# Ecological assessment of the Adelaide River catchment

NORTHERN TERRITORY GOVERNMENT

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| **Document title** | Ecological assessment of the Adelaide River catchment |
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| **Approved by** | Executive Director Water Resources |
| **Date approved** | March 2025 |
| **TRM number** | 42-D25-13653 |

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Report No: 13/2025

ISBN: 978-1-74350-472-7

To cite this report:

Dostine, P.L.[1], Wedd, D.[2], Perna, C.[3], Hammer, M.P.[4], Waugh, P.S.[5] and Tingle, X.[5] (2025). Ecological assessment of the Adelaide River catchment. Technical Report 13/2025. Department of Lands, Planning and Environment, Northern Territory Government, Darwin, Australia.

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**Acknowledgements:**

We gratefully acknowledge the generous assistance of the land owners and managers, organisations and individuals who aided and facilitated this research. Permission to access Aboriginal Land Trust areas was granted by the Northern Land Council.

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# Acronyms

| Acronym | Full form |
|---|---|
| CR | critically endangered |
| DNA | deoxyribonucleic acid |
| eDNA | environmental DNA |
| EN | endangered |
| EPBCA | *Environment Protection and Biodiversity Conservation Act 1999* |
| GL | gigalitre |
| ha | hectare |
| IUCN | International Union for Conservation of Nature |
| km | kilometre |
| $km^2$ | square kilometre |
| m | metre |
| $m^3/s$ | cubic meter per second |
| mm | millimetre |
| MAGNT | Museum and Art Gallery of the Northern Territory |
| mAHD | metres above Australian Height Datum |
| NT | Northern Territory |
| OTU | operational taxonomic unit |
| PCR | polymerase chain reaction |
| pH | potential of hydrogen |
| ppt | parts per thousand |
| qPCR | quantitative polymerase chain reaction |
| rRNA | ribosomal ribonucleic acid |
| TPWCA | *Territory Parks and Wildlife Conservation Act 1976* |
| µS/cm | microSiemens per centimetre |
| µm | micrometre |
| VU | vulnerable |

# Sites as identified in appendix 1

| Acronym | Full form |
|---|---|
| AGLN | Acacia Gap Lagoon |
| ARBR | Adelaide River Bridge Riffle |
| ARDD | Adelaide River, Dot and Dash |
| AR01 | Adelaide River site 1 |
| AR03 | Adelaide River site 3 |
| AULD | Auld's Lagoon |
| BHRF | Beatrice Hill Research Farm |
| BTCK | Beatrice Creek |
| CMCK | Coomalie Creek |
| DDRF | Dot and Dash Riffle |
| DLDD | Dash Lagoon |
| DNLG | Donald's Lagoon |
| DRRD | Daly River Road Crossing |
| KSCK | Kaissis Creek |
| MKBB | Mt Keppler Billabong |
| MKXG | Marrakai Crossing |
| MRJN | Margaret River junction |
| STRD | Strickland Road |

# Table of contents

# 1. Executive summary

This study sought to document the ecological assets of the Adelaide River catchment through a review of existing data and information, and by undertaking a field study of the composition of the freshwater vertebrate fauna at representative sites.

The confluence of the Adelaide and Margaret River marks the boundary of the Adelaide River floodplain system: a diverse mosaic of wetland habitats which support ecological assets of national and international significance. The floodplain system is recognised as a site of conservation significance in the Northern Territory (NT) and is listed in the Directory of important wetlands in Australia.

The Adelaide River floodplain system provides a major breeding area for magpie goose *Anseranas semipalmata*, saltwater crocodile *Crocodylus porosus*, and herons and allies. It is a major dry season refuge for waterbirds, and it is a significant migration stop over for shorebirds.

Analysis of the Flora and Fauna Division species database identified 171,758 individual records comprised of 588 vertebrate species in the Adelaide River catchment. Fish species are poorly represented in the database and comprised 0.5% of the total number of records. There are records of 30 threatened vertebrate species, and 15 threatened aquatic vertebrates. These include six migratory shorebird species, three elasmobranch species, three varanids, a burrowing frog, and an elapid snake.

There are long-term species management programs for magpie goose and saltwater crocodile. Aerial surveys to estimate goose populations have been conducted since 1983. Since 2011 surveys have been conducted using a consistent methodology across floodplains of the Top End, including on the Adelaide River floodplain. The Adelaide River floodplain supports about 8% of the Top End magpie goose population. The spatial distribution of this species varies within and among floodplain systems. Large scale water extraction may alter the frequency and duration of floodplain inundation, and adversely impact magpie goose habitat.

Surveys conducted between 1990 and 1999 identified three active waterbird breeding colonies and four unconfirmed or historical colonies. Colony W025 (Chatto 2000) may represent the largest, regular egret colony in Australia, with ten breeding species and use by up to 30,000 birds. There are no recent data on colony status or size.

There are 825 mapped patches of monsoon rainforest in the Adelaide River catchment. About 5,500 ha of rainforest (or 2% of the NT rainforest estate) occur as scattered patches mostly along the upland margin of the floodplain. Rainforest patches in proximity to the Adelaide River floodplain have been identified as one of six clusters of this habitat type required to capture rare endemic rainforest plant species.

A field survey of aquatic biodiversity was undertaken in 2024 at 18 sites in riverine channel, and off stream channel habitats from the upper reaches of the Adelaide River to the upper floodplain. Surveys detected 45 of 83 fish species known, or suspected to occur, from the freshwater and tidal freshwater reaches of the Adelaide River, seven of 18 aquatic or semiaquatic reptile species and eight decapod species.

The structure and composition of fish assemblages varied according to position in the landscape and habitat. The most diverse sites featured shallow edges with high macrophyte cover. The median number of fish species detected per site was 15, three sites featured more than 20 fish species. By contrast, a floodplain lagoon with a history of use by domestic stock, and extensive coverage of the invasive pasture grass *Hymenachne amplexicaulis* and low dissolved oxygen levels, featured 13 fish species. There were no sampling sites in the middle and lower portions of the floodplain. Further work is required to systematically sample fish assemblages in these habitats.

The tidal freshwater reach from the tidal limit at Marrakai Crossing to the confluence of Beatrice Creek features low salinity levels for most of the dry season, and purportedly supports a distinctive but largely undocumented suite of fish species. In this study, surveys conducted at three sites in the tidal freshwater reach identified 25 fish species, ten of which were restricted to tidal freshwater. Increased salinity due to large scale water extraction may reduce habitat availability for these species.

Environmental DNA samples were collected concurrently with biodiversity surveys at 18 sites in the Adelaide River catchment. Metabarcoding analyses identified 94 operational taxonomic units (OTU's), of which 58 were identified to species level. Twenty-three of 45 fish species identified by biodiversity surveys were not detected by eDNA. Of these, eight were obligate freshwater species and 15 were euryhaline species. There were no eDNA detections of the threatened largetooth sawfish.

There are long-term datasets for several ecological assets within the Adelaide River catchment, but none specifically address the relationship between variation in flow and biodiversity assets or ecological function. To some extent, this knowledge gap can be addressed through modelling the effects of water extraction scenarios on hydrological regimes and adopting a precautionary approach. Nevertheless, there is a clear need to establish long-term monitoring programs to better understand interannual variability in ecological processes in relation to variability in flows, and to determine whether these are driven by climate or water management.

# 2. Introduction

## 2.1. Background

The water allocation plan for the Adelaide River catchment aims to guide the future management of water resources in the catchment to meet agreed environmental, economic, social and cultural outcomes. Increasing demand for consumptive water use in the catchment has the potential to disrupt natural flow regimes and the ecological function of the river and associated floodplains. This document presents an assessment of the ecological values of the Adelaide River catchment with an emphasis on the biodiversity values of aquatic systems to inform the development of a water allocation plan for the catchment.

## 2.2. Objectives

The ecological assessment aimed to address the following attributes:

- identification and delineation of aquatic habitats
- fish and turtle species
- aquatic macroinvertebrate species
- threatened species and their habitat, and other matters protected by legislation
- other significant or representative species and their habitat.

The report addresses these objectives as follows:

- Chapter 3 presents a description of the vertebrate fauna of the catchment, based on species records within the species database of the Flora and Fauna Division, with an emphasis on threatened species. Compositional data of the fish fauna of freshwater and tidal freshwater reaches are provided from collection-based records from the Museum and Art Gallery of the Northern Territory (MAGNT).
- Chapter 4 presents a review of ten aquatic ecological assets, defined as species or communities with high cultural or conservation value, substantial long-term monitoring data, or considered suitable for monitoring impacts of altered flow regime.

- Chapter 5 describes variation in water quality parameters collected at biodiversity survey sites. This data provides a dry season baseline for water quality and explanatory variables for analysing spatial patterns in the biota.
- Chapter 6 describes results of systematic surveys of fish, aquatic and semiaquatic reptiles, and decapod crustacea in permanent waterbodies accessible for sampling in the mid dry season.
- Chapter 7 presents data on aquatic and non-aquatic species using metabarcoding and qPCR analyses of eDNA samples collected at biodiversity survey sites.
- Chapters 8 and 9 presents a summary of key results, conclusions, and recommendations for further research and ongoing monitoring.
- Appendix 1 presents a summary of the biota and water quality of each survey site.
- Appendix 2 presents a taxonomic list of aquatic fauna species recorded by this study.
- Appendix 3 presents data on the occurrence of species by survey site.

## 2.3. Study area

The Adelaide River catchment lies within the Darwin Coastal Bioregion. The river traverses 355 km from headwaters south of the township of Adelaide River to the mouth in Chambers Bay. The Adelaide River drains the western side of its catchment, while its main tributary, the Margaret River, drains the eastern portion of the catchment. The catchment has low relief throughout most of its area with only a few areas up to 300 mAHD in the hills around the basin edges. The confluence of the Margaret and the Adelaide River occurs just downstream of the upper extent of tidal influence and marks the approximate upper limit of the floodplain system. The extensive floodplain system of the Adelaide River covers approximately 18% of the total area of the catchment. The floodplain system comprises a diverse mosaic of wetland habitats which support ecological assets of national and international significance.

The Adelaide River coastal floodplain is recognised as a site of conservation significance in the NT and is listed on the Directory of important wetlands in Australia (DIWA: NT020 Adelaide River floodplain system) (Figure 2). The site forms part of an aggregation of coastal floodplains with the Mary River floodplain (DIWA: NT026) in the northeast.

Criteria for listing the site include:

- it is a wetland that plays an important ecological or hydrological role in the natural functioning of a major wetland system or complex
- it is a wetland that is important as the habitat for animal taxa at a vulnerable stage in their life cycle or provides a refuge when adverse conditions such as drought, prevail
- the wetland supports 1% or more of the national populations of any native plant or animal taxa
- the wetland supports native plant or animal taxa or communities that are considered endangered or vulnerable at the national level
- the wetland is of outstanding historical or cultural significance.

The Adelaide River floodplain system supports examples of 11 wetland types recognised by the ANZECC Wetlands Network (Table 1).

**Table 1.** Wetland types present on the Adelaide River floodplain system.

| A | Marine and coastal zone wetlands |
|---|---|
| A6 | Estuarine waters: permanent waters of estuaries and estuarine systems of deltas |
| A7 | Intertidal mud, sand or salt flats |
| A8 | Intertidal marshes: includes saltmarshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes |
| A9 | Intertidal forested wetlands: includes mangrove swamps, nipa swamps, tidal freshwater swamp forests |
| B | Inland wetlands |
| B1 | Permanent river and streams; includes waterfalls |
| B4 | Riverine floodplains: includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna |
| B6 | Seasonal/intermittent freshwater lakes (>8 ha), floodplain lakes |
| B9 | Permanent freshwater ponds |
| B10 | Seasonal/intermittent freshwater ponds and marshes on inorganic soils, includes sloughs, potholes; seasonally flooded meadows, sedge marshes |
| B14 | Freshwater swamp forest; seasonally flooded forest. Wooded swamps; on inorganic soils |
| C | Human made wetlands |
| C1 | Water storage areas; reservoirs, barrages, hydro-electric dams, impoundments (generally >8 ha) |

The Adelaide River floodplain system occupies an area of 134,800 ha and includes the entire floodplain of the Adelaide River from near the junction of the Margaret River downstream to the river mouth, mangrove swamps at the base of Cape Hotham peninsula, and intertidal mudflats. Large floodplain wetlands within the site include Lake Finniss, Melacca and Black Jungle Swamps, the artificial Fogg and Harrison Dams, and Tommy Policeman, Lambell's and Beatrice Lagoons.

There are four primary plant formations:

1. mangal low closed-forest
2. scattered chenopod low shrubland
3. patches of *Melaeuca* open-forest near the floodplain edge
4. mixed grassland/sedgeland (seasonal floodplain).

Patches of closed-forest monsoon vine thicket occur at the edges (Jaensch 1993). About 5,500 ha of rainforest (or 2% of the NT rainforest estate) occur as scattered patches mostly along the upland margin of the floodplain. Rainforests in proximity to the Adelaide River floodplain were identified as one of six clusters of rainforest patches required to capture NT rare endemic rainforest plant species (Price 1998).

Vegetation patterning on coastal floodplains, including the Adelaide River floodplain, has been described using census plots in a 2.5 km grid (Wilson *et al.* 1991). The study recognised 24 floristic groups based on herbaceous vegetation. Most of these groups were associated with distinct salinity and water depth regimes, and were divided into three broad groupings, namely saline/semi-saline, dry freshwater, and wet freshwater (Cowie *et al*. 2000). There are at least 13 discrete land unit or land resource mapping products within the catchment (Table 2). Land units are based on soil, vegetation and landform attributes.

**Table 2.** Map product datasets within the Adelaide River catchment.

| No. | Dataset code | Reference | Dataset name |
|---|---|---|---|
| 1 | MARRV_25 | Fogarty (1980) | Land Resources Marrakai Area |
| 2 | DARAS_50 | Hill and Edmeades (2008) | Acid Sulfate Soils Darwin Region |
| 3 | CPHD_50 | Anon (2006) | Land Resources Coastal Plains–Humpty Doo |
| 4 | GTRDW_25 | Fogarty, Howe and Dunlop (1979) | Land Resources Greater Darwin Area |
| 5 | GTDLS_50 | Anon (2013) | Land Suitability in the Greater Darwin region |
| 6 | WARRA_50 | Olsen (1985) | Land Resources Warrai Catchment |
| 7 | MTBUN_25 | Forster and Fogarty (1975) | Land Units Mount Bundy Station |
| 8 | MTRIN_25 | Van Cuylenburg and Czachorowski (1978) | Land Resources of Mt Ringwood Station |
| 9 | UARES_10 | Forster and Fogarty (1975) | Land Units Upper Adelaide River Area |
| 10 | COOMP_25 | Robinson, Forster and Van Cuylenberg (1972) | Land Resources Coomalie Creek Area |
| 11 | WN_50 | Laity and Day (1971) | Land Units Woolner Area |
| 12 | PLAIN_50 | Fett and Haddon (1993) | Land Resources Adelaide-Mary River Floodplain |
| 13 | CPMARY_50 | Anon (2006) | Land Resources Coastal Plains- Mary River |

### 2.3.1. Climate and rainfall

Median and mean annual rainfall at Middle Point research station are approximately 1,405 and 1,380 mm, mostly falling in December to March.

