riverine Environment Forum* Eds. R.J. Banens & R. Lehane) pp. 1–6. October 1996, Brisbane Queensland. Publ. Murray Darling Basin Commission.

Koster, W. M., Dawson, D. R., Clunie, P., Hames, F., McKenzie, J., Moloney, P. D., & Crook, D. A. (2015). Movement and habitat use of the freshwater catfish (*Tandanus tandanus*) in a remnant floodplain wetland. *Ecology of Freshwater Fish*, 24(3), 443-455.

Koster, W.M., Aarestrup, K., Birnie-Gauvin, K., Church, B., Dawson, D., Lyon, J., O'Connor, J., Righton, D., Rose, D., Westerberg, H. & Stuart, I. (2021). First tracking of the oceanic spawning migrations of Australasian short-finned eels (*Anguilla australis*). *Scientific reports*, 11(1), 1-13.

Lake Eyre Basin Ministerial Forum (2017). Lake Eyre Basin: State of the Basin Condition Assessment 2016 Report. Department of Agriculture and Water Resources, Canberra.

Larned, S. T., Datry, T., Arscott, D. B., & Tockner, K. (2010). Emerging concepts in temporary-river ecology. Freshwater Biology, 55(4), 717-738.

Lenth, R.V. (2021). emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version 1.6.0. https://CRAN.R-project.org/package=emmeans

Lintermans, M. (2000). Recolonization by the mountain galaxias *Galaxias olidus* of a montane stream after the eradication of rainbow trout Oncorhynchus mykiss. *Marine and freshwater research*, 51(8), 799-804.

Lintermans, M. (2007) 'Fishes of the Murray-Darling Basin: An Introductory Guide. MDBC Publication No. 10/07.' (Murray-Darling Basin Commission: Canberra).

Lintermans, M., & Raadik, T. (2001). Local eradication of trout from streams using rotenone: the Australian experience. In Managing invasive freshwater fish in New Zealand. Proceedings of a workshop hosted by Department of Conservation (pp. 10-12).

Macdonald, J. I., Tonkin, Z. D., Ramsey, D. S., Kaus, A. K., King, A. K., & Crook, D. A. (2012). Do invasive eastern gambusia (*Gambusia holbrooki*) shape wetland fish assemblage structure in south-eastern Australia?. *Marine and Freshwater Research*, 63(8), 659-671.

Maddern, M.G., (2008). Distribution and spread of the introduced one-spot livebearer *Phalloceros caudimaculatus* (Pisces: Poeciliidae) in southwestern Australia. *Journal of the Royal Society of Western Australia*, 91, p.229.

Marchetti, M. P. & Moyle, P. B. (2001). Effects of flow regime on fish assemblages in a regulated California stream. *Ecological Applications*, 11, 530–539.

Marshall, I.R., Brauer, C.J., Wedderburn, S.D., Whiterod, N.S., Hammer, M.P., Barnes, T.C., Attard, C.R., Möller, L.M. & Beheregaray, L.B., 2022. Longitudinal monitoring of neutral and adaptive genomic diversity in a reintroduction. *Conservation Biology*, p.e13889.

Mathwin, R., McNeil, D.G. & Schmarr, D.W. (2014). A Biological Condition Gradient Model Approach for Fish-Based Ecological Condition Monitoring in the Western Mount Lofty Ranges, South Australia. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2013/000020-1. SARDI Research Report Series No. 758. 35pp.

Mathwin, R., McNeil D.G. & Gillanders, B.M. (2015) The effect of barriers on the diadromous migration of *Galaxias brevipinnis* in the Middle River, Kangaroo Island, South Australia. SARDI Publication Number F2013/000439-1, SARDI Research Report Series No. 857. 43pp.

Matsuzaki, S.S., Usio, N., Takamura, N., & Washitani, I. (2009). Contrasting impacts of invasive engineers on freshwater ecosystems: an experiment and meta-analysis. *Oecologia,* 158: 673–86.

McDowall, R. M. (ed.) (1996). Freshwater Fishes of South-Eastern Australia, 2nd ed. Reed Books, Sydney. 247pp.

McDowall, R. M., (2006). Crying wolf, crying foul, or crying shame: alien salmonids and a biodiversity crisis in the southern cool-temperate galaxioid fishes? *Reviews in Fish biology and Fisheries.* 16:233–422.

McEwan, A. J., & Joy, M. K. (2014). Diel habitat use of two sympatric galaxiid fishes (*Galaxias brevipinnis* and *G. postvectis*) at two spatial scales in a small upland stream in Manawatu, New Zealand. *Environmental biology of fishes*, 97(8), 897-907.

McIntosh, A., McHugh, P., Dunn, N., Goodman, J., Howard, S., Jellyman, P., O'Brien, L., Nyström, P., & Woodford, Darragh. (2010). The Impact of Trout on Galaxiid Fishes in New Zealand. *New Zealand Journal of Ecology*. 34. 195–206.

McKinnon, L. J., & Gooley, G. J. (1998). Key environmental criteria associated with the invasion of *Anguilla australis* glass eels into estuaries of south-eastern Australia. *Bulletin Francais de la Peche et de la Pisciculture*, (349), 117-128.

McNeil, D. G. (2004) Ecophysiology and behaviour of Ovens River floodplain fish: hypoxia tolerance and the role of the physicochemical environment in structuring Australian billabong fish communities. PhD thesis, LaTrobe University.

McNeil, D. G. & Fredberg, J. (2011). Environmental Water Requirements of native fishes in the Middle River catchment, Kangaroo Island, South Australia. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000060-1. SARDI Research Report Series No. 528. 50pp.

McNeil, D.G. & Hammer, M (2007). Biological review of the freshwater fishes of the Mount Lofty Ranges. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Research Report Series No. 188. SARDI Publication number: F2006/000335. 104pp.

McNeil, D. & Wilson, P., 2008. The Speckled Livebearer (*Phalloceros caudimaculatus*): A New Alien Fish for South Australia. Adelaide: South Australian Research and Development Institute.

McNeil, D.G., Fredberg, J. & Wilson, P.J. (2009). Coastal Fishes and Flows in the Onkaparinga and Myponga Rivers. Report to the Adelaide and Mount Lofty Ranges Natural Resource Management Board. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Research Report Series No. 400. SARDI Publication No. F2009/000410-1. 76pp.

McNeil, D.G, Schmarr, D.W & Mathwin, R (2011). Condition of Freshwater Fish Communities in the Adelaide and Mount Lofty Ranges Management Region. Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Research Report Series No. 590. SARDI Publication No. F2011/000502-1. 65pp.

McNeil, D., Schmarr, D., Wilson, P. & Reid, D. (2011). Fish Community and Flow Ecology in the Western Mount Lofty Ranges Environmental Water Provisions Trial Reaches. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Research Report Series No. 581. SARDI Publication No. F2011/000313-1. 238pp.

McQueen, D. J., Post, J. R. & Mills, E. L. (1986). Trophic relationships in freshwater pelagic ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences*, 43, 1571–1581.

Miller, S.A., & Crowl, T.A. (2006). Effects of common carp (*Cyprinus carpio*) on macrophytes and invertebrate communities in a shallow lake. *Freshwater Biology,* 51: 85–94.

Milton D.A. & Arthington A.H., (1983). Reproductive biology of *Gambusia affinis holbrooki* Baird and Girard, *Xiphophorus helleri* (Gunther) and *X. maculatus* (Heckel) (Pisces; Poeciliidae) in Queensland, Australia. *Journal of Fish Biology*, 23(1):23–41.

Morgan, D.L. & Beatty, S.J., (2007). Feral Goldfish (*Carassius auratus*) in Western Australia: a case study from the Vasse River. *Journal of the Royal Society of Western Australia*, 90(3), pp.151-156.

Morgan, D.L., Unmack, P.J., Beatty, S.J., Ebner, B.C., Allen, M.G., Keleher, J., Donaldson, J.A. & Murphy, J.O.N., (2014). An overview of the 'freshwater fishes' of Western Australia. *Journal of the Royal Society of Western Australia*, 97, pp.263-278.

Morissette, O., Lecomte, F., Vachon, N., Drouin, A. & Sirois, P., (2021). Quantifying migratory capacity and dispersal of the invasive Tench (*Tinca tinca*) in the St. Lawrence River using otolith chemistry. *Canadian Journal of Fisheries and Aquatic Sciences*, 78(11),1628-1638.

Morrongiello, J., Beatty, S., Bennett, J., Crook, D., Ikedife, D., Kennard, M., Kerezsy, A., Lintermans, M., McNeil, D., Pusey, B. & Rayner, T. (2011). Climate change and its implications for Australia's freshwater fish. *Marine and Freshwater Research*, 62, 1082–1098.

Musyl, M. K., & Keenan, C. P. (1992). Population genetics and zoogeography of Australian freshwater golden perch, *Macquaria ambigua* (Richardson 1845) (Teleostei: Percichthyidae), and electrophoretic identification of a new species from the Lake Eyre Basin. *Australian Journal of Marine and Freshwater Research* 43, 1585-1601.

Musyl, M. & Keenan, C. (1996). Evidence for Cryptic Speciation in Australian Freshwater Eel-Tailed Catfish, Tandanus tandanus (Teleostei: Plotosidae). *Copeia*. 1996. 526–534. 10.2307/1447516.

O'Connor, W.G. & Koehn, J.D., (1991). Spawning of the mountain galaxias, *Galaxias olidus* Günther. Bruces Creek, Victoria. *Proceedings of the Royal Society of Victoria*, 103(2), pp.113-123.

O'Connor, W.G. & Koehn, J.D., (1998). Spawning of the broad-finned Galaxias, *Galaxias brevipinnis* Günther (Pisces: Galaxiidae) in coastal streams of southeastern Australia. *Ecology of Freshwater Fish*, 7(2), pp.95-100.

Parkos, J.J., Santucci, V.J., & Wahl, D.H. (2003). Effects of adult common carp (*Cyprinus carpio*) on multiple trophic levels in shallow mesocosms. *Canadian Journal of Fisheries and Aquatic Sciences,* 60: 182–192.