### 2.3.2. Land use and conservation areas

Approximately half of the Adelaide River floodplain is pastoral leasehold land, encompassing two pastoral properties (Woolner and Koolpinyah), about 10% is Crown leasehold land and 25% managed as conservation reserves. A number of discontinuous conservation reserves occur within the site including: Adelaide River Foreshore Conservation Area (2 $km^2$), Black Jungle/Lambell's Lagoon Conservation Reserve (40 $km^2$), Djukbinj National Park (325 $km^2$), Fogg Dam Conservation Reserve (18 $km^2$), Harrison Dam Conservation Area (33 $km^2$), and Melacca Swamp Conservation Area (23 $km^2$) (Figure 3). Substantial changes have occurred on the northern wetlands since European settlement from the impact of large numbers of feral buffalo (Story 1969, Messel *et al*. 1979, Fogarty 1982) and the spread of invasive shrubs and pasture grasses (Fogarty 1982, Ferdinands *et al.* 2005).

### 2.3.3. Hydrology

The catchment of the Adelaide River covers an area of approximately 7,445 $km^2$, and spans 335 km from headwater reaches south of the Adelaide River township to the mouth. The catchment falls within the wet-dry tropics, under the Köppen climate classification of Tropical Savannah. Median annual rainfall across the catchment is approximately 1,500 mm, with a slight rainfall gradient increasing to the north, however rainfall is highly variable from year to year. Almost all rain falls within the northern summer between October and April with December to March being the wettest months. Evapotranspiration exceeds rainfall from April to November.

The Adelaide River drains the western side of its catchment, while its main tributary, the Margaret River, drains the southern and eastern parts of the catchment. The catchment has generally low relief throughout most of its area. Of its 175 km north-south extent, much of the northern 100 km remains below 10 mAHD. Elevations remain below 50 mAHD for most of the catchment area north of Adelaide River Township, with only a few areas of higher elevation up to 300 mAHD in the foothills mostly found around the basin edges.

The Adelaide River is macrotidal, with daily tidal variations at the river mouth typically exceeding 4.0 m and exceeding 6.0 m during spring tides. Tidal influence extends 150 km upstream of the mouth (river length), passing through an extensive coastal and alluvial floodplain reaching 100 km inland. The Margaret River confluence with the Adelaide River occurs just downstream of the upper extent of tidal influence.

Streamflow is dominated by wet season runoff, with over 99% of total discharge from the upper catchment into the tidal reaches occurring during the wet season months. Groundwater discharges from the regional Tindal Limestone aquifer into headwater tributaries of the Adelaide River allow perennial flows in the Adelaide River East Branch down to Adelaide River Township in most years, while Coomalie Creek also flows perennially due to discharges from the Coomalie Dolostone and Whites formation. Other groundwater contributions from localised aquifers contribute to delayed flows in Manton River and Burrell Creek however these typically cease flowing late in the dry season. The primary Adelaide River channel flows perennially to its tidal reaches after large wet seasons, about 40% of the time, but otherwise ceases flowing by November. The Margaret River ceases flowing throughout its catchment by July every year, demonstrating no significant delayed discharges from surface or groundwater storages. Perennial pools persist throughout the dry season along the primary channels of the Adelaide River and in some locations along the Margaret River, protected by shading from riparian vegetation and high primary banks and possibly maintained by minor inflows from localised groundwater storages.

During the wet season, moderate and high flows spill from the primary channels of the Adelaide and Margaret Rivers to inundate large seasonal wetland areas upstream of the tidal reaches. A natural constriction immediately downstream of the Margaret River confluence regulates discharges from the upper catchment onto the coastal floodplain, allowing development of a large alluvial floodplain in the non-tidal reaches of the Adelaide and Margaret Rivers. As the wet season recedes, an extensive system of waterholes on the floodplain retain water later into the dry season and some larger waterholes may retain water perennially.

On average, 1,738 GL is discharged from the upper catchment to the tidal reaches every year, however records vary from 319 GL (1990) to 5067 GL (2011). Peak discharges may exceed 3,500 $m^3/s$. Modelled estimates of total catchment discharge including the tidal reaches average 2,693 GL per year (Petheram *et al*. 2018), of which 40% is derived from the ungauged portions of the catchment incorporating the tidal reaches and coastal floodplain. The lower (tidal) reaches of the Adelaide River catchment contains extensive coastal and alluvial floodplains covering an area of approximately 1,300 $km^2$. Vast seasonally and permanently inundated wetland systems occur within the floodplain, hosting a mosaic of diverse wetland habitats including tidal flats, swamps and mangroves considered to be of outstanding cultural and ecological significance (Close *et al*. 2012, Petheram *et al*. 2018).

High flows during the wet season expel saline water from the tidal reaches to the river mouth. As flooding recedes, macrotidal influences push saline water into the estuary extending a saltwater wedge beneath the freshwater lens to create an extensive contact boundary. As the dry season progresses and freshwater inflows reduce, the freshwater and saline water become well mixed creating a saline brackish freshwater gradient heading upstream from the river mouth. Saline water continues to replace fresh water lost from the upper estuary due to evapotranspiration, extending the saline gradient further into the estuary until wet season storms generate sufficient flows to commence flushing of the estuary with fresh water. The tidal hydrodynamics of the Adelaide River differ markedly from other northern macrotidal rivers including the South Alligator and Daly Rivers (Vertessy 1990). The tides at the mouths of these rivers are similar, but in the Adelaide River, there is strong tidal damping caused by a bedrock constriction a few kilometres inside the mouth. Spring tidal range at this point is reduced from 6 m to 3.5 m. Ebb/flood tide duration asymmetry is lowest for the Adelaide River. The saline water gradient extends approximately two thirds of the way up the estuary by the end of the dry season, with the upper third remaining fresh however this is likely to vary depending upon timing, magnitude and duration of wet season flows (Messel *et al*. 1979, Berra and Wedd 2017).

## 2.4. Floodplain function

Seasonally connected floodplains play a vital role in the function of aquatic ecosystems of naturally flowing rivers of the Top End (Douglas *et al.* 2005, Jardine *et al*. 2015, Pettit *et al*. 2017), providing food subsidies to both the aquatic and terrestrial environments (Beesley *et al.* 2021, Allen *et al.* 2024). Primary productivity from seasonally inundated floodplains underpins aquatic food webs through predictable but variable magnitude flooding and connectivity (Pusey *et al*. 2010, Jardine *et al.* 2015). Perennial wetlands (waterholes) on remnant river channels on floodplains provide refuge habitat for characteristically freshwater species that retreat from tidal reaches of the river in the dry season. Degradation of floodplains can be attributed to habitat loss and homogenisation from physical alteration of the land for agricultural development. Connectivity of floodplains to the rivers are lost or reduced when natural flows are modified for water resource development. The two afore mentioned impacts will have broad reaching implications for ecosystem function in large floodplain rivers of the Top End.

Understanding aquatic faunal distribution and community structure, and seasonal energy flows (Jardine *et al*. 2012, Pettit *et al*. 2017, O'Mara *et al*. 2024) will help to manage impacts from resource development proposals increasing in tropical Australia (Bunn and Arthington 2002). Australian freshwater fish have evolved to exploit seasonally variable water levels and energy inputs (Bunn and Arthington 2002, Baumgartner *et al*. 2014, Carpenter-Bundhoo *et al*. 2022) but planned water resource development in northern Australia may disrupt this predictable but annual natural flow regime leading to community wide impacts to species richness, community fitness and biomass (Humphries *et al*. 2020). Establishing baselines for these ecosystem attributes can be used to establish environmental management targets that will minimise impacts to freshwater fish communities. There is well established *post hoc* evidence of the impacts to unregulated water resource developments from the southern parts of the continent (Humphries *et al*. 1999, Lintermans *et al*. 2024). Removal of lateral connectivity and floodplain modification for agriculture has disrupted the flow of energy and reproductive processes of the fish in these rivers (Sharpe 2011, Koehn *et al*. 2020) and increase extinction risk as well as aiding in the proliferation of alien fish species.

## 2.5. General methods

This section summarises the field and analytical methods used in the studies presented in this report. Details of methods used are presented in individual chapters.

*Chapter 3: Composition of vertebrate fauna*

The Flora and Fauna Division species database includes species records from multiple sources, including several external agencies. Data for the Adelaide River catchment was extracted from the NT Fauna Atlas using the Adelaide River catchment boundary in Geofabric V3.2. Data on the composition of the fish fauna of the freshwater and tidal freshwater reaches were sourced from curated records of MAGNT.

*Chapter 4: Review of ecological assets*

This chapter presents a review of relevant literature and data for ten ecological assets for the Adelaide River catchment, defined as species or communities with high cultural or conservation value, substantial long-term monitoring data, or considered suitable for monitoring impacts of altered flow regime.

*Chapter 5: Spatial variation in water quality*

Surface water quality parameters were measured in the field, and water samples were collected for laboratory analysis, concurrently with the aquatic biodiversity sampling program. Data included field measurements of electrical conductivity, pH, dissolved oxygen and temperature, and laboratory measurements of total nutrients, chlorophyll *a*, ionic composition, and isotopic composition. Spatial patterns in ionic composition are presented as Piper diagrams, which show the relative dominance of anions and cations. Isotopic data can infer the influence of groundwater on a waterbody, based on differential evaporative loss of hydrogen and oxygen isotopes. There was no assessment of seasonal variation in surface water quality.

*Chapter 6: Spatial variation in aquatic biodiversity*

Standardised surveys of aquatic biodiversity were conducted at 18 sites in the study area over an 18 day period from 5 to 23 August 2024. Sampling sites were selected to span the range of aquatic habitats accessible for sampling in the mid-dry season. Sites were mostly located in, or adjacent to, the main channel of the Adelaide River from upstream reaches to tidal freshwater reaches. Multiple sampling methods were deployed at each site (Table 3). At most sites, sampling occurred within an 8 hour period from 08:00 to 16:00 hours. Methods included boat electro-fishing, backpack electro-fishing, gill netting, fyke netting, baited traps and cast netting (Figure 1). Most fish and all turtles were released unharmed at the site of capture. Some fish were retained as voucher specimens for further taxonomic and genetic study and general quality assurance /quality control of identifications. Voucher specimens were registered with MAGNT.

*Chapter 7: Environmental DNA*

Environmental DNA samples were collected at each site for metabarcoding analysis using vertebrate and decapod assays, and by qPCR for detection of largetoothed sawfish *Pristis pristis*. Samples were collected using Smith-Root DNA filters and a Smith-Root backpack sampler, or a Smith-Root citizen science sampler. At most sites, three filtered samples were collected from a moving boat at three different points in the waterbody, and a filtered control sample was collected to detect infield contamination. Samples were analysed by the commercial laboratory EnviroDNA.

**Table 3.** Sampling scheme for assessment of aquatic biodiversity in the study area.

| Method | Target species | Effort |
|---|---|---|
| bait traps | small fish and decapods | 10 traps |
| fyke nets | small, active, littoral fish | single and double wing nets |
| gill netting | large active fish in habitats > 3 m depth | single 4 inch multi-braid 30 m net |
| back-pack electro-fishing | small, cryptic fish in wade-able riffle habitat | 8 shots of 150 seconds |
| boat electro-fishing | fish and turtles in edge habitats in large waterbodies | up to 15 shots of 90 seconds |
| turtle traps | primarily turtles, but some fish | 5 traps |
| benthic sampling | decapods, small littoral fish | opportunistic |

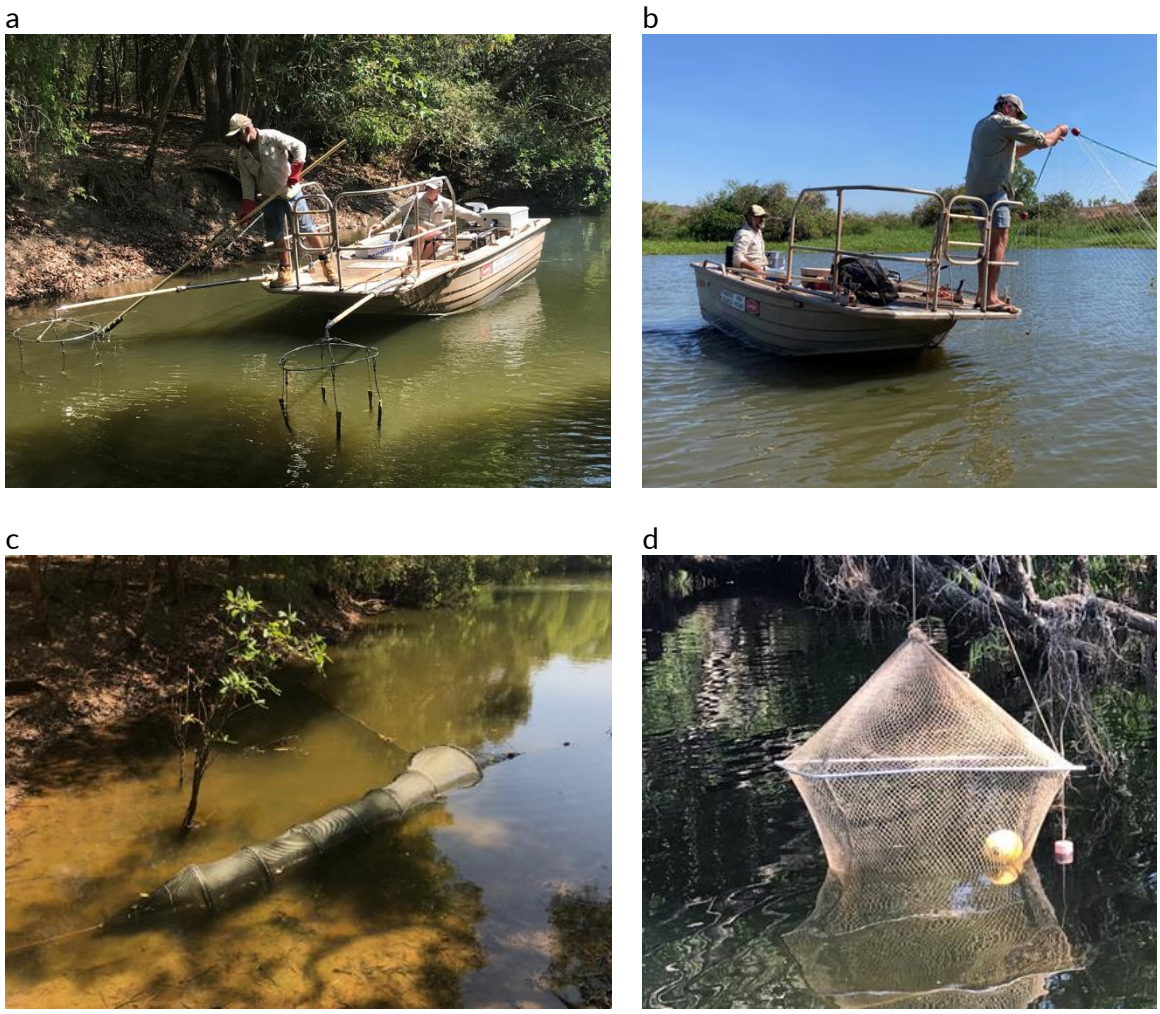


**Figure 1.** Sampling methods used at study sites in the Adelaide River catchment (a) boat electro-fishing, (b) multi-filament gill net, (c) single-wing fyke net, and (d) turtle trap.

## 2.6. Limitations of this study

There are several limitations to this study, including the following:

1. Surveys were undertaken within a period of 18 days in the mid-dry season month of August and represent a snapshot of aquatic biodiversity composition and spatial pattern. There was no attempt to capture seasonal or interannual variability in composition or spatial pattern.

2. The survey was designed to capture the range of aquatic habitats available for sampling in the mid-dry season and focussed on habitats within and near the main river channel of the Adelaide River. Shallow swamps and ephemeral wetlands were not sampled. Further, approval to access several candidate sites could not be obtained.

3. The target taxa for survey included fish, aquatic reptiles and decapods, and excludes other ecological assets present in the catchment such as aquatic macrophytes, waterbirds and shorebirds, and terrestrial vertebrates.

4. Sites were selected from upper headwater reaches to the tidal freshwater reaches downstream of the tidal limit. There was no attempt to quantify fish assemblages of the lower estuarine reaches.

5. The study trialled DNA based detection of aquatic biodiversity, using assays for vertebrates and decapods, and freshwater sawfish. Further work is required to build a comprehensive, adequate reference sequence database for detection of aquatic species, and to allow discrimination of closely related taxa. Several freshwater fish species cannot be identified to species-level using the 12S vertebrate assay. These include common species in the families Melanotaeniidae and Terapontidae.

6. The study sought to document the composition and spatial patterning of aquatic species amongst habitat types. It does not provide information on environmental flow requirements of individual species. Such information requires targeted studies on the variability of biotic responses through time and across hydrological variability and is beyond the scope of this study. The study includes a review of relevant ecological research on ecohydrological relationships.

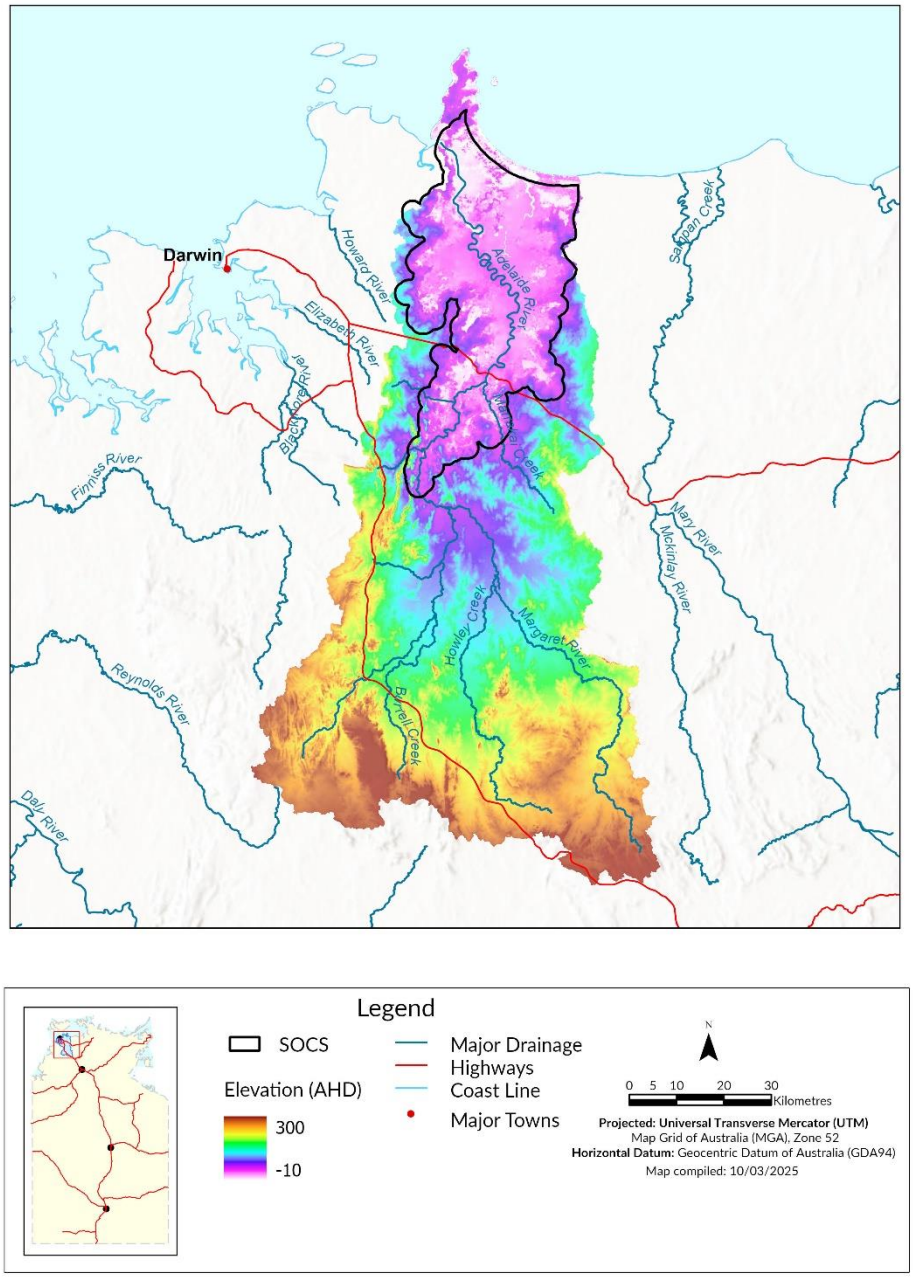


**Figure 2.** Elevation (mAHD) of Adelaide River catchment and boundary of Adelaide River floodplain site of conservation significance (SOCS).

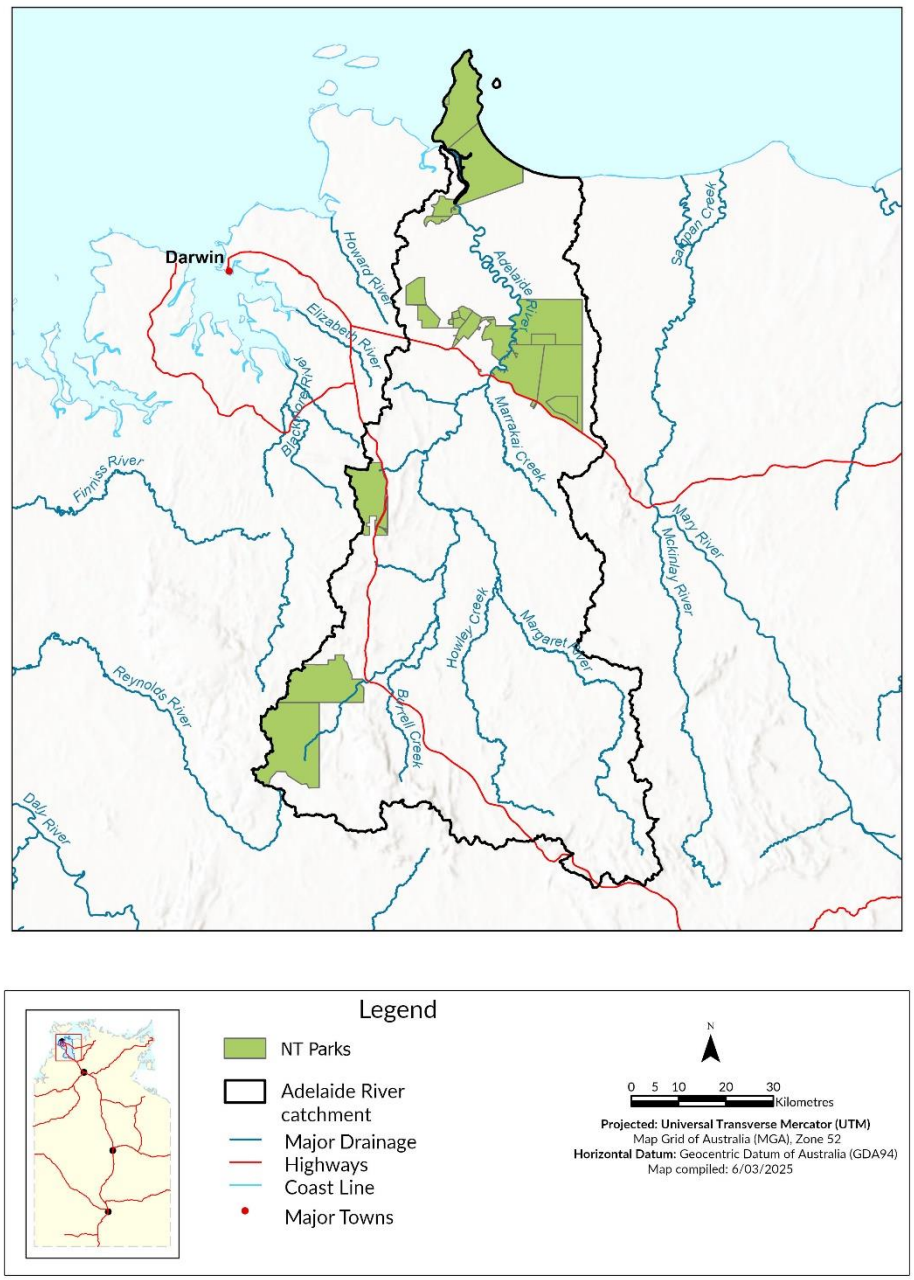


**Figure 3.** Conservation areas in Adelaide River catchment.

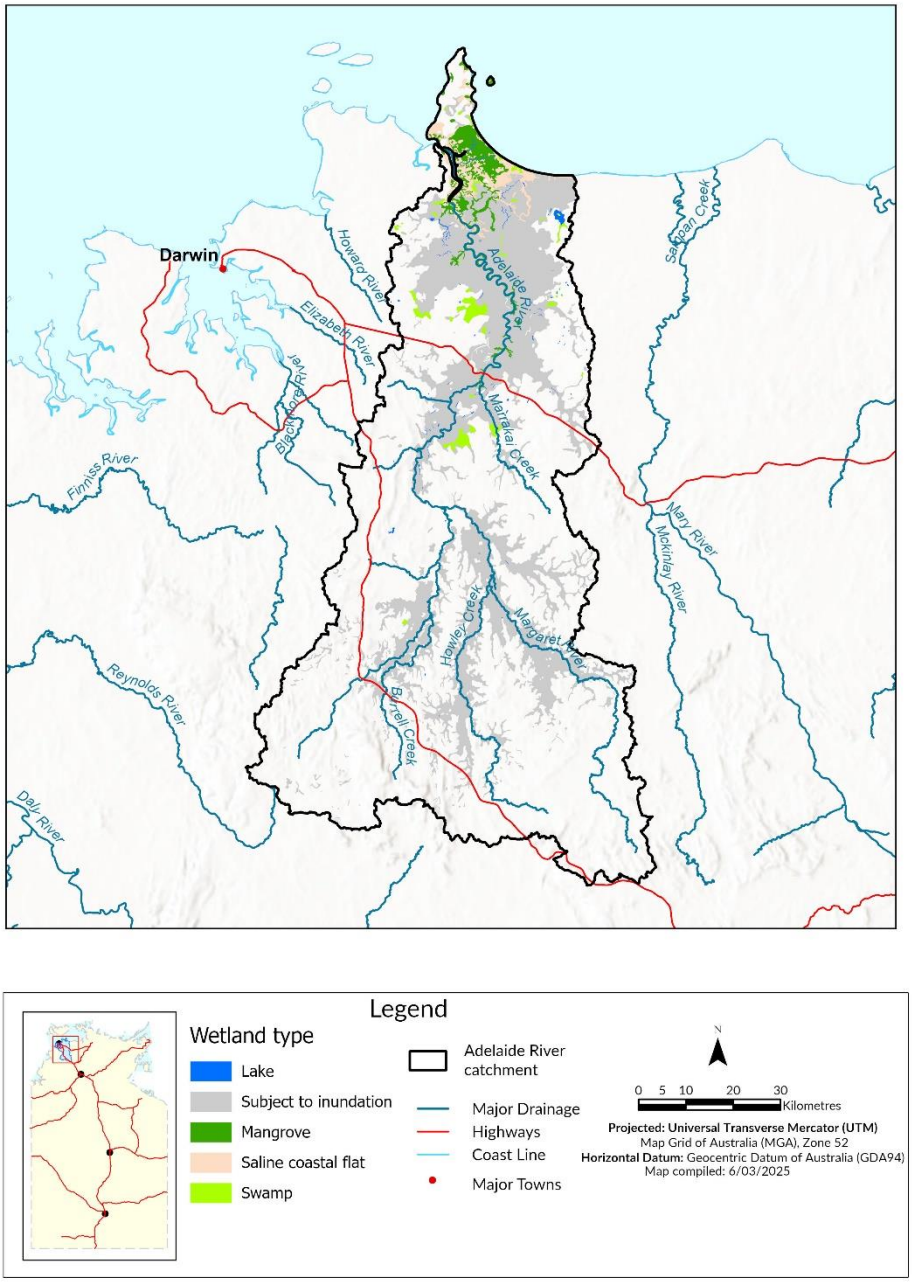


**Figure 4.** Wetland categories of the Adelaide River catchment.

# 3. Composition of vertebrate fauna

This chapter summarises the results from an analysis of records of vertebrate species in the Adelaide River catchment extracted from the Flora and Fauna Division species database. Fish are poorly represented in the database. Data on the composition of the freshwater and tidal freshwater fish fauna is based on records from MAGNT, and given relatively limited previous sampling in the Adelaide River, expert opinion of other species known from adjacent systems that are likely to occur (e.g. Pusey *et al.* 2016). Threatened taxa include species listed under either the *Territory Parks and Wildlife Conservation Act 1976* or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* under the threat categories vulnerable, endangered or critically endangered. Aquatic species includes all fish and frogs, and those species affiliated with aquatic habitats, including ephemeral aquatic habitats such as floodplains. It includes shorebirds which may occur on marine coastal shorelines, freshwater waterbirds, as well as species that occur in shrub habitats on drying floodplains such as the yellow chat, and species which prefer dry grasslands or bare ground on floodplains including the grass owl, little curlew and oriental pratincole.

## 3.1. Vertebrate species

The species record dataset for Adelaide River includes 171,758 individual records and included records of 588 vertebrate species. Of these >80% were records of bird species and <1% were records of fish species (Table 4). Two species, saltwater crocodile *Crocodylus porosus* and magpie goose *Anseranas semipalmata* comprised ~12% of the total number of records (Table 5). Both species have been intensively and systematically surveyed for several years under species management programs conducted by the Flora and Fauna Division. The distribution of species records in the Adelaide River catchment reflects the distribution of survey effort for these management programs, and the influence of the road network (Figure 5).

**Table 4.** Number of records, and percent number of records, in each vertebrate class in NT Fauna Atlas for Adelaide River catchment.

| Taxon | No. records | % records | No. species | % species |
|---|---|---|---|---|
| birds | 140,645 | 81.9 | 305 | 51.9 |
| fish | 942 | 0.5 | 77 | 13.1 |
| frogs | 3,556 | 2.1 | 26 | 4.4 |
| mammals | 9,849 | 5.7 | 67 | 11.4 |
| reptiles | 16,766 | 9.8 | 113 | 19.2 |
| total | 171,758 | 100 | 588 | 100 |

**Table 5.** Number of records, and percent number of records, of ten most frequently recorded species in NT Fauna Atlas for Adelaide River catchment.

| Species name | Common name | # records | % records |
|---|---|---|---|
| *Crocodylus porosus* | saltwater crocodile | 11,748 | 6.84 |
| *Anseranas semipalmata* | magpie goose | 8,454 | 4.92 |
| *Notamacropus agilis* | agile wallaby | 4,150 | 2.42 |
| *Geopelia humeralis* | bar-shouldered dove | 3,109 | 1.81 |
| *Egretta picata* | pied heron | 2,493 | 1.45 |
| *Vanellus miles* | masked lapwing | 2,454 | 1.43 |
| *Ardea plumifera* | plumed egret | 2,387 | 1.39 |
| *Merops ornatus* | rainbow bee-eater | 2,384 | 1.39 |
| *Milvus migrans* | black kite | 2,363 | 1.38 |
| *Todirhamphus macleayii* | forest kingfisher | 2,336 | 1.36 |

## 3.2. Fish species of freshwater and tidal freshwater

Table 6 presents a list of species known, or suspected, to be present in the freshwater and tidal freshwater reaches of the Adelaide River, annotated by life history, in other words, obligate freshwater, euryhaline or diadromous. Of the list of 83 species, 43 are regarded as euryhaline 51.8%; 33 as obligate freshwater 39.8%; and seven as diadromous 8.4%. Diadromous species include barramundi *Lates calcarifer*, oxeye herring *Megalops cyprinoides*, and blue catfish *Neoarius graeffei*. One species of invasive fish is known to be present, Siamese fighting fish *Betta splendens*, a relatively recent arrival (Hammer *et al*. 2019).