Pearce, L., Bice, C., Whiterod, N. & Raadik, T. (2019). *Nannoperca australis. The IUCN Red List of Threatened Species* 2019: e.T123358579A123382811.

Pike, C., Crook, V. & Gollock, M. (2019). *Anguilla australis* (errata version published in 2019). *The IUCN Red List of Threatened Species* 2019: e.T195502A154801652.

Poff, N. L. & Allan, J. D. (1995). Functional Organization of Stream Fish Assemblages in Relation to Hydrological Variability. *Ecology*, 76, 606–627.

Poff, N., Brinson, M. & Day, J. (2002). Aquatic Ecosystems & Global Climate Change – Potential Impacts on Inland Freshwater and Coastal Wetland Ecosystems in the United States. Pew Center for Global Change.

Poff, N.L., Richter, B.D., Arthington, A.H., Bunn, S.E., Naiman, R.J., Kendy, E., Acreman, M., Apse, C., Bledsoe, B.P., Freeman, M.C. & Warner, A. (2010). The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater biology*, 55(1), 147-170.

Power, M. (2007). Fish population bioassessment. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland, 561-624.

Puckridge, J. T., & Walker, K. F. (1990). Reproductive biology and larval development of a gizzard shad, *Nematalosa erebi* (Gunther)(Dorosomatinae: Teleostei), in the River Murray, South Australia. *Marine and Freshwater Research*, 41(6), 695-712.

Pyke, G. H. (2008). Plague Minnow or Mosquito Fish? A Review of the Biology and Impacts of Introduced Gambusia Species. *Annual Review of Ecology, Evolution, and Systematics*, 39, 171–191.

Raadik, T. (2014). Fifteen from one: A revision of the *Galaxias olidus* Günther, 1866 complex (Teleostei, Galaxiidae) in south-eastern Australia recognises three previously described taxa and describes 12 new species. *Zootaxa*, 3898, 1–198.

Raadik, T. (2019). *Galaxias olidus. The IUCN Red List of Threatened Species* 2019: e.T122902529A123382141.

Raadik, T., Bice, C., David, B., West, D, Franklin, P., Crow, S., Ling, N., Allibone, R & Hitchmough, R. (2019). *Galaxias brevipinnis*. The IUCN Red List of Threatened Species 2019: e.T197277A129040345.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Robertson, A. I., & Rowling, R. W. (2000). Effects of livestock on riparian zone vegetation in an Australian dryland river. *Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management*, 16(5), 527-541.

Rourke, M.L., Fowler, A.M., Hughes, J.M., Broadhurst, M.K., DiBattista, J.D., Fielder, S., Wilkes Walburn, J. & Furlan, E.M., (2022). Environmental DNA (eDNA) as a tool for assessing fish biomass: A review of approaches and future considerations for resource surveys. *Environmental DNA*, 4(1), pp.9-33.

Rourke, M. & Gilligan, D. (2010). Population Genetic Structure of Freshwater Catfish (*Tandanus tandanus*) in the Murray–Darling Basin and Coastal Catchments of New South Wales: Implications for Future Re-Stocking Programs.

Rowe, D.K. (2007). Exotic fish introductions and the decline of water clarity in small North Island, New Zealand lakes: A multi-species problem. *Hydrobiologia*, 583 (1), pp. 345-358.

Rowe, D. K., Moore, A., Giorgetti, A., Maclean, C., Grace, P., Wadhwa, S. & Cooke, J. (2008). Review of the impacts of gambusia, redfin perch, tench, roach, yellowfin goby and streaked goby in Australia. Prepared for the Australian Government Department of the Environment, Water, Heritage and the Arts.

Rumbelow, K., Speziali, A., & Bloomfield, A. (2010). Working towards a state-wide inventory of estuaries: advancing the inventory of estuaries in five NRM regions of South Australia. Adelaide, Department of Environment and Natural Resources.

Ryan, S., Morden, B., & Perrin, T., (2018). Fish barrier removal and river connectivity support Glenelg River tupong populations. International Conference on Engineering and Ecohydrology for Fish Passage. 27.

Schallenberg, M. & Sorrell, B., 2009. Regime shifts between clear and turbid water in New Zealand lakes: environmental correlates and implications for management and restoration. *New Zealand Journal of Marine and Freshwater Research*, 43(3), pp.701-712.

Schmarr, D.W., Mathwin, R. & McNeil, D.G. (2011). Mapping threats to aquatic biota movement and recovery with the provision of environmental water in selected reaches of the South Para, Torrens and Onkaparinga Rivers - RESTRICTED. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000418-1. SARDI Research Report Series No. 570. 8pp.

Schmarr, D.W., Mathwin, R. & Cheshire D.L.M. (2014). Western Mount Lofty Ranges Fish Condition Report 2012–13. Incorporating the Barossa Valley Prescribed Water Resource Area Fish Community Study, the Verification of Water Allocation Science Project (VWASP) and the Western Mount Lofty Ranges Fish Community Monitoring. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2014/000113-1. SARDI Research Report Series No. 780. 84pp.

Schmarr, D.W., Mathwin, R. & Cheshire, D.L.M. (2018). Fish monitoring across regional catchments of the Adelaide and Mount Lofty Ranges region 2015–17. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2018/000217-1. SARDI Research Report Series No. 990. 101pp.

Schmarr, D.W. & Thwaites, L. (2019). Fish monitoring across regional catchments of the Adelaide and Mount Lofty Ranges region 2019. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2018/000217-2. SARDI Research Report Series No 1055. 31pp.

Schmidt, D.J., Crook, D.A., Macdonald, J.I., Huey, J.A., Zampatti, B.P., Chilcott, S., Raadik, T.A. & Hughes, J. M. (2014). Migration history and stock structure of two putatively diadromous teleost fishes, as determined by genetic and otolith chemistry analyses. *Freshwater Science*, 33(1), 193-206.

Scott, K., Lintermans, M. & Bice, C. (2019). *Philypnodon macrostomus. The IUCN Red List of Threatened Species* 2019: e.T123359936A123382891.

Shelton, J.M., Samways, M.J. & Day, J.A., (2015). Predatory impact of non-native rainbow trout on endemic fish populations in headwater streams in the Cape Floristic Region of South Africa. *Biological Invasions*, 17(1), pp.365-379.

Sibbing, F.A., Osse, J.W.M., & Terlouw, A. (1986). Food handling in the carp (*Cyprinus carpio*): Its movement patterns, mechanisms and limitations. *Journal of the Zoological Society of London*, 210: 161–203.

Smith, B.B. (2005). The state of the art: a synopsis of information on common carp (*Cyprinus carpio*) in Australia. SARDI Aquatic Sciences, Publication No. RD04/0064-2; SARDI Research Report Series No. 77, Adelaide. 68 pp.

Sowersby, W., Thompson, R.M. & Wong, B.B.M. (2016). Invasive predator influences habitat preferences in a freshwater fish. *Environmental Biology of Fishes*, 99 (2-3), 187-193.

Stuart, I.G., Fanson, B.G., Lyon, J.P., Stocks, J., Brooks, S., Norris, A., Thwaites, L., Beitzel, M., Hutchison, M., Ye, Q. & Koehn, J.D., 2021. Continental threat: How many common carp (Cyprinus carpio) are there in Australia? *Biological Conservation*, 254, p.108942.

Thwaites, L. A. (2011). Proof of concept of a novel wetland carp separation cage at Lake Bonney, South Australia. A summary report for the Invasive Animals Cooperative Research Centre and the South Australian Murray-Darling Basin Natural Resources Management Board. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000086-1. SARDI Research Report Series No. 530. 38pp.

Thwaites, L., Fredberg, J. & Ryan, S. (2016). Understanding and managing Common Carp (*Cyprinus carpio* L.) in the Glenelg River, Victoria, Australia. Final report to the Glenelg Hopkins Catchment Management Authority. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2012/000122-4. SARDI Research Report Series No. 915. 53pp.

Thwaites, L. & Schmarr, D.W. (2019) 2019 Torrens Lake Carp Harvest: Summary report for the City of Adelaide.

Thwaites, L. A., Smith, B. B., Decelis, M., Fleer, D., & Conallin, A. (2010). A novel push trap element to manage carp (*Cyprinus carpio* L.): a laboratory trial. *Marine and Freshwater Research*, 61(1), 42-48.

Todd, C.R., Koehn, J.D., Pearce, L., Dodd, L., Humphries, P. & Morrongiello, J.R., (2017). Forgotten fishes: What is the future for small threatened freshwater fish? Population risk assessment for southern pygmy perch, *Nannoperca australis*. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27(6), 1290-1300.

Tonkin, Z., King, A. J., & Mahoney, J. (2008). Effects of flooding on recruitment and dispersal of the Southern Pygmy Perch (*Nannoperca australis*) at a Murray River floodplain wetland. *Ecological Management & Restoration*, 9(3), 196-201.

Unmack, P. J. (2000). The genus *Hypseleotris* in southeastern Australia: its identification and breeding biology. Fishes of Sahul 14, 645–657.

Unmack, P. (2019). *Hypseleotris klunzingeri*. *The IUCN Red List of Threatened Species* 2019: e.T68001287A129047243.

Waters, J. M. & Wallis, G. P. (2001). Cladogenesis and loss of the marine life-history phase in freshwater Galaxiid fishes (Osmeriformes: Galaxiidae). 55, 587–597.

Webb, J. A., Koster, W. M., Stuart, I. G., Reich, P., & Stewardson, M. J. (2018). Make the most of the data you’ve got: Bayesian models and a surrogate species approach to assessing benefits of upstream migration flows for the endangered Australian grayling. *Environmental management*, 61(3), 398-407.

Wedderburn, S., Hammer, M. & Bice, C. (2012). Shifts in small-bodied fish assemblages resulting from drought-induced water level recession in terminating lakes of the Murray-Darling Basin, Australia. *Hydrobiologia*, 691, 35–46.