**Table 6.** List of fish species known, or suspected to be present, from freshwater and tidal freshwaters of the Adelaide River, annotated by life history.

| Family | Species | Common name | Life history |
|---|---|---|---|
| Ambassidae | *Ambassis elongata* | elongate glassfish | euryhaline |
| Ambassidae | *Ambassis interrupta* | long-spined glassfish | euryhaline |
| Ambassidae | *Ambassis macleayi* | Macleay's glassfish | obligate freshwater |
| Ambassidae | *Ambassis* sp. NW | northwest glassfish | obligate freshwater |
| Ambassidae | *Ambassis vachellii* | Vachelli's glassfish | euryhaline |
| Ambassidae | *Denariusa bandata* | pennyfish | obligate freshwater |
| Anguillidae | *Anguilla bicolor* | Indonesian shortfin eel | diadromous |
| Apogonidae | *Glossamia aprion* | mouth almighty | obligate freshwater |
| Ariidae | *Cinetodus froggatti* | smallmouth catfish | euryhaline |
| Ariidae | *Hemiarius dioctes* | warrior catfish | euryhaline |
| Ariidae | *Neoarius berneyi* | highfin catfish | obligate freshwater |
| Ariidae | *Neoarius graeffei* | blue catfish | diadromous |
| Ariidae | *Neoarius leptaspis* | salmon catfish | euryhaline |
| Ariidae | *Neoarius midgleyi* | silver cobbler | obligate freshwater |
| Atherinidae | *Craterocephalus mugiloides* | spotted hardyhead | euryhaline |
| Atherinidae | *Craterocephalus stercusmuscarum* | fly-specked hardyhead | obligate freshwater |
| Belonidae | *Strongylura krefftii* | freshwater longtom | obligate freshwater |
| Carcharhinidae | *Carcharhinus leucas* | bull shark | euryhaline |
| Carcharhinidae | *Glyphis garricki* | northern river shark | euryhaline |
| Carcharhinidae | *Glyphis glyphis* | speartooth shark | euryhaline |
| Clupeidae | *Nematalosa come* | hairback herring | euryhaline |
| Clupeidae | *Nematalosa erebi* | bony bream | obligate freshwater |
| Cynoglossidae | *Cynoglossus heterolepis* | freshwater tongue sole | euryhaline |
| Dasyatidae | *Urogymnus dalyensis* | freshwater whipray | diadromous |
| Eleotridae | *Bostrychus zonatus* | sunset gudgeon | euryhaline |
| Eleotridae | *Butis butis* | crimsontip gudgeon | euryhaline |
| Eleotridae | *Hypseleotris compressa* | empire gudgeon | euryhaline |
| Eleotridae | *Mogurnda mogurnda* | northern purple-spotted gudgeon | obligate freshwater |
| Eleotridae | *Oxyeleotris lineolata* | sleepy cod | obligate freshwater |
| Eleotridae | *Oxyeleotris nullipora* | poreless gudgeon | obligate freshwater |
| Eleotridae | *Oxyeleotris selheimi* | giant gudgeon | obligate freshwater |
| Eleotridae | *Prionobutis microps* | smalleye gudgeon | euryhaline |

| Family | Species | Common name | Life history |
|---|---|---|---|
| Elopidae | *Elops hawaiensis* | giant herring | euryhaline |
| Engraulidae | *Thryssa brevicauda* | freshwater anchovy | euryhaline |
| Engraulidae | *Thryssa malabarica* | freshwater anchovy | euryhaline |
| Gobiidae | *Caragobius rubristriatus* | worm goby | euryhaline |
| Gobiidae | *Caragobius urolepis* | worm goby | euryhaline |
| Gobiidae | *Chlamydogobius ranunculus* | tadpole goby | euryhaline |
| Gobiidae | *Glossogobius aureus* | golden flathead goby | obligate freshwater |
| Gobiidae | *Glossogobius circumspectus* | mangrove flathead goby | euryhaline |
| Gobiidae | *Glossogobius laticeps* | coastal tank goby | euryhaline |
| Gobiidae | *Glossogobius munroi* | square blotch goby | euryhaline |
| Gobiidae | *Glossogobius nanus* | dwarf goby | obligate freshwater |
| Gobiidae | *Mugilogobius rivulus* | drain mangrove goby | euryhaline |
| Gobiidae | *Mugilogobius wilsoni* | Wilson's mangrove goby | euryhaline |
| Gobiidae | *Periophthalmus weberi* | Weber's mudskipper | euryhaline |
| Gobiidae | *Redigobius nanus* | dwarf speckled goby | euryhaline |
| Hemiramphidae | *Arrhamphus sclerolepis* | snub-nosed garfish | euryhaline |
| Hemiramphidae | *Hyporhamphus quoyi* | longtail garfish | euryhaline |
| Kurtidae | *Kurtus gulliveri* | nurseryfish | euryhaline |
| Latidae | *Lates calcarifer* | barramundi | diadromous |
| Lutjanidae | *Lutjanus argentimaculatus* | mangrove jack | euryhaline |
| Megalopidae | *Megalops cyprinoides* | oxeye herring | diadromous |
| Melanotaeniidae | *Melanotaenia exquisita* | exquisite rainbowfish | obligate freshwater |
| Melanotaeniidae | *Melanotaenia nigrans* | blackbanded rainbowfish | obligate freshwater |
| Melanotaeniidae | *Melanotaenia splendida inornata* | chequered rainbowfish | obligate freshwater |
| Mugilidae | *Planiliza ordensis* | Ord River mullet | euryhaline |
| Oshronemidae | *Betta splendens* | Siamese fighting fish | obligate freshwater |
| Osteoglossidae | *Scleropages jardinii* | northern saratoga | obligate freshwater |
| Plotosidae | *Anodontiglanis dahli* | toothless catfish | obligate freshwater |
| Plotosidae | *Neosilurus ater* | black catfish | obligate freshwater |
| Plotosidae | *Neosilurus hyrtlii* | Hyrtl's catfish | obligate freshwater |
| Plotosidae | *Porochilus obbesi* | Obbes' catfish | obligate freshwater |
| Plotosidae | *Porochilus rendahli* | Rendahl's catfish | obligate freshwater |
| Pristidae | *Pristis pristis* | largetooth sawfish | diadromous |
| Pseudomugilidae | *Pseudomugil cyanodorsalis* | blueback blue-eye | euryhaline |
| Pseudomugilidae | *Pseudomugil gertrudae* | spotted blue-eye | obligate freshwater |
| Pseudomugilidae | *Pseudomugil tenellus* | delicate blue-eye | obligate freshwater |
| Scatophagidae | *Scatophagus argus* | spotted scat | euryhaline |
| Scatophagidae | *Selenotoca multifasciata* | banded scat | euryhaline |
| Soleidae | *Brachirus selheimi* | freshwater sole | euryhaline |
| Soleidae | *Leptachirus darwinensis* | Darwin sole | euryhaline |
| Synbranchidae | *Ophisternon bengalense* | one-gill eel | diadromous |

| Family | Species | Common name | Life history |
|---|---|---|---|
| Synbranchidae | *Ophisternon gutturale* | swamp eel | obligate freshwater |
| Terapontidae | *Amniataba percoides* | barred grunter | obligate freshwater |
| Terapontidae | *Hephaestus fuliginosus* | sooty grunter | obligate freshwater |
| Terapontidae | *Leiopotherapon unicolor* | spangled perch | obligate freshwater |
| Terapontidae | *Pingalla lorentzi* | Lorentz's grunter | obligate freshwater |
| Terapontidae | *Syncomistes butleri* | sharpnose grunter | obligate freshwater |
| Toxotidae | *Toxotes chatareus* | sevenspot archerfish | euryhaline |
| Toxotidae | *Toxotes lorentzi* | primitive archerfish | euryhaline |
| Zenarchopteridae | *Zenarchopterus caudovittatus* | long-jaw river garfish | euryhaline |
| Zenarchopteridae | *Zenarchopterus dispar* | spoonfin river garfish | euryhaline |

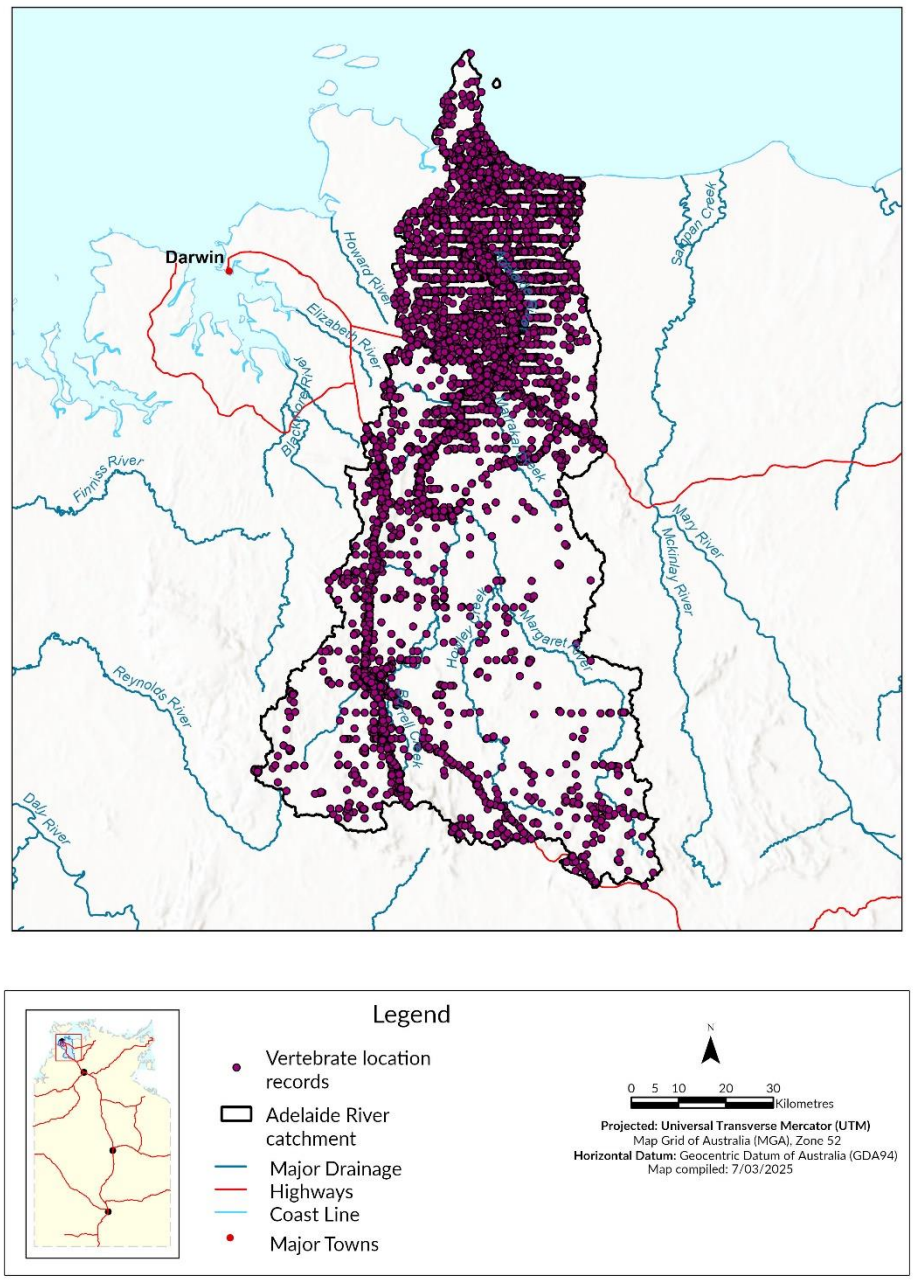


**Figure 5.** Distribution of vertebrate species records from the Adelaide River catchment from the NT Fauna Atlas.

## 3.3. Aquatic and semiaquatic reptiles

The species records dataset includes 18 species of aquatic and semiaquatic reptiles. Of these, 11 primarily occur in freshwater, and four primarily occur in mangrove habitats (Table 7). The dataset includes a single record of Worrell's turtle *Emydura subglobosa worrelli*, based on photographs of an individual observed at Fogg Dam.

**Table 7.** List of aquatic and semiaquatic reptile species occurring in the Adelaide River catchment.

| Family | Species name | Common name | Habitat |
|---|---|---|---|
| Acrochordidae | *Acrochordus arafurae* | Arafura file snake | freshwater |
| Chelidae | *Chelodina rugosa* | northern snake-necked turtle | freshwater |
| Chelidae | *Elseya flaviventralis* | yellow-bellied snapping turtle | freshwater |
| Chelidae | *Emydura subglobosa worrelli* | Worrell's turtle | freshwater |
| Chelidae | *Emydura tanybaraga* | northern yellow-faced turtle | freshwater |
| Colubridae | *Tropidonophis mairii* | freshwater snake | freshwater |
| Crocodylidae | *Crocodylus johnstoni* | freshwater crocodile | freshwater |
| Crocodylidae | *Crocodylus porosus* | saltwater crocodile | freshwater/estuarine |
| Elapidae | *Acanthophis hawkei* | plains death adder | floodplain |
| Homalopsidae | *Cerberus australis* | bockadam | mangrove |
| Homalopsidae | *Fordonia leucobalia* | white-bellied mangrove snake | mangrove |
| Homalopsidae | *Myron richardsonii* | Richardson's mangrove snake | mangrove |
| Homalopsidae | *Pseudoferania polylepis* | Macleay's water snake | freshwater |
| Pythonidae | *Liasis fuscus* | water python | freshwater |
| Varanidae | *Varanus indicus* | mangrove monitor | mangrove |
| Varanidae | *Varanus mertensi* | Mertens' water monitor | freshwater |
| Varanidae | *Varanus mitchelli* | Mitchell's water monitor | freshwater |
| Varanidae | *Varanus panoptes* | yellow-spotted monitor | floodplain |

## 3.4. Threatened species

Thirty threatened vertebrate species occur in the Adelaide River catchment (Table 8). Of these, 15 are terrestrial species occurring in savanna woodland, with the remainder being aquatic or affiliated with aquatic habitats such as floodplains and marine intertidal shorelines (Table 9). The list of threatened vertebrates of aquatic habitats includes six migratory shorebird species, three elasmobranch species and three varanid species. Threatening processes for each group differ markedly. Migratory shorebirds are threatened by habitat loss and degradation at staging points on the East Asian-Australasian Flyway; elasmobranchs are threatened by commercial and recreational fishing (Kyne and Feutry 2017) and potentially by hydrological alteration; and varanid species suffer high mortality after ingestion of a toxic invasive pest, the cane toad *Rhinella marina* (Griffiths and McKay 2007). There have been no systematic surveys of any of these listed species, though much of the suitable sandplain habitat of the Howard River toadlet has been surveyed for the presence of the toadlet. Most records of threatened aquatic vertebrate species occur in the downstream reach of the Adelaide River, or in the vicinity of Fogg Dam Reserve (Figure 6).

**Table 8.** Threatened vertebrate species in Adelaide River catchment, showing habitat and listing under *Territory Parks and Wildlife Conservation Act 1976* (TPWCA) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBCA). Categories: vulnerable (VU), endangered (EN) or critically endangered (CR).

| Species name | Common name | Taxon | TPWCA | EPBCA | Habitat |
|---|---|---|---|---|---|
| *Calidris canutus* | red knot | birds | EN | EN | marine shoreline |
| *Calidris ferruginea* | curlew sandpiper | birds | CR | CR | marine shoreline |
| *Calidris tenuirostris* | great knot | birds | CR | CR | marine shoreline |
| *Anarhynchus leschenaultii* | greater sand plover | birds | VU | VU | marine shoreline |
| *Anarhynchus mongolus* | Siberian sand plover | birds | EN | EN | marine shoreline |
| *Epthianura crocea tunneyi* | yellow chat | birds | EN | EN | floodplain |
| *Chloebia gouldiae* | Gouldian finch | birds | VU | EN | savanna woodland |
| *Numenius madagascariensis* | far eastern curlew | birds | CR | CR | marine shoreline |
| *Erythrotriorchis radiatus* | red goshawk | birds | VU | EN | savanna woodland |
| *Falco hypoleucos* | grey falcon | birds | VU | VU | savanna woodland |
| *Geophaps smithii smithii* | partridge pigeon | birds | VU | VU | savanna woodland |
| *Tyto novaehollandiae kimberli* | masked owl | birds | VU | VU | savanna woodland |
| *Glyphis garricki* | northern river shark | fish | EN | EN | euryhaline |
| *Glyphis glyphis* | speartooth shark | fish | VU | CR | euryhaline |
| *Pristis pristis* | largetooth sawfish | fish | VU | VU | euryhaline |
| *Uperoleia daviesae* | Howard River toadlet | frogs | VU | VU | sand-sheet heath |
| *Antechinus bellus* | fawn antechinus | mammals | EN | VU | savanna woodland |
| *Conilurus penicillatus* | brush-tailed rabbit-rat | mammals | EN | VU | savanna woodland |
| *Dasyurus hallucatus* | northern quoll | mammals | CR | EN | savanna woodland |
| *Macroderma gigas* | ghost bat | mammals | NT | VU | savanna woodland |
| *Mesembriomys gouldii gouldii* | black-footed tree-rat | mammals | EN | EN | savanna woodland |
| *Mesembriomys macrurus* | golden-backed tree-rat | mammals | CR | Not listed | savanna woodland |
| *Petrogale concinna canescens* | nabarlek | mammals | EN | EN | savanna woodland |
| *Phascogale pirata* | northern brush-tailed phascogale | mammals | EN | VU | savanna woodland |
| *Rattus tunneyi* | pale field-rat | mammals | VU | Not listed | savanna woodland |
| *Trichosurus vulpecula arnhemensis* | common brush-tailed possum | mammals | NT | VU | savanna woodland |
| *Acanthophis hawkei* | plains death adder | reptiles | VU | VU | floodplain |
| *Varanus mertensi* | Mertens' water monitor | reptiles | VU | EN | freshwater |
| *Varanus mitchelli* | Mitchell's water monitor | reptiles | VU | CR | freshwater |
| *Varanus panoptes* | yellow-spotted monitor | reptiles | VU | Not listed | floodplain |

**Table 9.** Number of species by habitat for threatened vertebrates in NT Fauna Atlas for Adelaide River catchment.

| Taxon | Terrestrial | Aquatic or with aquatic affiliation | | | | |
|---|---|---|---|---|---|---|
| | Savanna woodland | Marine shoreline | Euryhaline | Freshwater | Floodplain | Sandsheet heath |
| birds | 5 | 6 | | | 1 | |
| fish | | | 3 | | | |
| frogs | | | | | | 1 |
| mammals | 10 | | | | | |
| reptiles | | | | 2 | 2 | |
| total | 15 | 6 | 3 | 2 | 3 | 1 |

**Plains death adder *Acanthophis hawkei* (137 records)**

The plains death adder has a disjunct distribution, it is found on cracking soil plains of the Mitchell Grass Downs of western Queensland and the Barkly Tableland in the NT, and on coastal floodplains in the Darwin region. Prey consists predominantly of frogs, reptiles and rodents. Threats include toxic poisoning by cane toads.

**Red knot *Calidris canutus* (6 records)**

The red knot is a migratory visitor to shorelines in northwestern Australia and southeastern Australia and New Zealand after breeding in high arctic areas. Classified as endangered in Australia, with decline due to habitat loss, particularly in East Asia's Bohai Bay, China.

**Curlew sandpiper *Calidris ferruginea* (36 records)**

The curlew sandpiper is a small to medium size migratory shorebird that breeds in central and eastern Siberia and migrates annually along the East Asian-Australasian Flyway to overwinter in Africa, Southern Asia and Australasia. They are widely distributed in Australia during the non-breeding season in both coastal and inland areas. Key threatening processes include habitat loss and degradation, coastal development, invasive plant species and changes in hydrological processes.

**Great knot *Calidris tenuirostris* (14 records)**

The great knot is a migratory shorebird that breeds in northeast Siberia and northeast Russia and migrates along the East Asia-Australasian Flyway to overwinter in the southern hemisphere. In the NT the species has been recorded in most coastal areas and is rarely recorded far inland from the coast. In Australia, threats to the species include habitat decline and loss due to pollution, invasive plant and mangrove encroachment, human disturbance and changes to hydrological processes.

**Greater sand plover *Anarhynchus leschenaultii* (9 records)**

The greater sand plover is a small to medium sized shorebird which breeds in eastern and central Asia; one subspecies migrates to Australia. In Australia, it occurs along most coastlines, especially in the north, favours sandy, shelly, or muddy beaches and intertidal mudflats. Habitat loss and degradation in the Yellow Sea region pose significant threats to its population, along with pollution, human disturbance, and climate change impacts.

**Siberian sand plover *Anarhynchus mongolus* (23 records)**

The Siberian sand plover is a migratory shorebird with two subspecies *Anarhynchus mongolus mongolus* and *Anarhynchus mongolus stegmanni* that occur in Australia. Both subspecies breed primarily in far eastern Siberia (Russia) and migrate along the East Asian Australasian Flyway to overwinter in East Asia, South-East Asia, New Guinea and Australia. The greatest cause of decline for the species is habitat loss and degradation of migratory staging grounds in the Yellow Sea region. In Australia, threats include ongoing human disturbance, habitat loss and degradation from pollution, changes to hydrological processes and invasive plants.

**Yellow chat (Alligator Rivers) *Epthianura crocea tunneyi* (6 records)**

The yellow chat subspecies *Ephianura crocea tunneyi* is endemic to the NT and has only been recorded in a small geographic area in the river catchments between Oenpelli and Darwin. The primary threatening processes to the species are loss and degradation of preferred floodplain habitat due to invasion by exotic plant species and vegetation change due to grazing by buffalo and cattle, altered fire regimes and wallowing and rooting by pigs.

**Northern river shark *Glyphis garricki* (57 records)**

The northern river shark occurs in the Adelaide, East Alligator and South Alligator River systems. Little is known of the species biology. It has not been recorded as occurring in coastal marine areas, suggesting that it is restricted to shallow and brackish reaches of large rivers and associated floodplains. Both G. *glyphis* and *G. garricki* are considered naturally rare, with specific habitat preferences and low reproductive rates making their populations vulnerable to habitat degradation and impacts from fishing (Kyne and Feutry 2017).

**Speartooth shark *Glyphis glyphis* (301 records)**

In the NT the speartooth shark has been recorded in the Adelaide River, South, East and West Alligator Rivers, Murganella Creek, Daly River, Wildman River, Sampan Creek, and the Roper River (Constance *et al*. 2024). The species is listed as vulnerable under the *Territory Parks and Wildlife Conservation Act 1976* (TPWCA), critically endangered under the and *Environment Protection and Biodiversity Conservation Act 1999* (EPBCA), and as vulnerable on the International Union for Conservation of Nature (IUCN) Red List. There have been few studies investigating the biology of *G. glyphis*. Evidence suggests that this species migrates offshore for parts of its lifecycle and feeding and migrates inshore to breed. Tracked individuals in the Adelaide River exhibited tidal-driven movement (Pillans *et al.* 2010). This species requires a minimum salinity of 2 ppt and cannot tolerate pure freshwater (D. Wedd pers. comm).

**Far eastern curlew *Numenius madagascariensis* (26 records)**

The far eastern curlew is endemic to the East Asian-Australasian Flyway, breeding in Russia, Mongolia and northeastern China, and overwintering primarily in Australia and Southeast Asia. It has been recorded along the entire NT coastline and on many offshore islands. The loss or degradation of intertidal flats and other important staging grounds within the East Asian-Australasian Flyway, and in particular, along the coast of the Yellow Sea is the greatest threat to far eastern curlew populations. Within Australia, disturbance of habitat utilized by the species for feeding and roosting poses the main threat.

**Largetooth sawfish *Pristis pristis* (25 records)**

The largetooth sawfish is listed as vulnerable under the EPBC and TPWC Acts and is listed as critically endangered on the IUCN Red List. In the NT, the species has been recorded in the Adelaide, Victoria, Daly, Alligator, Liverpool, Roper and McArthur rivers. Juveniles and sub-adults occur predominantly in rivers and estuaries, while large mature adults are found predominantly in coastal and offshore environments. Fishing, and in particular gill net fishing, has been identified as the main contributor to a rapid population decline. The Adelaide River remains a stronghold for this species; the removal of commercial fishing from the coastal flats has reduced the frequency of incidental encounters with gill nets.

**Howard river toadlet *Uperoleia daviesae* (222 records)**

The Howard River toadlet is a small burrowing frog from the family Myobatrachidae. It is endemic to the NT and is listed as vulnerable under the EPBC and TPWC Acts and endangered on the IUCN Red List. This species is found in seasonally inundated sandsheet heath. It is restricted to the Howard River, Elizabeth River, Adelaide River and Blackmore River catchments, with an extent of occurrence of approximately 824 $km^2$. The main threatening process is decline in the extent and quality of habitat due to urban development and sand mining.

**Mertens' water monitor *Varanus mertensi* (43 records)**

The Mertens' water monitor is a semiaquatic varanid; broadly distributed in coastal and inland waters across Northern Australia. Its diet consists predominantly of fish, frogs and carrion, but insects and small terrestrial vertebrates are also consumed. The cane toad, *Rhinella marina*, represents the most significant threat to the species.

**Mitchell's water monitor *Varanus mitchelli* (17 records)**

The mitchell's water monitor is a semiaquatic varanid that inhabits margins of watercourses, swamps and lagoons. It occurs in the Kimberly, at an isolated locality in northwestern Queensland, and across the Top End of the NT. The diet of the mitchell's water monitor is comprised of mostly aquatic insects, fish, small lizards and frogs. This species is highly susceptible to cane toad toxin, and it potentially competes with the cane toad for food. The introduction of *Rhinella marina* has therefore had a significant impact on Mitchell's water monitor.

**Yellow-spotted monitor *Varanus panoptes* (47 records)**

The yellow-spotted monitor is a large terrestrial monitor broadly distributed across far northern Australia. Habitats include coastal areas, floodplains and woodlands, where it preys on small vertebrates and insects. The species is listed as vulnerable due to its susceptibility to cane toad toxins. Population declines of up to 90% have occurred in some areas. Conservation efforts focus on monitoring and preventing the spread of cane toads, especially in areas where the monitor populations are at risk.

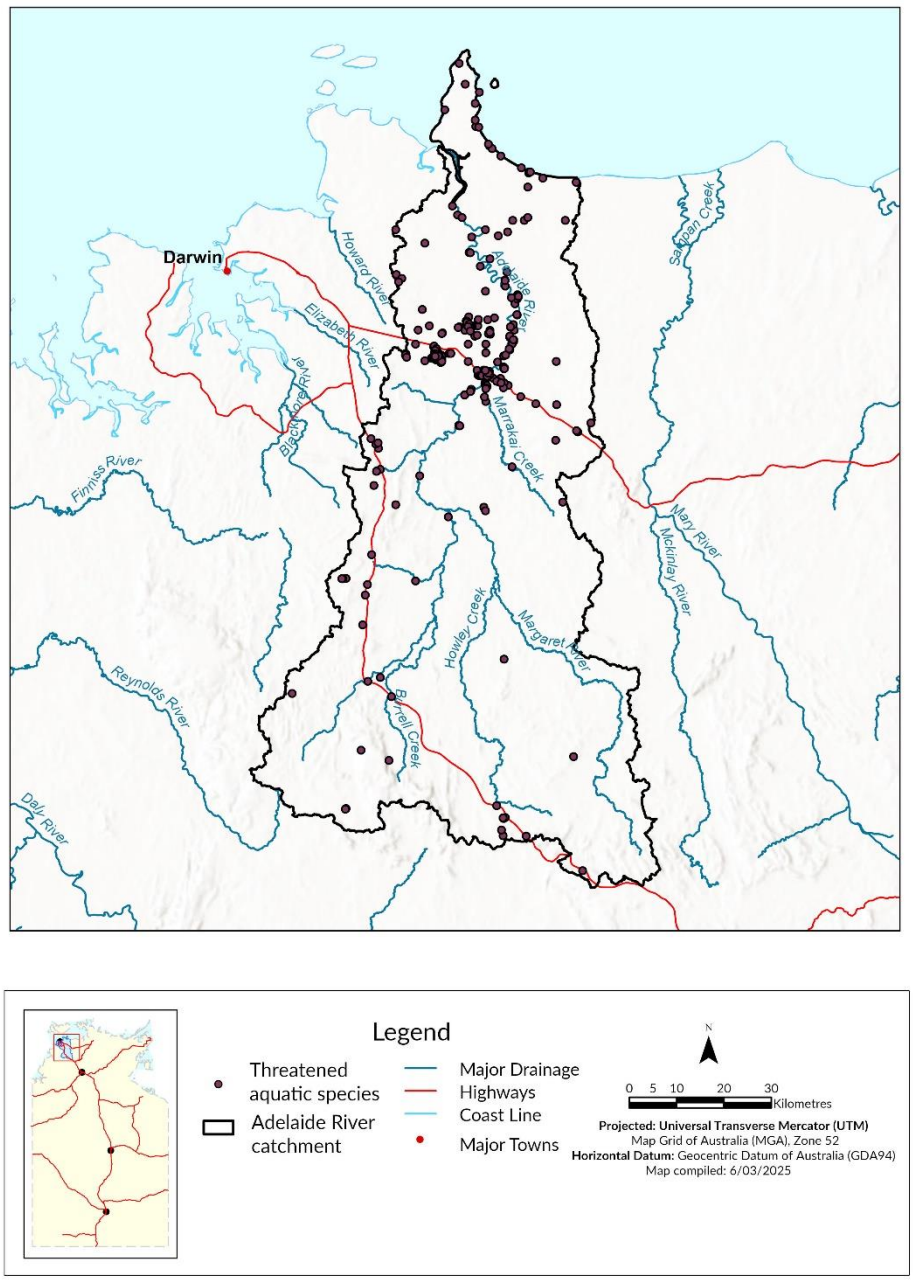


**Figure 6.** Distribution of records of threatened aquatic vertebrate species from the Adelaide River catchment from the NT Fauna Atlas.