Wedderburn, S., Bice, C. & Barnes, T. (2014). Prey selection and diet overlap of native golden perch and alien redfin perch under contrasting hydrological conditions. *Australian Journal of Zoology*. 62, 374–381.

Wedderburn, S. D., & Barnes, T. C. (2016). Piscivory by alien redfin perch (*Perca fluviatilis*) begins earlier than anticipated in two contrasting habitats of Lake Alexandrina, South Australia. *Australian Journal of Zoology*, 64(1), 1-7.

Wilson, P.J., McNeil, D.G. & Gillanders, B.M. (2008). Impacts of introduced redfin perch on native flathead gudgeons in the South Para River. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. 47 pp. SARDI Aquatic Sciences Publication Number: F2007/000882-1

Winemiller, K. O., & Rose, K. A. (1992). Patterns of life-history diversification in North-American fishes- Implications for population regulation. *Canadian Journal of Fisheries and Aquatic Sciences*, 49: 2196–2218.

Woodford, D.J., Mcintosh, A.R. (2010). Evidence of source-sink metapopulations in a vulnerable native galaxiid fish driven by introduced trout. *Ecological Applications*, 20 (4), pp. 967-977.

Woodford, D.J., McIntosh, A.R. (2013). Effects of introduced trout predation on non-diadromous galaxiid fish populations across invaded riverscapes. *Science for Conservation*, (320), pp. 1-23.

Ye, Q., Bucater, L., Zampatti, B. P., Bice, C. M., Wilson, P. J., Suitor, L., Wegener, I. K., Short, D. A. & Fleer, D. (2015). Population dynamics and status of freshwater catfish (*Tandanus tandanus*) in the lower River Murray, South Australia. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2014/000903-1. SARDI Research Report Series No 841. 51pp.

Yick, J. L., Wisniewski, C., Diggle, J., & Patil, J. G. (2021). Eradication of the invasive common carp, *Cyprinus carpio* from a Large Lake: Lessons and insights from the Tasmanian experience. *Fishes*, 6(1), pp.1-17.

Zampatti, B.P., Bice, C.M. & Jennings, P.R. (2012). Fish assemblage response and fishway effectiveness at Goolwa, Tauwitchere and Hunters Creek Barrages in 2010/11. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000186-2. SARDI Research Report Series No. 605. 66pp.

APPENDIX 1. CATCHMENT SPECIES PRESENCE

Species present (X) in watercourses of the WMLR between 2007–2021. ANG AUS Anguilla australis, BID BID Bidyanus bidyanus,GAL BRE Galaxias brevipinnis, GAL MAC Galaxias maculatus, GAL OLI, Galaxias olidus HYP SPP Hypseleotris spp, MAC AMB Macquaria ambigua ambigua, MEL FLU Melanotaenia fluviatilis, NAN AUS Nannoperca australis, NEM ERE Nematalosa erebi, PHI GRA Philypnodon grandiceps, PHI MAC Philypnodon macrostomus, PSE OLO Pseudogobius olorum, PSE URV Pseudaphritis urvillii, TAN TAN Tandanus tandanus, CAR AUR Carassius auratus, CYP CAR Cyprinus carpio, GAM HOL Gambusia holbrooki, ONC MYK Oncorhynchus mykiss, PER FLU Perca fluviatilis, PHA CAU Phalloceros caudimaculatus, SAL TRU Salmo trutta, TIN TIN Tinca tinca

Catchment	Watercourse	ANG AUS	BID BID	GAL BRE	GAL MAC	GAL OLI	HYP SPP	MAC AMB	MEL FLU	NAN AUS	NEM ERE	PHI GRA	PHI MAC	PSE OLO	PSE URV	TAN TAN	CAR AUR	CYP CAR	GAM HOL	ONC MYK	PER FLU	PHA CAU	SAL TRU	TIN TIN
Boat Harbour	Boat Harbour			X	X																		X	
Boolaparudda Creek	Boolaparudda Creek East			X	X										X									
Bungala	Bungala River			X	X							X	X	X	X				X		X			
Callawonga	Callawonga			X	X										X								X	
Carrickalinga	Carrickalinga			X	X	X									X						X			
Christie's Creek	Christie's Creek				X												X		X					
Deep Creek	Deep Creek			X	X										X								X	
Field River	Field River				X			X				X			X	X		X		X	X			
Gawler	Gawler River				X							X		X	X		X	X	X					
Gawler	Greenock Creek																		X					
Gawler	Jacobs Creek					X						X									X			
Gawler	Little Para River						X					X							X					
Gawler	North Para River		X		X							X		X	X		X	X	X		X			X
Gawler	South Para River			X								X									X			
Gawler	Tanunda Creek					X													X					
Hindmarsh	Hindmarsh River	X		X	X	X			X			X	X	X	X				X	X	X		X	
Inman	BackValley Trib			X	X		X			X														
Inman	Boundy River			X						X									X					
Inman	Inman River	X		X	X		X				X	X		X	X			X	X		X			
Light	Light River				X							X					X	X	X					
Myponga	Myponga River			X	X	X						X	X	X	X				X		X			
Onkaparinga	Aldgate Creek			X		X													X		X			
Onkaparinga	Field River				X										X									
Onkaparinga	Lenswood Ck					X															X			
Onkaparinga	Onkaparinga River			X	X	X						X	X	X	X				X		X		X	
Onkaparinga	Scott Creek					X													X				X	
Parananacooka	Parananacooka				X										X									
Patawalonga	Brownhill Creek	X		X	X	X			X					X	X		X	X	X		X			
Patawalonga	Patawalonga				X									X					X					
Patawalonga	Sturt Creek				X	X								X		X		X	X	X	X		X	X
Pedler Creek	Pedler Creek				X	X								X	X		X	X	X					
Rarkang creek	Rarkang Creek			X	X																			
The Washpool	Washpool Creek				X							X			X									
Torrens	First Creek					X															X		X	
Torrens	Fourth Creek					X																		
Torrens	Lower Torrens River			X	X	X	X		X			X				X	X		X		X			
Torrens	Millers Creek					X																		
Torrens	Sixth Creek					X														X			X	
Torrens	Upper Torrens					X						X	X				X	X	X		X			
Tunkalilla	Tunkalilla Creek			X	X										X									
Willunga Creek	Willunga Creek					X																X		
Yankalilla	Yankalilla River			X	X	X						X			X								X	
Yattagolinga	Yattagolinga River			X	X																			

APPENDIX 2. BCG SCORES

BCG scores across the WMLR (n=467). Good (green) 1 to 2.7, intermediate (amber) 2.7 to 4.3 and poor (red) 4.3 to 6

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Boat Harbour	Boat Harbour	Boat Harbour Beach	Hills Fleurieu South	253984	6052940	20/06/2013	2.17
Boat Harbour	Boat Harbour	Boat Harbour Beach	Hills Fleurieu South	253984	6052940	5/12/2019	2.50
Boat Harbour	Boat Harbour	Boat Harbour Gate 42	Hills Fleurieu South	252865	6055571	19/06/2013	1.50
Boat Harbour	Boat Harbour	Boat Harbour Gate 42	Hills Fleurieu South	252865	6055571	4/12/2019	1.40
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	20/06/2013	2.50
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	12/11/2013	2.90
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	24/04/2015	1.20
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	21/10/2015	2.60
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	8/03/2016	1.50
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	30/11/2016	2.00
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	18/04/2017	1.50
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	14/12/2017	1.90
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	11/04/2019	2.30
Boat Harbour	Boat Harbour	Boat Harbour Gauge	Hills Fleurieu South	254144	6056107	5/12/2019	1.90
Boolaparudda Creek	Boolaparudda Creek East	Boolaparuda campsite	Hills Fleurieu South	264215	6055370	1/12/2016	2.56
Boolaparudda Creek	Boolaparudda Creek East	Boolaparuda campsite	Hills Fleurieu South	264215	6055370	12/04/2017	2.31
Boolaparudda Creek	Boolaparudda Creek East	Boolaparudda east DS	Hills Fleurieu South	264709	6053330	1/12/2016	3.14
Boolaparudda Creek	Boolaparudda Creek East	Boolaparudda east DS	Hills Fleurieu South	264709	6053330	12/04/2017	3.31
Boolaparudda Creek	Boolaparudda Creek East	Boolaparudda east gorge	Hills Fleurieu South	264949	6053827	1/12/2016	2.72
Boolaparudda Creek	Boolaparudda Creek East	Boolaparudda east gorge	Hills Fleurieu South	264949	6053827	12/04/2017	2.64
Boolaparudda Creek	Boolaparudda West	Boolaparudda West Dam	Hills Fleurieu South	264543	6053212	1/12/2016	4.20
Bungala	Bungala River	Bartletts	Hills Fleurieu South	260494	6071077	15/03/2011	3.72
Bungala	Bungala River	Bungala Caravan Park Bridge	Hills Fleurieu South	255785	6073996	16/03/2015	2.71
Bungala	Bungala River	Bungala Caravan Park Bridge	Hills Fleurieu South	255785	6073996	12/10/2015	2.89
Bungala	Bungala River	Bungala Caravan Park Bridge	Hills Fleurieu South	255785	6073996	23/03/2016	2.93
Bungala	Bungala River	Bungala Caravan Park Bridge	Hills Fleurieu South	255785	6073996	17/10/2016	3.11
Bungala	Bungala River	Bungala Caravan Park Bridge	Hills Fleurieu South	255785	6073996	3/04/2017	2.64
Bungala	Bungala River	Bungala Caravan Park Bridge	Hills Fleurieu South	255785	6073996	7/12/2017	2.93
Bungala	Bungala River	Bungala South Rd	Hills Fleurieu South	256512	6073933	15/03/2011	2.52
Bungala	Bungala River	Bungala South Rd	Hills Fleurieu South	256512	6073933	16/03/2015	2.45
Bungala	Bungala River	Bungala South Rd	Hills Fleurieu South	256512	6073933	12/10/2015	2.71
Bungala	Bungala River	Bungala South Rd	Hills Fleurieu South	256512	6073933	23/03/2016	2.88
Bungala	Bungala River	Bungala South Rd	Hills Fleurieu South	256512	6073933	17/10/2016	3.10
Bungala	Bungala River	Bungala South Rd	Hills Fleurieu South	256512	6073933	3/04/2017	2.52
Bungala	Bungala River	Bungala South Rd	Hills Fleurieu South	256512	6073933	7/12/2017	2.67
Bungala	Bungala River	Hay Flat Rd	Hills Fleurieu South	256971	6073610	15/03/2011	2.52
Bungala	Bungala River	Hay Flat Rd	Hills Fleurieu South	256971	6073610	16/03/2015	2.74
Bungala	Bungala River	Hay Flat Rd	Hills Fleurieu South	256971	6073610	12/10/2015	3.10
Bungala	Bungala River	Hay Flat Rd	Hills Fleurieu South	256971	6073610	23/03/2016	3.15
Bungala	Bungala River	Hay Flat Rd	Hills Fleurieu South	256971	6073610	17/10/2016	3.93
Bungala	Bungala River	Hay Flat Rd	Hills Fleurieu South	256971	6073610	3/04/2017	2.60
Bungala	Bungala River	Hay Flat Rd	Hills Fleurieu South	256971	6073610	7/12/2017	2.85
Bungala	Bungala River	Stornoway	Hills Fleurieu South	261975	6071430	15/03/2011	2.83
Bungala	Bungala River	Stornoway	Hills Fleurieu South	261975	6071430	10/04/2017	1.98
Bungala	Bungala River	Yankalilla Rec Centre	Hills Fleurieu South	259296	6072943	15/03/2011	3.45
Callawonga	Callawonga	Balquhidder	Hills Fleurieu South	262891	6054203	3/12/2012	3.94
Callawonga	Callawonga	Callawonga	Hills Fleurieu South	261823	6055504	13/11/2012	3.83
Callawonga	Callawonga	Callawonga Beach	Hills Fleurieu South	263314	6053185	3/12/2012	1.94