# 4. Review of ecological assets

This chapter presents a review of relevant literature for ecological assets of the Adelaide River catchment. The consequences of hydrological manipulation for 12 freshwater and 11 marine ecological assets were considered by Pollino *et al*. (2018). Here, ecological assets include species or communities that have (i) a substantial public profile, (ii) substantial long-term monitoring data, or (iii) are considered suitable for monitoring impacts of hydrological manipulation (Table 10).

**Table 10.** Ecological assets of the Adelaide River catchment.

| Ecological asset | Key references |
|---|---|
| magpie geese | Annual monitoring reports |
| migratory birds | Bamford *et al*. (2008) |
| colonial breeding waterbirds | Chatto (2000) |
| euryhaline elasmobranchs | Pillans *et al*. (2010) |
| tidal freshwater fish | Berra and Wedd (2017), Pusey *et al*. (2016) |
| migratory aquatic species | Novak *et al*. (2015), Novak *et al*. (2017) |
| saltwater crocodile | Clancy and Fukuda (2024) |
| water pythons and dusky rats | Madsen and Shine (2000), Madsen *et al*. (2006) |
| frogs | Brown and Shine (2016) |
| monsoon rainforest | Price (1998) |

## 4.1. Magpie goose

The magpie goose *Anseranas semipalmata* is an iconic waterbird of the tropical wetlands of northern Australia. This species favours wetlands with a high abundance of food plants including wild rice *Oryza* and water chestnut *Eleocharis dulcis*. Populations may be impacted by habitat homogenisation by invasive grasses such as para grass *Urochloa mutica* (Whitehead and Saalfeld 2000), saltwater intrusion from rising sea levels (Bayliss *et al*. 2018), and potentially by changes to wet season inundation and flooding by water resource development.

Aerial surveys of magpie goose numbers on coastal floodplains of the Top End have been conducted with a consistent methodology since 2011 to inform the management of recreational hunting. Numbers fluctuate from year to year in response to climate impacts on recruitment and mortality. There are population estimates for two blocks of survey transects on the Adelaide River floodplain: downstream Adelaide River and upstream Adelaide River. Numbers in downstream Adelaide River exceed numbers in upstream Adelaide River by about 2:1 (Table 11). The percentage of the Top End magpie goose population on the Adelaide River floodplain varies from year to year, range 1.6 to 16.0%, mean 8.2%, n=13; and the percentage of the number of nests varies from year to year, range 1.3 to 63.6%, mean 14.7%, n=13 (Table 12). The distribution of magpie goose records in the Adelaide River catchment reflects the transect based survey design (Figure 7). The number and spatial distribution of this species on the Adelaide River floodplains vary from year to year, presumably in response to variation in regional rainfall and stream flow (Figure 8). Magpie goose populations in the NT between 1958 and 2000 exhibited 20 year trends coupled with similar trends in rainfall and stream flow (Bayliss and Ligtermoet 2017).

The floodplains of the Adelaide and Mary Rivers were identified as the most important nesting habitat for the magpie goose in the NT (Bayliss and Yeomans 1990). Densities of nests on the Adelaide River floodplain are highest in backswamps on the margins of the floodplain (Saalfeld 2014). In the Kakadu region, the distribution of wet season nesting 'hot spots' was associated with the occurrence of high abundance patches of tall *Eleocharis* sedge species and wild rice *Oryza* (Bayliss and Ligtermoet 2017).

Nest density on the Adelaide River floodplain fluctuated between 2011 and 2024; nesting failed or occurred only at low densities in 2016, 2019 and 2020. Nest density on the Mary River floodplain fluctuated markedly during 1988 to 1993, and nesting failed almost completely in unfavourable years. Nest density and timing of nesting correlated with variation in the timing of the onset of the wet season. Nest densities were higher, and nesting commenced earlier, in seasons preceded by sustained rainfall in the early wet season (Whitehead and Saalfeld 2000).

Further studies are required to examine spatial and temporal variation in the density of the magpie goose and its nests in relation to patterns of inundation and floodplain vegetation on the Adelaide River floodplain.

**Table 11.** Estimated numbers of magpie geese and geese nests in two survey blocks on the Adelaide River floodplain from 2011 to 2024.

| | Downstream Adelaide River | | | Upstream Adelaide River | | | |
|---|---|---|---|---|---|---|---|
| Year | Block size km$^2$ | Est. no. birds | Est. no. nests | Block size km$^2$ | Est. no. birds | Est. no. nests | Data source |
| 2011 | 1,161 | 125,788 | 27,538 | 1,101 | 81,762 | 7,019 | Saalfeld 2011 |
| 2013 | 798 | 132,986 | 6,944 | 719 | 40,125 | 1,323 | Saalfeld 2013 |
| 2014 | 798 | 92,117 | 10,013 | 719 | 31,960 | 1,574 | Saalfeld 2014 |
| 2015 | 798 | 45,058 | 2,555 | 719 | 57,587 | 279 | Saalfeld 2015 |
| 2016 | 798 | 45,559 | 0 | 719 | 1,800 | 589 | Saalfeld 2016 |
| 2017 | 798 | 78,635 | 20,227 | 719 | 22,529 | 1,409 | Groom 2017 |
| 2018 | 798 | 38,703 | 13,102 | 719 | 31,208 | 1,425 | Clancy 2018 |
| 2019 | 798 | 25,194 | 170 | 719 | 228 | 0 | Clancy 2019 |
| 2020 | 738 | 19,931 | 496 | 657 | 25,534 | 15 | Clancy 2020 |
| 2021 | 798 | 37,173 | 10,716 | 719 | 17,448 | 1,022 | Clancy 2021 |
| 2022 | 798 | 66,283 | 1,796 | 719 | 82,911 | 1,874 | Clancy 2022 |
| 2023 | 798 | 94,163 | 2,927 | 719 | 76,283 | 1,053 | Clancy 2023 |
| 2024 | 798 | 135,346 | 6,891 | 719 | 77,604 | 5,250 | Welch 2024 |

**Table 12.** Estimates of the numbers of magpie geese and magpie geese nests on the Adelaide River floodplain, and across all surveyed Top End floodplains.

| | Estimated number birds | | | Estimated number nests | | |
|---|---|---|---|---|---|---|
| Year | Adelaide River | Top End | % Top End | Adelaide River | Top End | % Top End |
| 2011 | 207,550 | 2,400,000 | 8.6 | 34,557 | 283,000 | 12.2 |
| 2013 | 173,111 | 2,500,000 | 6.9 | 8,267 | 13,000 | 63.6 |
| 2014 | 124,077 | 1,300,000 | 9.5 | 11,587 | 134,000 | 8.6 |
| 2015 | 102,645 | 1,200,000 | 8.6 | 2,834 | 105,000 | 2.7 |
| 2016 | 47,359 | 1,350,000 | 3.5 | 589 | 40,000 | 1.5 |
| 2017 | 101,164 | 724,500 | 14.0 | 21,636 | 95,000 | 22.8 |
| 2018 | 69,911 | 918,200 | 7.6 | 14,527 | 77,840 | 18.7 |
| 2019 | 25,422 | 1,542,943 | 1.6 | 170 | 10,484 | 1.6 |
| 2020 | 45,465 | 1,432,793 | 3.2 | 511 | 39,723 | 1.3 |
| 2021 | 54,621 | 982,156 | 5.6 | 11,738 | 44,010 | 26.7 |
| 2022 | 149,194 | 1,856,935 | 8.0 | 3,670 | 62,674 | 5.9 |

| | Estimated number birds | | | Estimated number nests | | |
|---|---|---|---|---|---|---|
| Year | Adelaide River | Top End | % Top End | Adelaide River | Top End | % Top End |
| 2023 | 170,446 | 1,260,454 | 13.5 | 3,980 | 45,900 | 8.7 |
| 2024 | 212,950 | 1,330,246 | 16.0 | 12,141 | 70,244 | 17.3 |
| average | 114,147 | 1,446,017 | 8.2 | 9,708 | 78,529 | 14.7 |

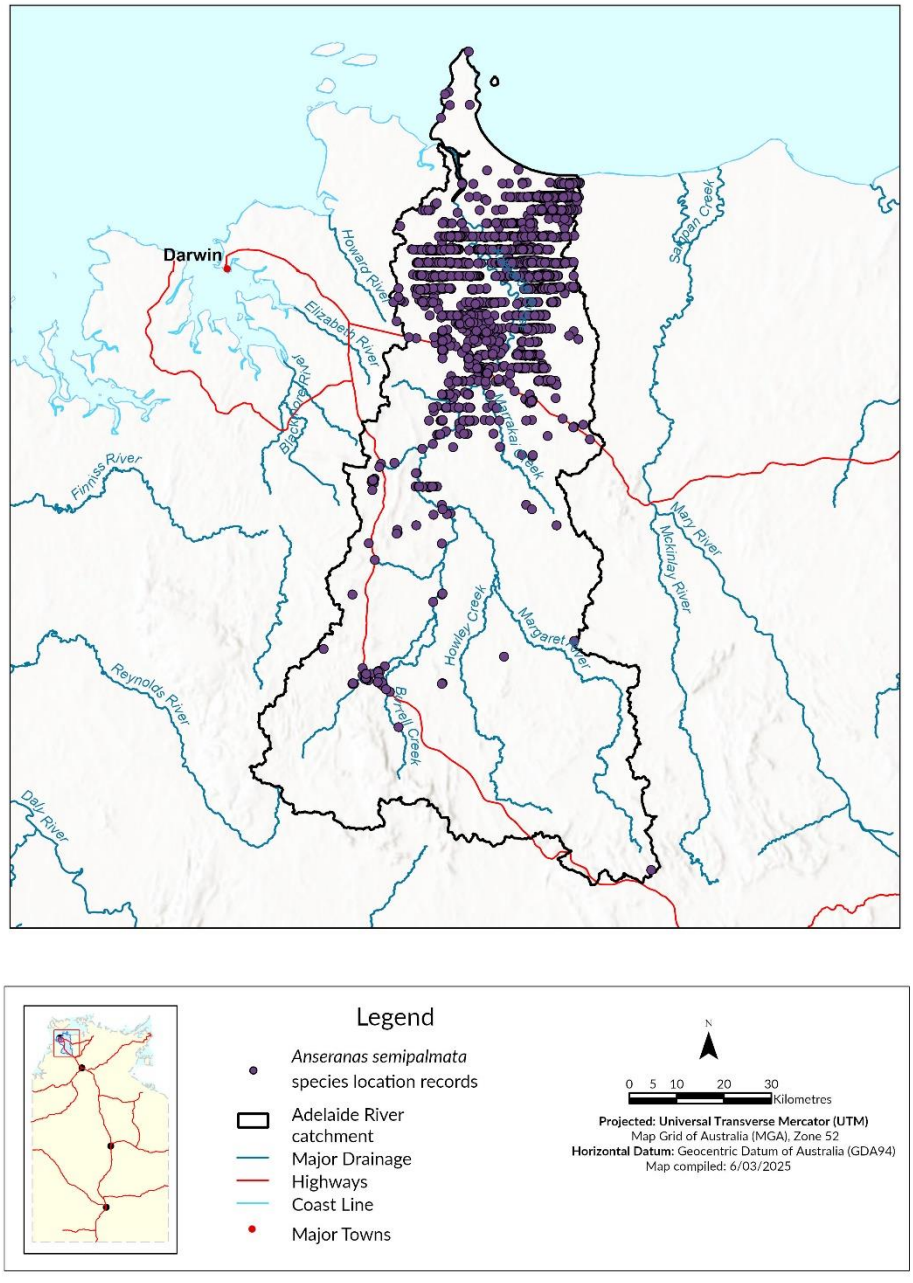


**Figure 7.** Distribution of magpie goose records in the NT Fauna Atlas for the Adelaide River catchment.

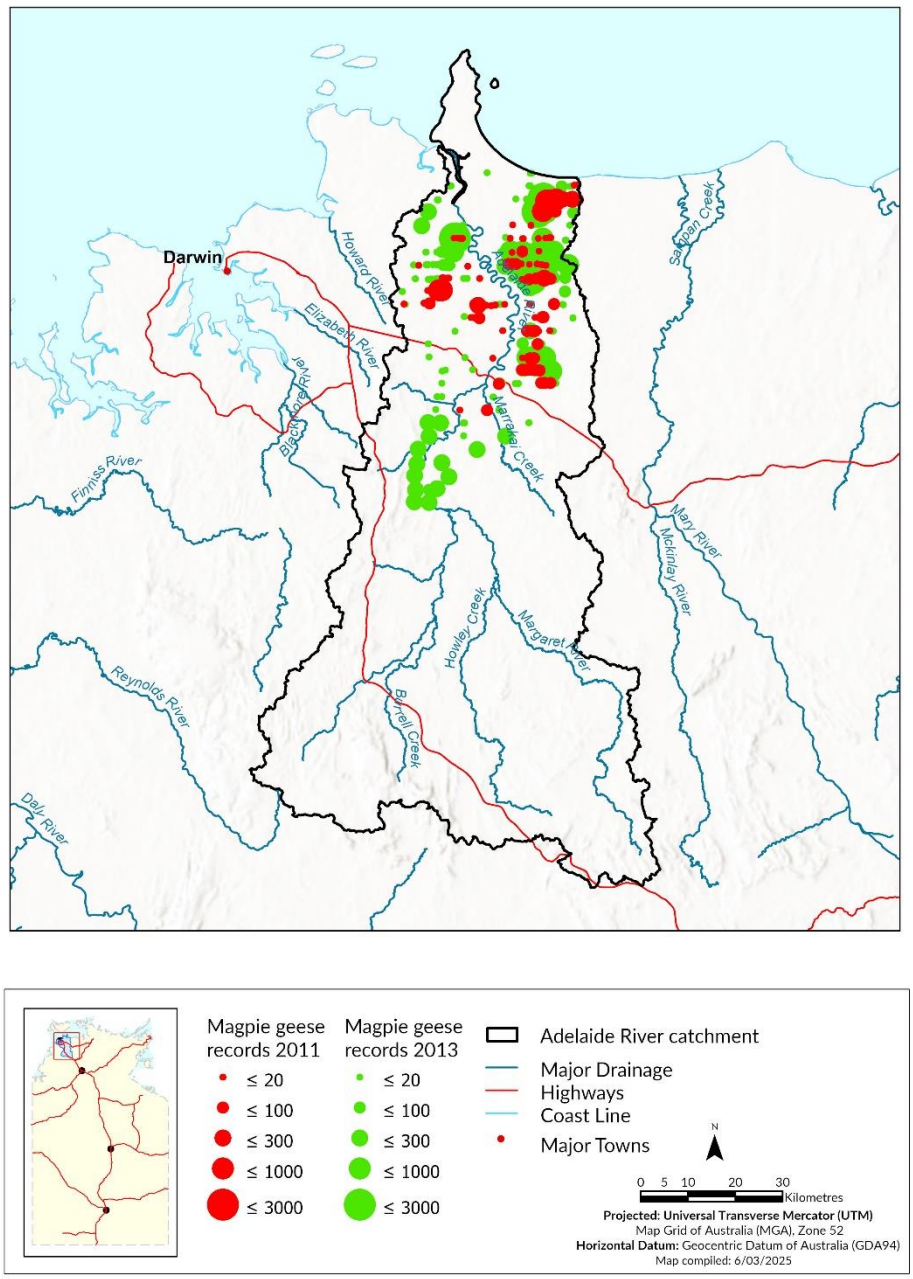


**Figure 8.** Distribution of magpie geese on Adelaide River floodplain from wet season surveys in 2011 and 2013.

## 4.2. Migratory shorebirds

The Adelaide River floodplain provides migration stop over habitat for migratory birds. Lake Finniss is identified as an internationally important site for migratory shorebirds in the East Asian-Australasian Flyway (Bamford *et al*. 2008). Maximum counts of species that are internationally significant (that is >1% global population) include 12,000 little curlew (Jaensch 1994), 3,000 red-necked avocet (Chatto 2006), and 2,000 black-tailed godwits (Chatto 2003). Coastal mudflats and nearby areas support internationally significant numbers of shorebirds, and thousands of Oriental pratincole *Glareola maldivarum* occur on the floodplain prior to the wet season. Important shorebird habitat is defined by the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* as supporting 0.1% of the flyway population, or 2,000 migratory shorebirds, or 15 migratory shorebird species.

Bilateral migratory bird agreements with Japan and China aim to conserve migratory birds in the East Asian-Australasian Flyway. The Japan-Australia Migratory Bird Agreement lists 66 migratory species; the China-Australia Migratory Bird Agreement lists 81 species. Australia is also a signatory to the Convention on Wetlands of International Importance, more commonly known as the Ramsar Convention. There are records of 42 migratory bird species from the Adelaide River floodplain (Table 13, Figure 9). At least 28 listed migratory bird species have been recorded from Fogg Dam Reserve.

**Table 13.** List of 42 migratory bird species recorded on Adelaide River floodplain and listed under either the Japan-Australia Migratory Bird Agreement, or the China-Australia Migratory Bird Agreement.

| Family | Species name | Common name | No. records | % no. |
|---|---|---|---|---|
| Acrocephalidae | *Acrocephalus orientalis* | Oriental reed-warbler | 17 | 0.9 |
| Charadriidae | *Anarhynchus leschenaultii* | greater sand plover | 9 | 0.5 |
| Charadriidae | *Anarhynchus mongolus* | Siberian sand plover | 23 | 1.2 |
| Charadriidae | *Charadrius veredus* | Oriental plover | 21 | 1.1 |
| Charadriidae | *Pluvialis fulva* | Pacific golden plover | 18 | 1.0 |
| Charadriidae | *Pluvialis squatarola* | grey plover | 26 | 1.4 |
| Glareolidae | *Glareola maldivarum* | Oriental pratincole | 61 | 3.2 |
| Laridae | *Chlidonias leucopterus* | white-winged black tern | 157 | 8.3 |
| Laridae | *Gelochelidon nilotica* | common gull-billed tern | 220 | 11.7 |
| Laridae | *Hydroprogne caspia* | Caspian tern | 60 | 3.2 |
| Laridae | *Onychoprion anaethetus* | bridled tern | 2 | 0.1 |
| Laridae | *Sterna hirundo* | common tern | 9 | 0.5 |
| Laridae | *Sterna sumatrana* | black-naped tern | 8 | 0.4 |
| Laridae | *Sternula albifrons* | little tern | 21 | 1.1 |
| Laridae | *Thalasseus bergii* | crested tern | 16 | 0.8 |
| Scolopacidae | *Actitis hypoleucos* | common sandpiper | 176 | 9.3 |
| Scolopacidae | *Arenia interpres* | ruddy turnstone | 7 | 0.4 |
| Scolopacidae | *Calidris acuminata* | sharp-tailed sandpiper | 144 | 7.6 |
| Scolopacidae | *Calidris alba* | sanderling | 2 | 0.1 |
| Scolopacidae | *Calidris canutus* | red knot | 6 | 0.3 |
| Scolopacidae | *Calidris falcinellus* | broad-billed sandpiper | 6 | 0.3 |
| Scolopacidae | *Calidris ferruginea* | curlew sandpiper | 36 | 1.9 |
| Scolopacidae | *Calidris melanotos* | pectoral sandpiper | 1 | 0.1 |
| Scolopacidae | *Calidris ruficollis* | red-necked stint | 36 | 1.9 |

| Family | Species name | Common name | No. records | % no. |
|---|---|---|---|---|
| Scolopacidae | *Calidris subminuta* | long-toed stint | 6 | 0.3 |
| Scolopacidae | *Calidris tenuirostris* | great knot | 14 | 0.7 |
| Scolopacidae | *Gallinago hardwickii* | latham's snipe | 1 | 0.1 |
| Scolopacidae | *Gallinago megala* | swinhoe's snipe | 7 | 0.4 |
| Scolopacidae | *Limnodromus semipalmatus* | Asian dowitcher | 6 | 0.3 |
| Scolopacidae | *Limosa lapponica* | bar-tailed godwit | 30 | 1.6 |
| Scolopacidae | *Limosa limosa* | black-tailed godwit | 54 | 2.9 |
| Scolopacidae | *Numenius madagascariensis* | far eastern curlew | 26 | 1.4 |
| Scolopacidae | *Numenius minutus* | little curlew | 197 | 10.4 |
| Scolopacidae | *Numenius phaeopus* | whimbrel | 51 | 2.7 |
| Scolopacidae | *Phalaropus lobatus* | red-necked phalarope | 1 | 0.1 |
| Scolopacidae | *Tringa brevipes* | grey-tailed tattler | 15 | 0.8 |
| Scolopacidae | *Tringa glareola* | wood sandpiper | 86 | 4.6 |
| Scolopacidae | *Tringa nebularia* | common greenshank | 134 | 7.1 |
| Scolopacidae | *Tringa stagnatilis* | marsh sandpiper | 139 | 7.4 |
| Scolopacidae | *Tringa totanus* | common redshank | 8 | 0.4 |
| Scolopacidae | *Xenus cinereus* | terek sandpiper | 17 | 0.9 |
| Anatidae | *Spatula querquedula* | garganey | 13 | 0.7 |

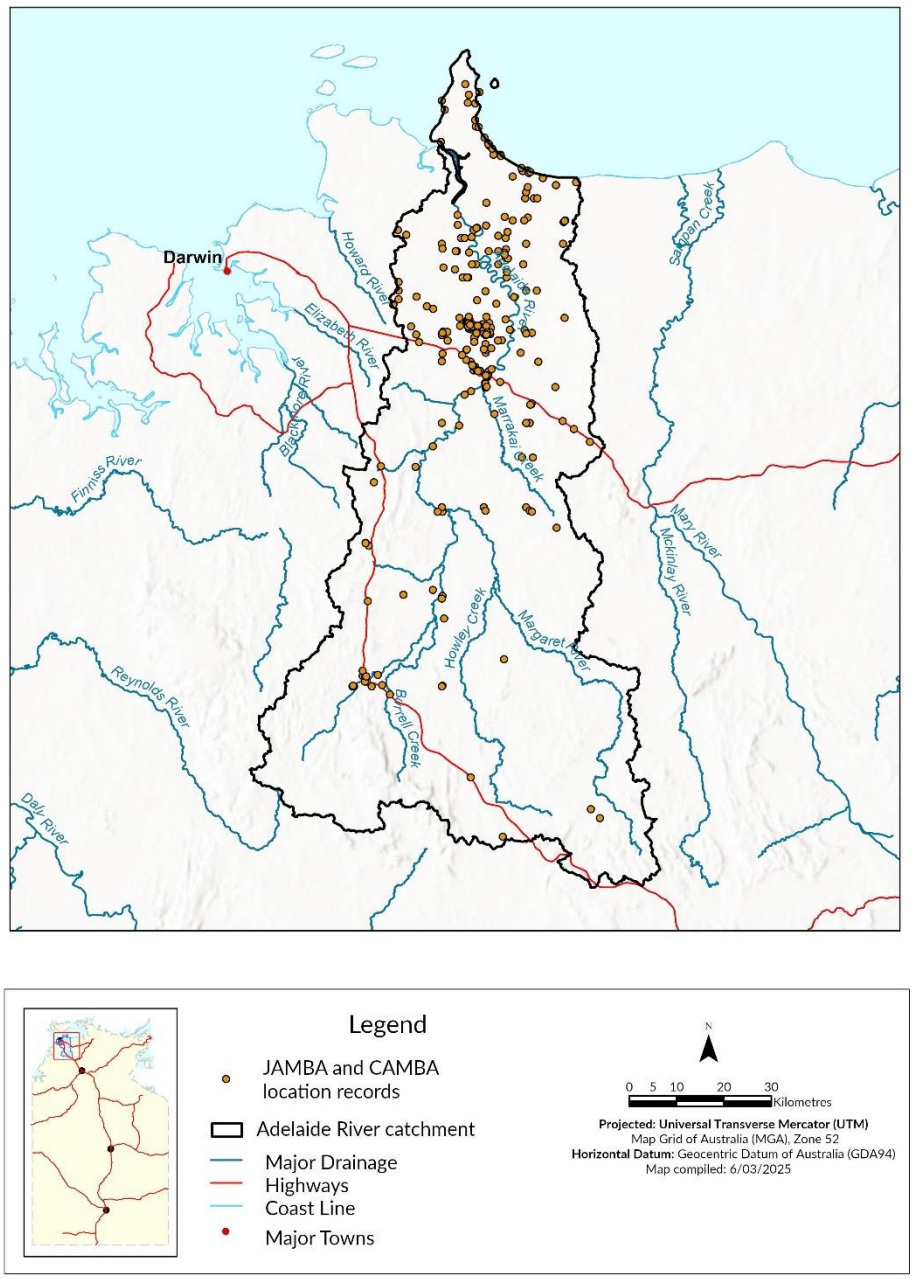


**Figure 9.** Distribution of records of migratory bird species listed under the Japan-Australia Migratory Bird Agreement of the China-Australia Migratory Bird Agreement.

## 4.3. Colonial breeding waterbirds

Breeding sites of 15 colonial breeding waterbird species were identified during aerial surveys of the coast and coastal floodplains of the Top End from 1990 to 1999 (Chatto 2000). Surveys identified 76 confirmed colonial waterbird breeding sites, 27 of which were considered as nationally significant. Of these, 12 were found between the Finniss River and the Moyle River, and eight were between the Adelaide River and Murganella Creek. Most of the larger colonies were located on the western side of the Top End. The largest single colony (W025), supporting up to 30,000 birds, was found on a tributary of the Adelaide River (Figure 10). Chatto (2000) documented three confirmed active colonies and four unconfirmed or historical colonies on the Adelaide River (Figure 11).

### 4.3.1. Confirmed colonies

W025. Located in mangroves 5 kms up a tributary of the Adelaide River and 15 kms from the mouth. Ten confirmed species breeding. Nesting from early November to late August, with a sequence of nesting activity commencing with cattle egrets, and finishing with royal spoonbills and Australian white ibis.

W046. Western bank of the Adelaide River, 15 kms from mouth. Two confirmed species breeding (little black cormorant and darter). Small colony less than10 kms from W025.

W015. Small, relatively insignificant darter and nankeen night-heron colony in paperbark on a creek between Adelaide and Mary Rivers.

### 4.3.2. Unconfirmed or historical colonies

W944. Extinct colony near mouth of Adelaide River reported by Frith and Davies (1961), with six breeding species, and in excess of 10,000 birds.

W949. Adelaide River north-east of Tommy Policeman Lagoon. Probably inactive but reported as a very dense mixed species colony over 100 m long on the Adelaide River.

W915. Small breeding site for royal spoonbill and intermediate egret in the vicinity of Fogg Dam Reserve.

W932. Nankeen night-heron site reported to be active sometime between January 1944 and January 1945 on Marrakai Creek.

There have been no recent surveys to assess the current status of these colonies, or to identify additional colonies. Further work is required to assess current activity and status of these colonies, and to develop methods to quantify seasonal and interannual variability in nesting activity.

**Figure 10.** Cattle egrets breeding in colony W025, in a tributary of the Adelaide River, November 1988 (from Chatto 2000).

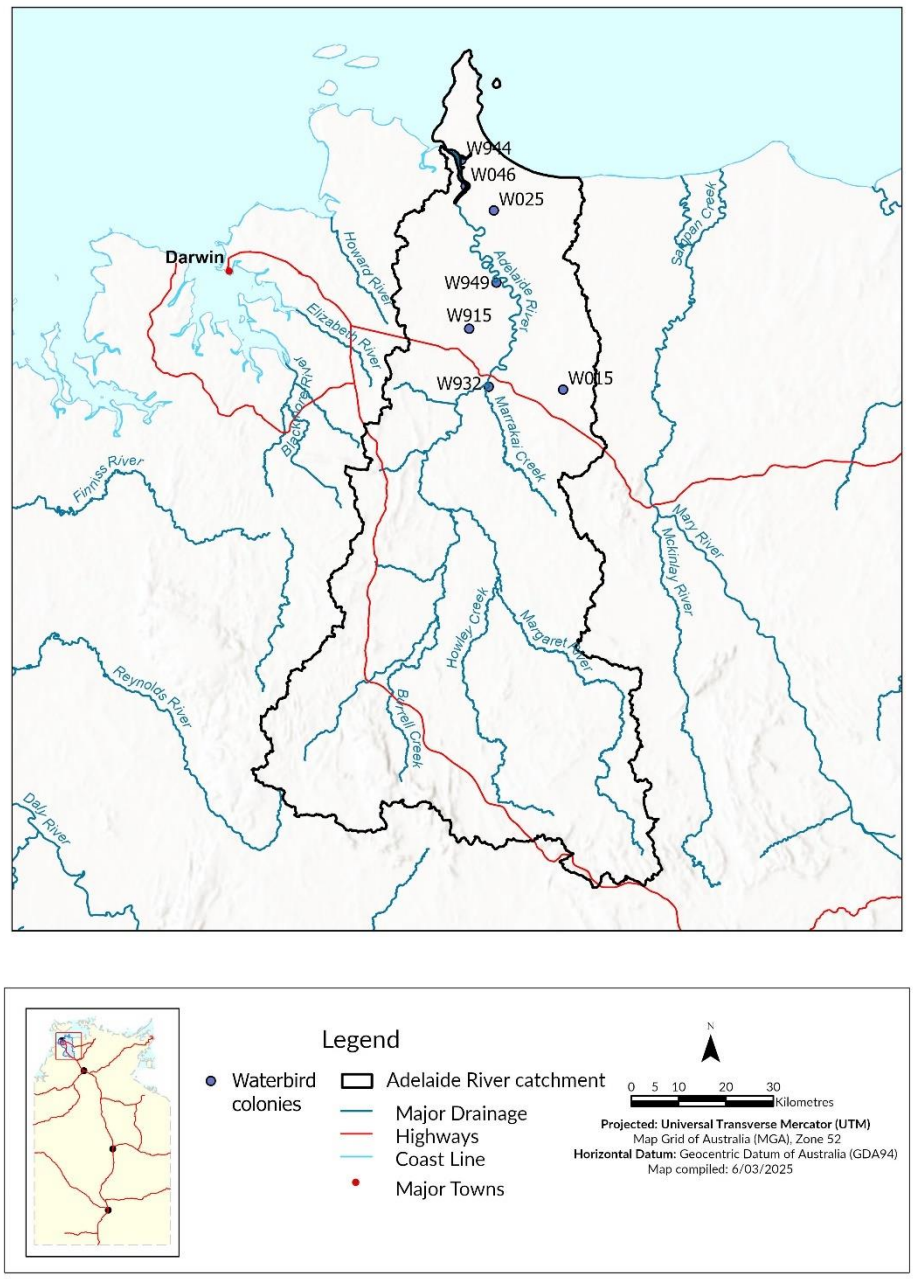


**Figure 11.** Location of three confirmed (W046, W025 and W015) and four unconfirmed or historical (W944, W949, W915 and W932) waterbird breeding colonies on the Adelaide River.