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Callawonga	Callawonga	Callawonga Dam	Hills Fleurieu South	263353	6060378	16/11/2012	3.67
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	12/11/2013	4.07
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	5/06/2014	4.47
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	23/04/2015	4.37
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	21/10/2015	4.47
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	8/03/2016	4.37
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	30/11/2016	4.27
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	18/04/2017	4.37
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	6/12/2017	4.27
Callawonga	Callawonga	Callawonga Gauge	Hills Fleurieu South	262147	6055176	11/04/2019	4.47
Callawonga	Callawonga	Walker's Place	Hills Fleurieu South	261239	6056293	13/11/2012	4.30
Callawonga	Callawonga	Walker's Waterfall	Hills Fleurieu South	261239	6056293	13/11/2012	2.33
Carrickalinga	Carrickalinga	Riverview Drive	Hills Fleurieu South	257133	6075782	11/06/2013	3.06
Carrickalinga	Carrickalinga	Riverview Drive	Hills Fleurieu South	257133	6075782	1/11/2016	2.43
Carrickalinga	Carrickalinga	Rose Cottage	Hills Fleurieu South	259671	6074597	9/06/2013	4.31
Carrickalinga	Carrickalinga	Rose Cottage	Hills Fleurieu South	259671	6074597	1/11/2016	4.47
Carrickalinga	Carrickalinga	Rose Cottage	Hills Fleurieu South	259671	6074597	13/12/2017	4.14
Christie's Creek	Christie's Creek	Christie Wetland	Green Adelaide	273287	6110639	29/05/2013	5.20
Christie's Creek	Christie's Creek	Galloway Rd	Green Adelaide	270456	6110088	29/05/2013	4.83
Christie's Creek	Christie's Creek	Thaxted Park Golf Course	Green Adelaide	277264	6110873	30/05/2013	4.80
Deep Creek	Deep Creek	Deep Creek Crossing	Hills Fleurieu South	249647	6054166	20/06/2013	3.25
Deep Creek	Deep Creek	Deep Creek Crossing	Hills Fleurieu South	249647	6054166	14/12/2017	2.60
Deep Creek	Deep Creek	Deep Creek Crossing	Hills Fleurieu South	249647	6054166	4/12/2019	2.50
Deep Creek	Deep Creek	Deep Creek Estuary	Hills Fleurieu South	250525	6051116	2/12/2019	1.58
Deep Creek	Deep Creek	Deep Creek Waterfall	Hills Fleurieu South	249285	6052091	18/06/2013	2.92
Deep Creek	Deep Creek	Deep Creek Waterfall	Hills Fleurieu South	249285	6052091	3/12/2019	2.17
Deep Creek	Deep Creek	Deep Creek WF Below	Hills Fleurieu South	249285	6052091	19/06/2013	3.00
Deep Creek	Deep Creek	Dog Trap Creek	Hills Fleurieu South	250289	6056528	16/03/2011	3.25
Deep Creek	Deep Creek	Dog Trap Creek	Hills Fleurieu South	250289	6056528	18/06/2013	2.50
Deep Creek	Deep Creek	Dog Trap Creek	Hills Fleurieu South	250289	6056528	2/12/2019	1.80
Deep Creek	Deep Creek	Rangers Pump	Hills Fleurieu South	250432	6056211	18/06/2013	4.21
Deep Creek	Deep Creek	Rangers Pump	Hills Fleurieu South	250432	6056211	24/04/2015	3.38
Deep Creek	Deep Creek	Wither Swamp	Hills Fleurieu South	248562	6053419	4/12/2019	1.20
Field River	Field River	Field	Green Adelaide	271668	6114451	4/05/2011	2.79
Field River	Field River	Field River 1	Green Adelaide	271537	6114751	11/05/2021	3.50
Field River	Field River	Field River 2	Green Adelaide	271623	6114526	11/05/2021	3.81
Field River	Field River	Field River 4	Green Adelaide	272090	6113997	11/05/2021	3.14
Field River	Field River	Field River 5	Green Adelaide	272208	6113899	11/05/2021	3.64
Field River	Field River	Railway Tunnel	Green Adelaide	271807	6114210	25/03/2015	3.05
Field River	Field River	Railway Tunnel	Green Adelaide	271807	6114210	19/10/2015	2.76
Field River	Field River	Railway Tunnel	Green Adelaide	271807	6114210	9/03/2016	2.43
Field River	Field River	Railway Tunnel	Green Adelaide	271807	6114210	19/04/2017	2.29
Field River	Field River	Railway Tunnel	Green Adelaide	271807	6114210	13/12/2017	2.29
Field River	Field River	Railway Tunnel	Green Adelaide	271807	6114210	9/04/2019	2.71
Field River	Field River	Railway Tunnel	Green Adelaide	271807	6114210	11/05/2021	3.00
Gawler	Duck Ponds Creek	DS Duck Ponds Pool	Northern Yorke	322970	6186088	18/02/2013	4.80
Gawler	Duck Ponds Creek	Rex's Place	Northern Yorke	324742	6186174	18/02/2013	4.80
Gawler	Duck Ponds Creek	US Duck Ponds Pool	Northern Yorke	322970	6186088	18/02/2013	4.80
Gawler	Gawler River	Gawler Dam	Northern Yorke	295441	6173116	22/03/2011	4.50
Gawler	Gawler River	Gawler Flood Pool	Northern Yorke	287628	6167168	24/06/2013	4.07
Gawler	Gawler River	Old Port Wakefield Road	Northern Yorke	275237	6164525	24/06/2013	4.36
Gawler	Gawler River	Pony Club	Northern Yorke	290650	6167442	22/03/2011	4.40
Gawler	Gawler River	Pony Club	Northern Yorke	290650	6167442	24/06/2013	4.04

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Gawler	Greenock Creek	Owen's Grange	Northern Yorke	309444	6180519	14/02/2013	4.60
Gawler	Greenock Creek	Owen's Grange Hermitage	Northern Yorke	309444	6180519	14/02/2013	4.60
Gawler	Greenock Creek	Seppeltsfield Weir	Northern Yorke	309001	6183865	14/02/2013	5.63
Gawler	Jacobs Creek	Jacobs Creek Crossing	Northern Yorke	311077	6173269	7/02/2013	3.45
Gawler	Jacobs Creek	Jacobs Creek Old Gauge	Northern Yorke	312983	6172766	11/02/2013	2.74
Gawler	Jacobs Creek	Jacobs Creek Old Gauge	Northern Yorke	312983	6172766	7/11/2013	2.67
Gawler	Jacobs Creek	Jacobs Creek Old Gauge	Northern Yorke	312983	6172766	29/05/2014	2.74
Gawler	Jacobs Creek	Jacobs Creek Old Gauge	Northern Yorke	312983	6172766	2/05/2017	3.10
Gawler	Jacobs Creek	Jacobs Creek Visitors Centre	Northern Yorke	310541	6173476	7/02/2013	3.69
Gawler	Little Para River	Happy Home Reserve	Northern Yorke	284168	6151175	25/06/2013	4.24
Gawler	Little Para River	Old Spot	Northern Yorke	287667	6151695	22/03/2011	4.24
Gawler	Little Para River	One Tree Hill Crossing	Northern Yorke	294464	6150854	5/02/2013	4.45
Gawler	Little Para River	Whites Road Wetland	Northern Yorke	279514	6148445	25/06/2013	4.81
Gawler	North Para River	Barossa Novotel	Northern Yorke	311941	6177837	11/02/2013	4.18
Gawler	North Para River	Brooks Property	Northern Yorke	324059	6174302	21/02/2013	4.78
Gawler	North Para River	Cornerstone Stud	Northern Yorke	324015	6174813	20/02/2013	4.60
Gawler	North Para River	DS Chattertons	Northern Yorke	307320	6172830	4/02/2013	4.57
Gawler	North Para River	DS Evans Weir	Northern Yorke	323664	6177070	20/02/2013	4.82
Gawler	North Para River	DS Landcare Reserve	Northern Yorke	308654	6172059	7/02/2013	4.67
Gawler	North Para River	DS Matchos	Northern Yorke	313802	6180918	13/02/2013	4.86
Gawler	North Para River	DS Nuritoopta Caravan Park	Northern Yorke	316956	6184088	14/02/2013	4.86
Gawler	North Para River	Gomersal Rd Bridge	Northern Yorke	311447	6176663	23/03/2015	5.19
Gawler	North Para River	Gomersal Rd Bridge	Northern Yorke	311447	6176663	3/03/2016	5.24
Gawler	North Para River	Gomersal Rd Bridge	Northern Yorke	311447	6176663	2/05/2017	4.95
Gawler	North Para River	Gomersal Rd Bridge	Northern Yorke	311447	6176663	8/04/2019	4.88
Gawler	North Para River	Gumhill	Northern Yorke	323610	6182763	27/03/2013	5.14
Gawler	North Para River	Hahn's paddock	Northern Yorke	314324	6181706	13/02/2013	4.74
Gawler	North Para River	Kochs	Northern Yorke	306431	6172616	4/02/2013	4.60
Gawler	North Para River	Moculta	Northern Yorke	327282	6184778	10/03/2011	4.73
Gawler	North Para River	Mt McKenzie	Northern Yorke	323913	6173438	10/03/2011	4.78
Gawler	North Para River	Mt McKenzie	Northern Yorke	323913	6173438	4/11/2013	4.69
Gawler	North Para River	North Para Old Gauge	Northern Yorke	323842	6172738	19/02/2013	4.94
Gawler	North Para River	North Para Old Gauge	Northern Yorke	323842	6172738	2/06/2014	4.86
Gawler	North Para River	Nuriootpa	Northern Yorke	316838	6183919	10/03/2011	4.22
Gawler	North Para River	Nuritootpa Caravan Park	Northern Yorke	316956	6184088	14/02/2013	4.39
Gawler	North Para River	Old Moculta Bridge	Northern Yorke	323077	6184249	18/02/2013	5.24
Gawler	North Para River	Penrice gauge	Northern Yorke	321644	6184762	5/11/2013	5.02
Gawler	North Para River	Penrice Quarry	Northern Yorke	321912	6184861	21/02/2013	4.88
Gawler	North Para River	Penrice Quarry	Northern Yorke	321912	6184861	6/11/2013	4.38
Gawler	North Para River	Penrice Quarry	Northern Yorke	321912	6184861	2/06/2014	4.95
Gawler	North Para River	Penrice Quarry 2	Northern Yorke	321912	6184861	21/02/2013	5.27
Gawler	North Para River	Smithe St Crossing	Northern Yorke	312702	6178876	13/02/2013	4.62
Gawler	North Para River	St Hallets Bike Path	Northern Yorke	310805	6174301	11/02/2013	4.55
Gawler	North Para River	St Hallets Crossing (138)	Northern Yorke	311326	6174943	12/02/2013	4.65
Gawler	North Para River	Tanunda Heinemann Guage	Northern Yorke	311706	6177112	12/02/2013	4.95
Gawler	North Para River	Tanunda Township	Northern Yorke	311941	6177837	12/02/2013	4.75
Gawler	North Para River	Third Evan's Weir	Northern Yorke	323543	6178226	27/03/2013	4.69
Gawler	North Para River	Thorne-Clarke Ford	Northern Yorke	323603	6180600	18/02/2013	5.40
Gawler	North Para River	US Chattertons	Northern Yorke	307467	6172586	5/02/2013	4.17
Gawler	North Para River	US Cornerstone Stud	Northern Yorke	322875	6174371	21/02/2013	4.61
Gawler	North Para River	US Evan's Weir	Northern Yorke	323677	6177029	20/02/2013	4.94
Gawler	North Para River	US Landcare Reserve	Northern Yorke	309093	6171107	7/02/2013	4.92
Gawler	North Para River	US McEvoy Weir	Northern Yorke	323154	6179163	19/02/2013	4.82

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Gawler	North Para River	US Thorne-Clarke	Northern Yorke	323446	6179772	19/02/2013	4.86
Gawler	North Para River	US Yaldara weir	Northern Yorke	305977	6172421	4/02/2013	4.24
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	11/03/2011	3.96
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	4/02/2013	4.21
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	6/11/2013	4.00
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	28/05/2014	4.04
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	23/03/2015	4.39
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	6/10/2015	4.38
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	3/03/2016	4.25
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	8/11/2016	3.93
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	2/05/2017	4.50
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	12/12/2017	4.24
Gawler	North Para River	Yaldara	Northern Yorke	305086	6172145	8/04/2019	4.36
Gawler	South Para River	Mt Crawford	Northern Yorke	313033	6158509	11/03/2011	3.64
Gawler	South Para River	Mt Crawford	Northern Yorke	313033	6158509	1/05/2017	2.89
Gawler	South Para River	Portuguese Bridge	Northern Yorke	315604	6159517	11/03/2011	3.80
Gawler	South Para River	Victoria Creek	Northern Yorke	307970	6161152	11/03/2011	1.72
Gawler	South Para River	Victoria Creek	Northern Yorke	307970	6161152	2/03/2016	2.39
Gawler	South Para River	Victoria Reserve	Northern Yorke	306706	6161154	2/03/2016	3.67
Gawler	Tanunda Creek	DS Tanunda Creek Rd	Northern Yorke	318378	6175335	6/02/2013	5.33
Gawler	Tanunda Creek	Tanunda Ck Gauge	Northern Yorke	315074	6175575	5/11/2013	3.44
Gawler	Tanunda Creek	Tanunda Ck Gauge	Northern Yorke	315074	6175575	29/05/2014	3.93
Gawler	Tanunda Creek	Tanunda Ck Gauge	Northern Yorke	315074	6175575	6/10/2015	3.93
Gawler	Tanunda Creek	Tanunda Ck Gauge	Northern Yorke	315074	6175575	8/11/2016	3.69
Gawler	Tanunda Creek	Tanunda Ck Gauge	Northern Yorke	315074	6175575	12/12/2017	3.78
Gawler	Tanunda Creek	Tanunda Railway Crossing	Northern Yorke	313406	6176528	6/02/2013	4.40
Gawler	Tanunda Creek	US Tanunda Creek Rd	Northern Yorke	318698	6174762	6/02/2013	4.77
Hindmarsh	Hindmarsh River	Byrt	Hills Fleurieu South	280411	6076816	9/12/2019	3.44
Hindmarsh	Hindmarsh River	Cootamundra Reserve	Hills Fleurieu South	284630	6065460	17/03/2011	2.65
Hindmarsh	Hindmarsh River	Cootamundra Reserve	Hills Fleurieu South	284630	6065460	26/06/2013	2.62
Hindmarsh	Hindmarsh River	Cootamundra Reserve	Hills Fleurieu South	284630	6065460	19/03/2015	2.81
Hindmarsh	Hindmarsh River	Cootamundra Reserve	Hills Fleurieu South	284630	6065460	14/10/2015	2.43
Hindmarsh	Hindmarsh River	Cootamundra Reserve	Hills Fleurieu South	284630	6065460	10/03/2016	2.36
Hindmarsh	Hindmarsh River	Cootamundra Reserve	Hills Fleurieu South	284630	6065460	3/11/2016	2.71
Hindmarsh	Hindmarsh River	Cootamundra Reserve	Hills Fleurieu South	284630	6065460	6/04/2017	2.43
Hindmarsh	Hindmarsh River	Cootamundra Reserve	Hills Fleurieu South	284630	6065460	4/12/2017	2.76
Hindmarsh	Hindmarsh River	Coxes	Hills Fleurieu South	280608	6072969	10/12/2019	2.76
Hindmarsh	Hindmarsh River	Cressbrook	Hills Fleurieu South	280408	6075626	9/12/2019	4.03
Hindmarsh	Hindmarsh River	Hindmarsh Estuary	Hills Fleurieu South	284830	6064037	19/03/2015	3.31
Hindmarsh	Hindmarsh River	Hindmarsh Estuary	Hills Fleurieu South	284830	6064037	14/10/2015	2.44
Hindmarsh	Hindmarsh River	Hindmarsh Estuary	Hills Fleurieu South	284830	6064037	10/03/2016	2.95
Hindmarsh	Hindmarsh River	Hindmarsh Estuary	Hills Fleurieu South	284830	6064037	3/11/2016	2.70
Hindmarsh	Hindmarsh River	Hindmarsh Estuary	Hills Fleurieu South	284830	6064037	6/04/2017	2.92
Hindmarsh	Hindmarsh River	Hindmarsh Estuary	Hills Fleurieu South	284830	6064037	4/12/2017	2.81
Hindmarsh	Hindmarsh River	Hindmarsh Falls	Hills Fleurieu South	280549	6075438	17/03/2011	1.69
Hindmarsh	Hindmarsh River	Hindmarsh Falls	Hills Fleurieu South	280549	6075438	25/06/2013	3.11
Hindmarsh	Hindmarsh River	Hindmarsh Falls	Hills Fleurieu South	280549	6075438	13/11/2013	2.94
Hindmarsh	Hindmarsh River	Hindmarsh Falls	Hills Fleurieu South	280549	6075438	3/06/2014	3.94
Hindmarsh	Hindmarsh River	Hindmarsh Falls	Hills Fleurieu South	280549	6075438	16/04/2019	3.94
Hindmarsh	Hindmarsh River	Hindmarsh Gauge	Hills Fleurieu South	284397	6066670	3/06/2014	1.93
Hindmarsh	Hindmarsh River	Hindmarsh Gauge	Hills Fleurieu South	284397	6066670	27/06/2014	2.40
Hindmarsh	Hindmarsh River	Hindmarsh Gauge	Hills Fleurieu South	284397	6066670	22/03/2016	2.26
Hindmarsh	Hindmarsh River	Hindmarsh Gauge	Hills Fleurieu South	284397	6066670	11/04/2017	2.26

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Hindmarsh	Hindmarsh River	Hindmarsh Gauge	Hills Fleurieu South	284397	6066670	4/12/2017	2.79
Hindmarsh	Hindmarsh River	Hindmarsh Gauge	Hills Fleurieu South	284397	6066670	10/04/2019	2.49
Hindmarsh	Hindmarsh River	Hindmarsh Gauge	Hills Fleurieu South	284397	6066670	13/10/2020	2.21
Hindmarsh	Hindmarsh River	Lamont Rd	Hills Fleurieu South	284422	6064459	19/03/2015	3.50
Hindmarsh	Hindmarsh River	Lamont Rd	Hills Fleurieu South	284422	6064459	14/10/2015	2.90
Hindmarsh	Hindmarsh River	Lamont Rd	Hills Fleurieu South	284422	6064459	10/03/2016	3.86
Hindmarsh	Hindmarsh River	Lamont Rd	Hills Fleurieu South	284422	6064459	3/11/2016	3.36
Hindmarsh	Hindmarsh River	Lamont Rd	Hills Fleurieu South	284422	6064459	6/04/2017	2.87
Hindmarsh	Hindmarsh River	Lamont Rd	Hills Fleurieu South	284422	6064459	4/12/2017	2.75
Hindmarsh	Hindmarsh River	SAWater Lower Falls	Hills Fleurieu South	280928	6074736	10/12/2019	4.06
Hindmarsh	Hindmarsh River	SAWater Lower Falls	Hills Fleurieu South	280549	6075438	10/12/2019	3.68
Hindmarsh	Hindmarsh River	Sawpit Rd	Hills Fleurieu South	281054	6072445	18/03/2011	2.13
Hindmarsh	Hindmarsh River	Sawpit Rd	Hills Fleurieu South	281054	6072445	25/06/2013	2.88
Hindmarsh	Hindmarsh River	Sawpit Rd	Hills Fleurieu South	281054	6072445	16/04/2019	2.95
Hindmarsh	Hindmarsh River	Sawpit Rd	Hills Fleurieu South	281054	6072445	10/12/2019	3.06
Hindmarsh	Hindmarsh River	Wardle Bridge	Hills Fleurieu South	283721	6070058	17/04/2019	2.93
Inman	BackValley Trib	BackValley Gauge	Hills Fleurieu South	273970	6064352	17/03/2011	4.36
Inman	BackValley Trib	BackValley Gauge	Hills Fleurieu South	273970	6064352	13/11/2013	3.43
Inman	BackValley Trib	BackValley Gauge	Hills Fleurieu South	273970	6064352	5/06/2014	3.50
Inman	BackValley Trib	BackValley Gauge	Hills Fleurieu South	273970	6064352	23/04/2015	3.29
Inman	BackValley Trib	Dunstan 1	Hills Fleurieu South	277313	6065255	23/04/2020	3.36
Inman	BackValley Trib	Dunstan 2	Hills Fleurieu South	277444	6065340	23/04/2020	3.64
Inman	BackValley Trib	Hastings 1	Hills Fleurieu South	272980	6064138	23/04/2020	3.71
Inman	BackValley Trib	Hastings 10	Hills Fleurieu South	273966	6064379	23/04/2020	3.83
Inman	BackValley Trib	Hastings 2	Hills Fleurieu South	272999	6064130	23/04/2020	3.93
Inman	BackValley Trib	Hastings 3	Hills Fleurieu South	273130	6064172	23/04/2020	4.21
Inman	BackValley Trib	Hastings 4	Hills Fleurieu South	273194	6064219	23/04/2020	4.42
Inman	BackValley Trib	Hastings 5	Hills Fleurieu South	273339	6064272	23/04/2020	4.14
Inman	BackValley Trib	Hastings 6	Hills Fleurieu South	273415	6064262	23/04/2020	3.71
Inman	BackValley Trib	Hastings 7	Hills Fleurieu South	273603	6064254	23/04/2020	4.25
Inman	BackValley Trib	Hastings 8	Hills Fleurieu South	273750	6064324	23/04/2020	4.50
Inman	BackValley Trib	Hastings 9	Hills Fleurieu South	273802	6064391	23/04/2020	3.83
Inman	BackValley Trib	Robertson 1	Hills Fleurieu South	276880	6065246	17/04/2019	3.11
Inman	BackValley Trib	Robertson 2	Hills Fleurieu South	277228	6065262	17/04/2019	3.14
Inman	BackValley Trib	Robin 1	Hills Fleurieu South	274484	6064707	17/04/2019	4.21
Inman	BackValley Trib	Robin 2	Hills Fleurieu South	274664	6064846	17/04/2019	2.79
Inman	Boundy River	Teague Property	Hills Fleurieu South	271165	6072083	15/11/2012	2.57
Inman	Inman River	Armstrong Rd Bridge	Hills Fleurieu South	283146	6063206	18/03/2015	3.94
Inman	Inman River	Armstrong Rd Bridge	Hills Fleurieu South	283146	6063206	13/10/2015	4.00
Inman	Inman River	Armstrong Rd Bridge	Hills Fleurieu South	283146	6063206	7/03/2016	3.75
Inman	Inman River	Armstrong Rd Bridge	Hills Fleurieu South	283146	6063206	2/11/2016	3.44
Inman	Inman River	Armstrong Rd Bridge	Hills Fleurieu South	283146	6063206	5/04/2017	3.63
Inman	Inman River	Armstrong Rd Bridge	Hills Fleurieu South	283146	6063206	5/12/2017	3.78
Inman	Inman River	Forrest Dam	Hills Fleurieu South	271766	6068367	4/12/2012	3.67
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	17/03/2011	4.24
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	20/11/2012	3.95
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	13/11/2013	3.31
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	4/06/2014	3.45
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	24/04/2015	3.45
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	15/10/2015	3.67
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	9/03/2016	4.15
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	1/11/2016	4.02
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	11/04/2017	4.17

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	6/12/2017	4.10
Inman	Inman River	Glacier Rock	Hills Fleurieu South	274479	6069038	11/04/2019	3.95
Inman	Inman River	Gunter's	Hills Fleurieu South	276077	6068639	14/11/2012	4.42
Inman	Inman River	Hay Bales	Hills Fleurieu South	271165	6072083	15/11/2012	4.33
Inman	Inman River	Inman Divine Gauge	Hills Fleurieu South	280615	6063902	17/03/2011	4.00
Inman	Inman River	Inman Divine Gauge	Hills Fleurieu South	280615	6063902	23/04/2015	3.93
Inman	Inman River	Inman Divine Gauge	Hills Fleurieu South	280615	6063902	15/10/2015	4.11
Inman	Inman River	Inman Divine Gauge	Hills Fleurieu South	280615	6063902	9/03/2016	4.04
Inman	Inman River	Inman Divine Gauge	Hills Fleurieu South	280615	6063902	11/04/2017	3.85
Inman	Inman River	Inman Divine Gauge	Hills Fleurieu South	280615	6063902	6/12/2017	3.98
Inman	Inman River	Inman Divine Gauge	Hills Fleurieu South	280615	6063902	10/04/2019	3.75
Inman	Inman River	Inman estuary	Hills Fleurieu South	283376	6062134	18/03/2015	3.43
Inman	Inman River	Inman estuary	Hills Fleurieu South	283376	6062134	13/10/2015	2.74
Inman	Inman River	Inman estuary	Hills Fleurieu South	283376	6062134	7/03/2016	3.09
Inman	Inman River	Inman estuary	Hills Fleurieu South	283376	6062134	2/11/2016	2.99
Inman	Inman River	Inman estuary	Hills Fleurieu South	283376	6062134	5/04/2017	2.80
Inman	Inman River	Inman estuary	Hills Fleurieu South	283376	6062134	5/12/2017	2.49
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	20/11/2012	4.43
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	13/11/2013	4.21
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	4/06/2014	3.79
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	18/03/2015	4.50
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	13/10/2015	4.11
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	7/03/2016	4.25
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	2/11/2016	4.75
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	5/04/2017	4.14
Inman	Inman River	Swains Crossing Road	Hills Fleurieu South	282000	6064240	5/12/2017	4.79
Inman	Inman River	White's Property	Hills Fleurieu South	277846	6067803	14/11/2012	4.60
Inman	Sawpit Gully	Walker	Hills Fleurieu South	278292	6069290	16/04/2019	4.17
Light	Light River	Light Ford	Northern Yorke	305541	6194389	9/03/2011	4.50
Light	Light River	Marrabel	Northern Yorke	304599	6220354	9/03/2011	3.70
Light	Light River	Rockies	Northern Yorke	279557	6191998	9/03/2011	3.86
Myponga	Myponga River	DS Myponga River Gauge	Hills Fleurieu South	274911	6085605	3/12/2012	3.83
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	4/10/2006	2.20
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	6/07/2007	2.38
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	26/09/2007	2.38
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	18/12/2007	1.95
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	18/03/2008	2.38
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	10/07/2008	2.17
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	17/03/2015	2.35
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	20/10/2015	2.88
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	22/03/2016	2.62
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	31/10/2016	2.85
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	30/11/2016	2.42
Myponga	Myponga River	Myponga estuary	Hills Fleurieu South	262875	6082021	10/04/2017	2.49
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	4/10/2006	3.14
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	6/07/2007	3.07
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	26/09/2007	3.00
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	18/12/2007	2.29
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	18/03/2008	2.64
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	10/07/2008	2.64
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	17/03/2015	3.00
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	20/10/2015	2.57
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	22/03/2016	2.79

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	31/10/2016	2.18
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	30/11/2016	2.64
Myponga	Myponga River	Myponga pumphouse	Hills Fleurieu South	262586	6081770	10/04/2017	2.29
Myponga	Myponga River	Myponga Township	Hills Fleurieu South	269884	6080978	15/07/2011	5.05
Myponga	Myponga River	Myponga Township	Hills Fleurieu South	269884	6080978	21/11/2012	4.33
Myponga	Myponga River	Myponga Township	Hills Fleurieu South	269884	6080978	13/10/2020	4.80
Myponga	Myponga River	Pages Flat	Hills Fleurieu South	271331	6082284	14/07/2011	4.17
Myponga	Myponga River	Pages Flat	Hills Fleurieu South	271331	6082284	17/03/2015	4.29
Myponga	Myponga River	Pages Flat	Hills Fleurieu South	271331	6082284	13/10/2020	3.75
Myponga	Myponga River	Roger's Property	Hills Fleurieu South	273088	6083605	21/11/2012	3.17
Myponga	Myponga River	Rogers Rd Culvert	Hills Fleurieu South	273191	6084172	22/11/2012	4.08
Onkaparinga	Aldgate Creek	Aldgate Bridge	Hills Fleurieu North	293239	6123008	4/12/2012	3.73
Onkaparinga	Aldgate Creek	Aldgate Bridge	Hills Fleurieu North	293239	6123008	14/11/2013	2.98
Onkaparinga	Aldgate Creek	Dixons	Hills Fleurieu North	295518	6120653	12/12/2012	2.94
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	4/12/2012	2.73
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	26/05/2014	2.54
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	24/03/2015	2.85
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	7/10/2015	2.67
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	1/03/2016	3.17
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	9/11/2016	2.98
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	20/04/2017	2.98
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	13/12/2017	2.85
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	9/04/2019	2.85
Onkaparinga	Aldgate Creek	Mylor Bridge	Hills Fleurieu North	295761	6120278	21/04/2020	2.73
Onkaparinga	Aldgate Creek	Mylor Creek Dam	Hills Fleurieu North	295826	6119267	12/12/2012	4.60
Onkaparinga	Aldgate Creek	Nurrutti Reserve	Hills Fleurieu North	294131	6121078	12/12/2012	3.35
Onkaparinga	Lenswood Ck	Lenswood Gauge	Hills Fleurieu North	301139	6131973	29/11/2013	1.80
Onkaparinga	Lenswood Ck	Lenswood Gauge	Hills Fleurieu North	301139	6131973	27/05/2014	2.50
Onkaparinga	Lenswood Ck	Lenswood Gauge	Hills Fleurieu North	301139	6131973	8/11/2016	2.60
Onkaparinga	Lenswood Ck	Lenswood Gauge	Hills Fleurieu North	301139	6131973	1/05/2017	3.00
Onkaparinga	Lenswood Ck	Lenswood Gauge	Hills Fleurieu North	301139	6131973	11/12/2017	2.70
Onkaparinga	Lenswood Ck	Lenswood Gauge	Hills Fleurieu North	301139	6131973	8/04/2019	2.30
Onkaparinga	Lenswood Ck	Lenswood Gauge	Hills Fleurieu North	301139	6131973	21/04/2020	2.20
Onkaparinga	Onkaparinga River	Bakers Gully	Hills Fleurieu North	284297	6109157	13/07/2011	3.48
Onkaparinga	Onkaparinga River	Charleston	Hills Fleurieu North	308119	6134228	13/05/2011	3.90
Onkaparinga	Onkaparinga River	Charleston	Hills Fleurieu North	308119	6134228	5/06/2013	3.71
Onkaparinga	Onkaparinga River	Clisby Rd	Hills Fleurieu North	304611	6128240	5/06/2013	4.98
Onkaparinga	Onkaparinga River	Clisby Rd	Hills Fleurieu North	304611	6128240	20/04/2020	4.29
Onkaparinga	Onkaparinga River	Cox Creek	Hills Fleurieu North	294812	6124922	12/07/2011	3.63
Onkaparinga	Onkaparinga River	Hahndorf	Hills Fleurieu North	298451	6122459	13/05/2011	4.67
Onkaparinga	Onkaparinga River	MtBoldGate4	Hills Fleurieu North	286359	6112613	19/10/2015	4.98
Onkaparinga	Onkaparinga River	Oakbank	Hills Fleurieu North	301814	6126098	12/05/2011	4.98
Onkaparinga	Onkaparinga River	Oakwood Rd	Hills Fleurieu North	302927	6126893	5/06/2013	5.04
Onkaparinga	Onkaparinga River	Silverlakes	Hills Fleurieu North	295609	6116731	12/05/2011	4.63
Onkaparinga	Onkaparinga River	Silverlakes	Hills Fleurieu North	295609	6116731	5/06/2013	4.57
Onkaparinga	Onkaparinga River	Spoehrs Rd	Hills Fleurieu North	300274	6125278	5/06/2013	5.48
Onkaparinga	Onkaparinga River	Tiers Rd	Hills Fleurieu North	305803	6130233	20/04/2020	4.48
Onkaparinga	Onkaparinga River	Verdun	Hills Fleurieu North	298796	6123926	5/06/2013	5.05
Onkaparinga	Scott Creek	Scott Creek	Green Adelaide	289274	6117015	13/07/2011	3.40
Onkaparinga	Scott Creek	Scott Creek	Green Adelaide	289274	6117015	3/06/2013	3.40
Onkaparinga	Scott Creek	Scott Creek Cons. Park	Green Adelaide	288566	6115115	13/07/2011	3.61
Onkaparinga	Scott Creek	Scott Creek Gauge	Green Adelaide	288010	6113418	3/06/2013	3.92
Onkaparinga	Scott Creek	Scott Creek Gauge	Green Adelaide	288010	6113418	1/03/2016	3.92

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Paranancooka	Parananacooka	Old Bridge	Hills Fleurieu South	247668	6066547	7/12/2017	3.08
Patawalonga	Brownhill Creek	Brownhill Creek US	Green Adelaide	285345	6125646	5/03/2011	3.58
Patawalonga	Brownhill Creek	Brownhill Creek US	Green Adelaide	285345	6125646	14/11/2013	3.33
Patawalonga	Brownhill Creek	Brownhill Creek US	Green Adelaide	285345	6125646	9/04/2019	4.17
Patawalonga	Brownhill Creek	Brownhill Ford	Green Adelaide	285344	6125645	24/01/2013	3.06
Patawalonga	Brownhill Creek	Craigburn Dam	Green Adelaide	281583	6119478	24/03/2015	5.19
Patawalonga	Brownhill Creek	DS Brownhill Caravan Park	Green Adelaide	283296	6126115	5/03/2011	4.42
Patawalonga	Brownhill Creek	DS Brownhill Caravan Park	Green Adelaide	283296	6126115	24/01/2013	4.25
Patawalonga	Brownhill Creek	DS Brownhill Caravan Park	Green Adelaide	283296	6126115	26/05/2014	3.67
Patawalonga	Brownhill Creek	DS Brownhill Caravan Park	Green Adelaide	283296	6126115	7/10/2015	3.42
Patawalonga	Brownhill Creek	DS Brownhill Caravan Park	Green Adelaide	283296	6126115	9/11/2016	3.33
Patawalonga	Brownhill Creek	DS Brownhill Caravan Park	Green Adelaide	283296	6126115	20/04/2017	4.17
Patawalonga	Brownhill Creek	DS Brownhill Caravan Park	Green Adelaide	283296	6126115	11/12/2017	3.67
Patawalonga	Brownhill Creek	DS Brownhill Caravan Park	Green Adelaide	283296	6126115	12/10/2020	4.25
Patawalonga	Brownhill Creek	Elliston Creek	Green Adelaide	284884	6126071	7/03/2011	3.50
Patawalonga	Brownhill Creek	Lake Michigan	Green Adelaide	286906	6126827	7/03/2011	3.67
Patawalonga	Brownhill Creek	Patawolonga	Green Adelaide	273370	6128469	14/07/2011	3.93
Patawalonga	Brownhill Creek	US Caravan Park	Green Adelaide	283322	6126002	1/03/2016	3.67
Patawalonga	Patawalonga	Adelaide Shores Golf Course	Green Adelaide	272861	6129566	25/06/2013	4.13
Patawalonga	Patawalonga	Adelaide Shores Skate Park	Green Adelaide	272917	6128528	25/06/2013	3.44
Patawalonga	Patawalonga	West Beach Road Bridge	Green Adelaide	272954	6130215	25/06/2013	4.13
Patawalonga	Patawalonga	West Beach Road Bridge	Green Adelaide	272954	6130215	11/12/2017	3.88
Patawalonga	Sturt Creek	Cherry Plantation	Green Adelaide	287394	6122713	2/03/2011	2.63
Patawalonga	Sturt Creek	Cherry Plantation	Green Adelaide	287394	6122713	13/06/2013	2.23
Patawalonga	Sturt Creek	DS Sturt Gorge Retention Dam	Green Adelaide	280217	6119735	7/10/2015	4.55
Patawalonga	Sturt Creek	Frank Smith Park	Green Adelaide	283655	6120736	23/05/2013	5.52
Patawalonga	Sturt Creek	Railway Dam Belair NP	Green Adelaide	285505	6122967	3/03/2011	3.50
Patawalonga	Sturt Creek	Riverglen Place	Green Adelaide	282016	6118768	4/03/2011	4.83
Patawalonga	Sturt Creek	Riverglen Place	Green Adelaide	282016	6118768	30/05/2013	5.00
Patawalonga	Sturt Creek	Riverglen Place	Green Adelaide	282016	6118768	22/04/2020	4.10
Patawalonga	Sturt Creek	Riverside Reserve	Green Adelaide	277735	6121455	4/03/2011	4.54
Patawalonga	Sturt Creek	Star & Arrow Rd	Green Adelaide	286850	6117906	13/06/2013	4.33
Patawalonga	Sturt Creek	Sturt Creek Trib	Green Adelaide	287827	6120919	3/03/2011	2.60
Patawalonga	Sturt Creek	Sturt Valley Rd	Hills Fleurieu North	289107	6121756	13/06/2013	4.33
Patawalonga	Sturt Creek	US Sturt Gorge FloodRetention Dam	Green Adelaide	280414	6119532	7/10/2015	4.80
Patawalonga	Sturt Creek	Warraparinga	Green Adelaide	277517	6121972	4/03/2011	4.00
Patawalonga	Sturt Creek	Weymouth Horse Trail	Green Adelaide	285727	6117971	28/05/2013	2.90
Patawalonga	Sturt Creek	Weymouth Reserve	Green Adelaide	282891	6118517	28/05/2013	3.20
Patawalonga	Sturt Creek	Willow Glen	Green Adelaide	287977	6121111	3/03/2011	4.92
Patawalonga	Sturt Creek	Willow Glen	Green Adelaide	287977	6121111	30/05/2013	4.54
Patawalonga	Sturt Creek	Wynns Rd	Green Adelaide	283215	6120313	30/05/2013	5.50
Pedler Creek	Pedler Creek	Commercial Rd Flood Ponds	Green Adelaide	270612	6101433	5/05/2011	5.28
Pedler Creek	Pedler Creek	DS Pedler Footbridge	Green Adelaide	270694	6100877	12/06/2013	4.00
Pedler Creek	Pedler Creek	Nashwauk	Green Adelaide	270612	6101433	5/05/2011	4.38
Rarkang creek	Rarkang Creek	Rarkang Dam	Hills Fleurieu South	242827	6051204	26/03/2015	1.81
The Washpool	Washpool Creek	Washpool	Green Adelaide	268118	6088618	5/05/2011	3.40
The Washpool	Washpool Creek	Washpool	Green Adelaide	268118	6088618	12/06/2013	4.55
The Washpool	Washpool Creek	Washpool US barrier	Green Adelaide	268172	6088699	12/06/2013	3.89
Torrens	First Creek	Chinaman's Hut	Hills Fleurieu North	288770	6127490	23/01/2013	1.30
Torrens	First Creek	Chinaman's Hut	Hills Fleurieu North	288770	6127490	10/11/2016	1.50
Torrens	First Creek	Chinaman's Hut	Hills Fleurieu North	288770	6127490	12/10/2020	1.40
Torrens	First Creek	Waterfall Gully	Green Adelaide	288379	6127717	10/05/2011	2.40
Torrens	First Creek	Waterfall Gully	Green Adelaide	288379	6127717	23/01/2013	1.50

Catchment	Watercourse	Site Name	Landscape Region	Easting	Northing	Date	BCG Score
Torrens	First Creek	Waterfall Gully	Green Adelaide	288379	6127717	29/11/2013	2.30
Torrens	First Creek	Waterfall Gully	Green Adelaide	288379	6127717	10/11/2016	1.50
Torrens	First Creek	Waterfall Gully Road	Green Adelaide	288058	6128307	12/10/2020	3.71
Torrens	Fourth Creek	Morialta	Hills Fleurieu North	290547	6135186	10/05/2011	1.47
Torrens	Lower Torrens River	Breakout HB Rd	Green Adelaide	273644	6132456	2/11/2012	4.57
Torrens	Lower Torrens River	Breakout HB Rd	Green Adelaide	273644	6132456	15/05/2015	4.42
Torrens	Lower Torrens River	Fox Creek	Hills Fleurieu North	302416	6138471	23/03/2011	2.50
Torrens	Lower Torrens River	Fox Creek	Hills Fleurieu North	302416	6138471	1/05/2017	3.17
Torrens	Lower Torrens River	Fox Creek	Hills Fleurieu North	302416	6138471	21/04/2020	3.00
Torrens	Millers Creek	Alexander Forest Road	Hills Fleurieu North	307422	6147864	14/12/2012	3.19
Torrens	Millers Creek	Martin Hill Rd	Hills Fleurieu North	309019	6149085	13/12/2012	3.90
Torrens	Millers Creek	Winton Rd	Hills Fleurieu North	307280	6146332	13/12/2012	3.47
Torrens	Sixth Creek	Collins	Hills Fleurieu North	293342	6129891	12/07/2011	2.33
Torrens	Sixth Creek	Corkscrew Bridge	Hills Fleurieu North	294926	6138288	11/05/2011	4.75
Torrens	Sixth Creek	Knotts Hill	Hills Fleurieu North	296063	6132539	12/07/2011	4.60
Torrens	Sixth Creek	Sixth Creek Firetrack	Hills Fleurieu North	297238	6135826	11/05/2011	5.08
Torrens	Sixth Creek	US Sixth Creek Gauge	Hills Fleurieu North	294747	6138741	29/11/2013	5.08
Torrens	Sixth Creek	US Sixth Creek Gauge	Hills Fleurieu North	294747	6138741	27/05/2014	5.33
Torrens	Upper Torrens	Cromer Rd Bridge	Hills Fleurieu North	313882	6145446	22/01/2013	4.79
Torrens	Upper Torrens	Cudlee Creek	Hills Fleurieu North	302373	6142245	23/03/2011	4.76
Torrens	Upper Torrens	Mount Pleasant Cottage	Northern Yorke	322250	6151599	21/01/2013	4.33
Torrens	Upper Torrens	Mount Pleasant Crash Repair	Northern Yorke	320320	6149927	21/12/2012	4.92
Torrens	Upper Torrens	Mount Pleasant Golf Course	Northern Yorke	323156	6152697	22/01/2013	4.33
Torrens	Upper Torrens	Mt Pleasant	Northern Yorke	321900	6151076	23/03/2011	4.42
Torrens	Upper Torrens	Mt Pleasant	Northern Yorke	321900	6151076	8/11/2013	4.00
Torrens	Upper Torrens	Talunga Park Bridge	Northern Yorke	321660	6150487	21/01/2013	4.58
Torrens	Upper Torrens	Talunga Park Bridge	Northern Yorke	321660	6150487	28/05/2014	4.33
Torrens	Upper Torrens	Talunga Park Bridge	Northern Yorke	321660	6150487	23/03/2015	4.58
Torrens	Upper Torrens	US Mount Pleasant Pipeline	Northern Yorke	319296	6148575	22/01/2013	4.57
Tunkalilla	Tunkalilla Creek	Eric Bonython conservation park	Hills Fleurieu South	258268	6056924	14/12/2017	2.39
Tunkalilla	Tunkalilla Creek	Eric Bonython conservation park	Hills Fleurieu South	258268	6056924	14/10/2020	2.72
Tunkalilla	Tunkalilla Creek	Tunkalilla	Hills Fleurieu South	257420	6058053	16/03/2011	2.44
Tunkalilla	Tunkalilla Creek	Tunkalilla	Hills Fleurieu South	257420	6058053	14/10/2020	2.69
Tunkalilla	Tunkalilla Creek	Tunkalilla Estuary	Hills Fleurieu South	259352	6052836	15/10/2020	2.36
Tunkalilla	Tunkalilla Creek	Tunkalilla Quarter	Hills Fleurieu South	259521	6053279	15/10/2020	2.44
Willunga Creek	Willunga Creek	Methodist St	Hills Fleurieu North	277324	6093443	5/06/2013	4.42
Willunga Creek	Willunga Creek	Ross Roses	Hills Fleurieu North	277443	6093250	19/04/2017	5.29
Willunga Creek	Willunga Creek	St. Johns Rd	Hills Fleurieu North	277842	6092861	5/06/2013	4.42
Willunga Creek	Willunga Creek	St. Johns Rd	Hills Fleurieu North	277842	6092861	19/04/2017	4.42
Willunga Creek	Willunga Creek	Wirra Creek Bridge	Hills Fleurieu North	277535	6094424	7/06/2013	3.63
Yankalilla	Yankalilla River	Chapmans	Hills Fleurieu South	262428	6063836	15/03/2011	2.81
Yankalilla	Yankalilla River	DS Yankalilla Crossing	Hills Fleurieu South	254907	6071444	17/06/2013	3.43
Yankalilla	Yankalilla River	Ingalalla Falls	Hills Fleurieu South	259093	6064811	16/03/2011	3.44
Yankalilla	Yankalilla River	Ingalalla Falls	Hills Fleurieu South	259093	6064811	26/03/2015	3.44
Yankalilla	Yankalilla River	Yankalilla Bridge River	Hills Fleurieu South	254887	6071365	11/06/2013	3.88
Yankalilla	Yankalilla River	Yankalilla Bridge River	Hills Fleurieu South	254887	6071365	25/03/2015	2.70
Yankalilla	Yankalilla River	Yankalilla Bridge River	Hills Fleurieu South	254887	6071365	4/04/2017	2.88
Yattagolinga	Yattagolinga River	Croser	Hills Fleurieu South	246129	6063091	4/04/2017	2.50

APPENDIX 3. CATCHMENT BCG SCORES

Sample size, minimum, maximum and mean BCG scores for each catchment in the WMLR from 2007–2021.

Catchment	Landscape region	Number of samples	Minimum BCG score	Maximum BCG score	Mean BCG score
Rarkang creek	H&F	1	1.8	1.8	1.8
Boat Harbour	H&F	14	1.2	2.9	2
Tunkalilla	H&F	6	2.4	2.7	2.5
Yattagolinga	H&F	1	2.5	2.5	2.5
Deep Creek	H&F	13	1.2	4.2	2.6
Bungala	H&F	24	2	3.9	2.9
Hindmarsh	H&F	42	1.7	4.1	2.9
Boolaparudda Creek	H&F	7	2.3	4.2	3
Field River	GA	12	2.3	3.8	3
Myponga	H&F	33	2	5.1	3
Parananacooka	H&F	1	3.1	3.1	3.1
Yankalilla	H&F	7	2.7	3.9	3.2
Onkaparinga	GA+H&F	42	1.8	5.5	3.6
Torrens	GA+H&F	34	1.3	5.3	3.6
Carrickalinga	H&F	5	2.4	4.5	3.7
Inman	H&F	65	2.5	4.8	3.8
Callawonga	H&F	15	1.9	4.5	3.9
The Washpool	H&F	3	3.4	4.5	3.9
Light	N&Y	3	3.7	4.5	4
Patawalonga	GA	40	2.2	5.5	4
Gawler	N&Y	84	1.7	5.6	4.4
Little Para	N&Y	4	4.2	4.8	4.4
Willunga Creek	GA	5	3.6	5.3	4.4
Pedler Creek	GA	3	4	5.3	4.6
Christie's Creek	GA	3	4.8	5.2	4.9
Total		**467**	**1.2**	**5.6**	**3.4**