## 4.4. Euryhaline elasmobranchs

Euryhaline and estuarine generalist elasmobranchs are poorly known and disproportionately threatened, with 72.4% at risk of extinction or data deficient (Constance *et al.* 2023). Three species of euryhaline sharks are known to occur in the Adelaide River (Pillans *et al*. 2010): the speartooth shark *Glyphis glyphis*, northern river shark *Glyphis garricki* and bull shark *Carcharhinus leucas*. A further two species of euryhaline rays, largetooth sawfish *Pristis pristis* and freshwater whipray *Urogymnus dalyensis* also inhabit the Adelaide River, occupying most habitats from the headwaters to the coastal flats. River sharks and rays utilise freshwater and low salinity reaches of the Adelaide River during the juvenile phase of their life cycle, presumably to avoid predation during the vulnerable phase.

Two species, northern river shark *Glyphis garricki* and speartooth shark *G. glyphis*, have limited ranges in northern Australia (Udyawer *et al*. 2021). The former species is listed as endangered, and the latter as critically endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. The third species, bull shark, *Carcharhinus leucas*, has a widespread global distribution. River sharks use the mid reaches of the Adelaide River in the late dry season and move downstream after the onset of the wet season (Kyne and Feutry 2017).

The broad scale movements of speartooth shark *Glyphis glyphis* within the tidal reaches of the Adelaide River have been studied for several years. Modelling of this data may reveal broad scale habitat preferences which can be used to assess effects of reduced flows and altered salinity dynamics. Although the life history traits of northern river sharks are poorly understood, they are sympatric with speartooth sharks and anecdotally share similar life history traits such as a reliance on upper estuarine habitats for juvenile development, with movement into the upper reaches of the tidal limit restricted by salinity gradients. Bull sharks utilise a wide range of salinities throughout their life cycle and unlike *Glyphis*, don't rely on salinity gradients as a barrier to migration. Literature on the habitat preferences of other fish species within the tidal reaches is sparse however there is some available (Berra and Wedd 2017).

Largetooth sawfish are threatened globally and listed under both Territory and Australian legislation. The Adelaide River is recognised as a stronghold for the species (Kyne *et al.* 2021). Sawfish utilise coastal river systems as juvenile nursery areas and remain in freshwater until they reach sexual maturity at a length of 3-4 m (Buckley *et al*. 2020). Sawfish utilise a range of aquatic habitats during this early growth phase and can remain landlocked in freshwater. Sawfish have been observed in the Adelaide River from the coastal mudflats up to the headwaters above Adelaide River township. Long-term acoustic tracking of juvenile sawfish in the Adelaide River (Buckley *et al*. 2020) revealed tidal assisted movement patterns within the main channel. Access throughout the river system main stem and floodplain refugia is integral to long-term survival of juvenile sawfish and disruption of flows during the dry season or restricted access to off-channel refugia may further impact an already imperilled population.

## 4.5. Tidal freshwater fish

The composition, habitat and environmental covariates of distribution of most fish species in the tidal rivers of northern Australia are poorly known. The fish assemblages of the tidal reaches of the South Alligator River were surveyed by beam trawl in 2012 (Pusey *et al.* 2016). The survey identified 81 taxa, 26 of which had not previously been recorded. There have been no similar quantitative surveys of the fish fauna of the Adelaide River. The fish fauna of the tidal freshwater reach of the Adelaide River is particularly understudied.

The spawning requirements of most fish species in the tidal rivers of northern Australia are similarly poorly known. Published studies for Adelaide River include a study on the environmental covariates of spawning in the nurseryfish *Kurtus gulliveri* (Berra and Wedd 2017). The nurseryfish is the only fish known to exhibit 'forehead brooding', where males carry the fertilized eggs on a supra-occipital hook. Within the period July to October, larval nurseryfish were found in the mid reaches of the Adelaide River, most commonly at salinities between 0.5 ppt and 13.6 ppt. Hydrological manipulation of the river could alter the area suitable for larval occupancy.

In addition to nurseryfish, there is a suite of species that inhabit the tidal freshwater interface referred to as 'tidal freshwater' species. The biology and ecology of most of these species are poorly known. In common with nurseryfish, hydrological manipulation of the river could lower habitat availability for these species.

## 4.6. Migratory aquatic species

### 4.6.1. Barramundi

The barramundi, *Lates calcarifer*, is a facultatively catadromous species of the tropical rivers of northern Australia. Growth rate, migration tendency and year class strength are linked to hydrological variability. Growth rates of estuarine barramundi are positively related to freshwater flow (Robins *et al.* 2006).

Populations contain coexisting contingents of migratory and resident individuals. Migration tendency of juvenile barramundi is influenced by resource availability (Roberts *et al.* 2023), with upstream migration more likely in years of scarce resources during lower rainfall years.

The life history of the barramundi features sequential hermaphroditism. Female maturation is linked to juvenile growth rate. Fast growing fish may make a disproportionate contribution to population fecundity; hence factors that reduce growth rates such as degradation of floodplain habitats are likely to impact the productivity of barramundi fisheries (Roberts *et al*. 2021).

Crook *et al.* (2022) used age and growth data from otoliths to model recruitment and growth, and climatic and river hydrology variables in four NT rivers, excluding the Adelaide River. They used river-specific hydrology analyses to predict the effect of abstraction on recruitment and growth. The study found strong evidence that recruitment is linked to the Australian monsoon index, and found strong negative effects of abstraction on recruitment, with effects varying among river systems.

Barramundi and salmon catfish, *Neoarius leptaspis*, undertake extensive movements between dry season refugia and inundated floodplain habitat in response to the wet season pulse of resources (Crook *et al*. 2019).

### 4.6.2. Cherabin

The palaemonid shrimp, *Macrobrachium spinipes*, (commonly known as cherabin) occurs widely throughout the rivers and streams of northern Australia. Cherabin have an amphidromous life cycle: larvae migrate from freshwater to estuarine water for development during the wet season, and juveniles undertake a recruitment migration 3 to 4 months later during the early dry season. A second palaemonid species, *M. bullatum* completes larval development entirely within freshwater. Other *Macrobrachium* species may also occur within the estuary. Palaemonids make a large contribution to the diet of predatory freshwater fish including spangled perch, sooty grunter and barramundi (Jardine *et al.* 2012).

The life history and population dynamics of cherabin in the Daly River were investigated by Novak *et al*. (2015, 2017). Ovigerous females can occur up to 400 km upstream. Reproduction is restricted to wet season months. Drifting larvae need to reach saline waters within seven days for development. Upstream migration by juveniles occurs in pulses over a 3 to 6 week period in late March and April. Migration rate is strongly associated with discharge, but the timing and environmental drivers of migration differed between the years of the study, with moon illumination significant in 2014 but not 2013. In addition, juvenile atyid shrimps of the genus *Caridina* were observed to migrate during the same period. An estimated 10 to 20 million shrimps migrate upstream during each wet season. Migration potentially plays an important role transporting nutrients between reaches, but there is no evidence of a direct marine subsidy to freshwater systems.

Studies of the timing, duration and environmental covariates of upstream migration by juvenile cherabin in the Adelaide River system would provide information on the environmental flow requirements of a key species.

### 4.6.3. Sooty grunter

Sooty grunter *Hephaestus fuliginosus* is a common species of rivers and streams throughout northern Australia. It is highly valued as food by Aboriginal people and is targeted by recreational anglers. Water extraction for agricultural development will potentially reduce habitat availability for this flow dependent species and will restrict longitudinal connectivity. Habitat selection studies in the Daly River suggest that the sooty grunter undertakes an ontogenetic habitat shift, with small fish utilising shallow, fast flowing riffle habitats and larger fish preferring deep, slow flowing pools (Keller *et al.* 2019). Habitat selection by juvenile sooty grunters has been studied in a reach of the Katherine River, using radiotelemetry to pinpoint the location of tagged fish, and hydrodynamic modelling to predict the distribution of depth and velocity under different flow scenarios (Crook *et al*. 2021). Modelled data were used to quantify minimum flow requirements. Broadscale longitudinal movements have been studied in the Daly River using acoustic telemetry. Tagged fish made long distance forays in both upstream and downstream directions (King *et al*. 2021). One individual moved 60 km upstream in 3.5 days before leaving the detection array.

## 4.7. Saltwater crocodile

Numbers and biomass of saltwater crocodiles are monitored in Top End rivers using standardised survey methods (Fukuda *et al*. 2013) as part of the NT crocodile management program. The Adelaide River is one of eight rivers monitored on a regular basis. Surveys of crocodile populations of the tidal portion of the Adelaide River have been conducted since 1977 and are now conducted on an annual basis. Modelling of population counts from the Adelaide River reveals a pattern of logistic growth, with numbers appearing to stabilise at an asymptote of between 4 and 5 sightings per kilometre (Clancy and Fukuda 2024), suggesting recovery to pre hunting levels. Crocodile eggs can be harvested from wild crocodile nests by permit holders. Returns from permit holders are closely monitored to ensure compliance with permit conditions. The concentration of saltwater crocodile records in the tidal portion of the Adelaide River reflects the extent of monitoring surveys (Figure 12).

Landsat satellite imagery and additional spatial information have been used to model the distribution of potentially suitable nesting habitat of *C. porosus* in the Adelaide River and Melacca Swamp wetlands (Harvey and Hill, 2003).

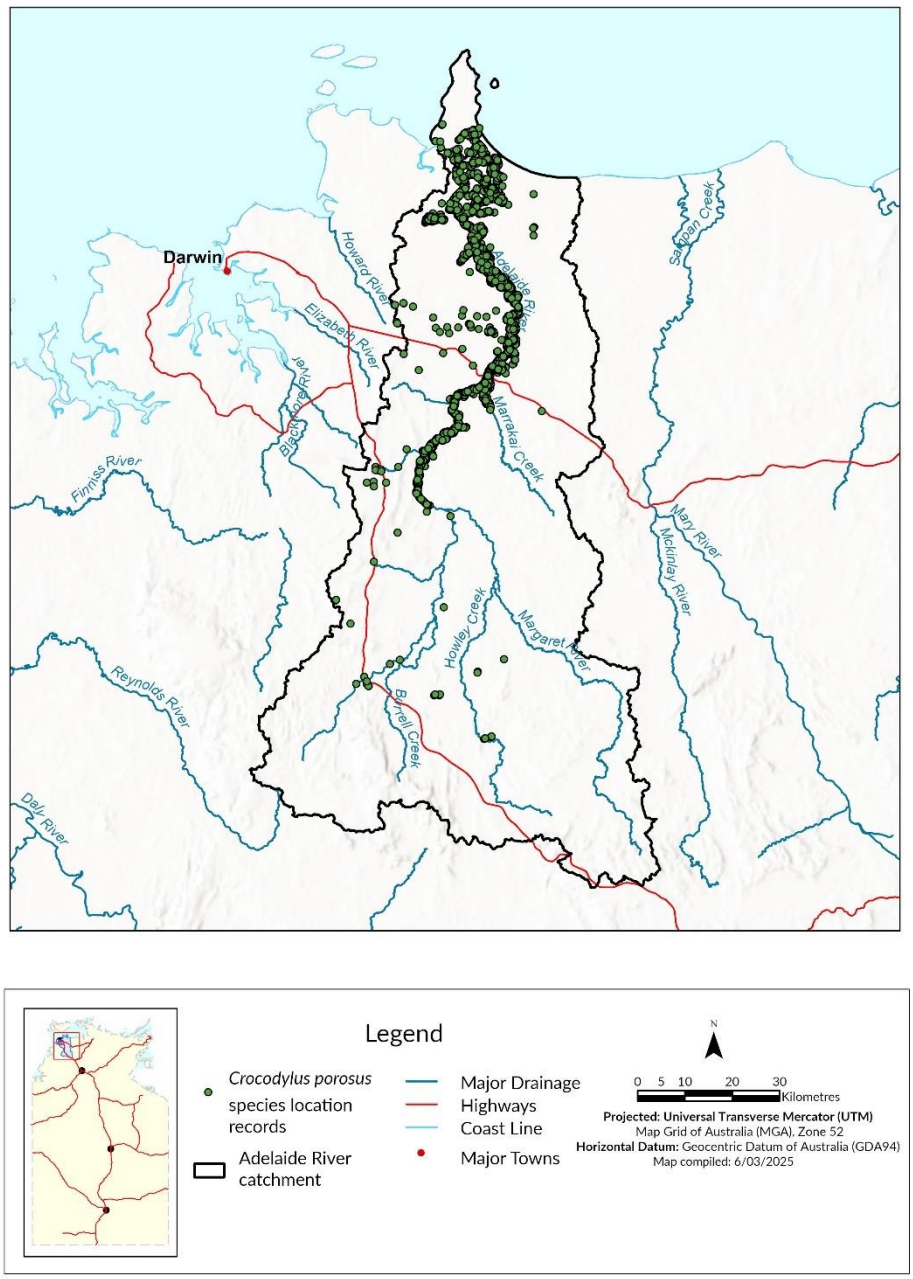


**Figure 12.** Distribution of records of saltwater crocodile *Crocodylus porosus* from the NT Fauna Atlas from the Adelaide River catchment.

## 4.8. Water python and dusky rat

Long-term studies of the demography of water python *Liasis fuscus* and its main prey, dusky rat, *Rattus colletti*, in the area of Fogg Dam Reserve showed climate driven fluctuations in numbers (Madsen *et al.* 2006). Rat numbers were low in years with low and high rainfall at the end of the wet season; annual fluctuations in rat numbers correlated with variation in female python reproduction, condition, and survival. Prolonged rat breeding is essential if hatchling pythons are to encounter ingestible size prey (Shine and Madsen 1997). Flood events in 2007 and 2011 caused the collapse of this predator prey system, and massive shifts in python demography (Ujvari *et al.* 2016).

A 10 year study of the demography Arafura file snake, *Acrochordus arafurae*, in the Alligator Rivers region showed that annual variation in rainfall pattern drives population dynamics. High rainfall late in the wet season caused prolonged inundation of the floodplain, high fish abundance, and high proportion of reproductive adult females (Madsen and Shine 2000).

## 4.9. Frogs

The Flora and Fauna Division species database contained 3,556 records representing 26 species of frogs for the Adelaide River catchment. Unlike in other parts of Australia and globally, there is no evidence of recent declines in frog species in the NT (Woinarski 1993, Stuart *et al*. 2004, Richards *et al*. 2006, Brown and Shine 2016). The frog fauna of the NT includes 47 species, of these, only one species is listed as of conservation concern. The Howard River toadlet, *Uperoleia daviesae*, has a restricted distribution within the greater Darwin area, is threatened by urban expansion, and is listed as vulnerable under NT and national legislation. The toadlet is one of several threatened species restricted to sandsheet heath. A 16 year survey of four native frog species in the Fogg Dam Reserve area found abrupt and asynchronous shifts in abundance and species composition from year to year which were not clearly linked to rainfall pattern, and there was no evidence of consistent declines over time (Brown and Shine 2016).

## 4.10. Monsoon rainforest

There are 825 mapped patches of monsoon rainforest in the Adelaide River catchment. About 5,500 ha of rainforest (or 2% of the NT rainforest estate) occur as scattered patches mostly along the upland margin of the floodplain (Figure 13). Rainforests in proximity to the Adelaide River floodplain have been identified as one of six clusters of rainforest patches required to capture rare endemic rainforest plant species (Price 1998).

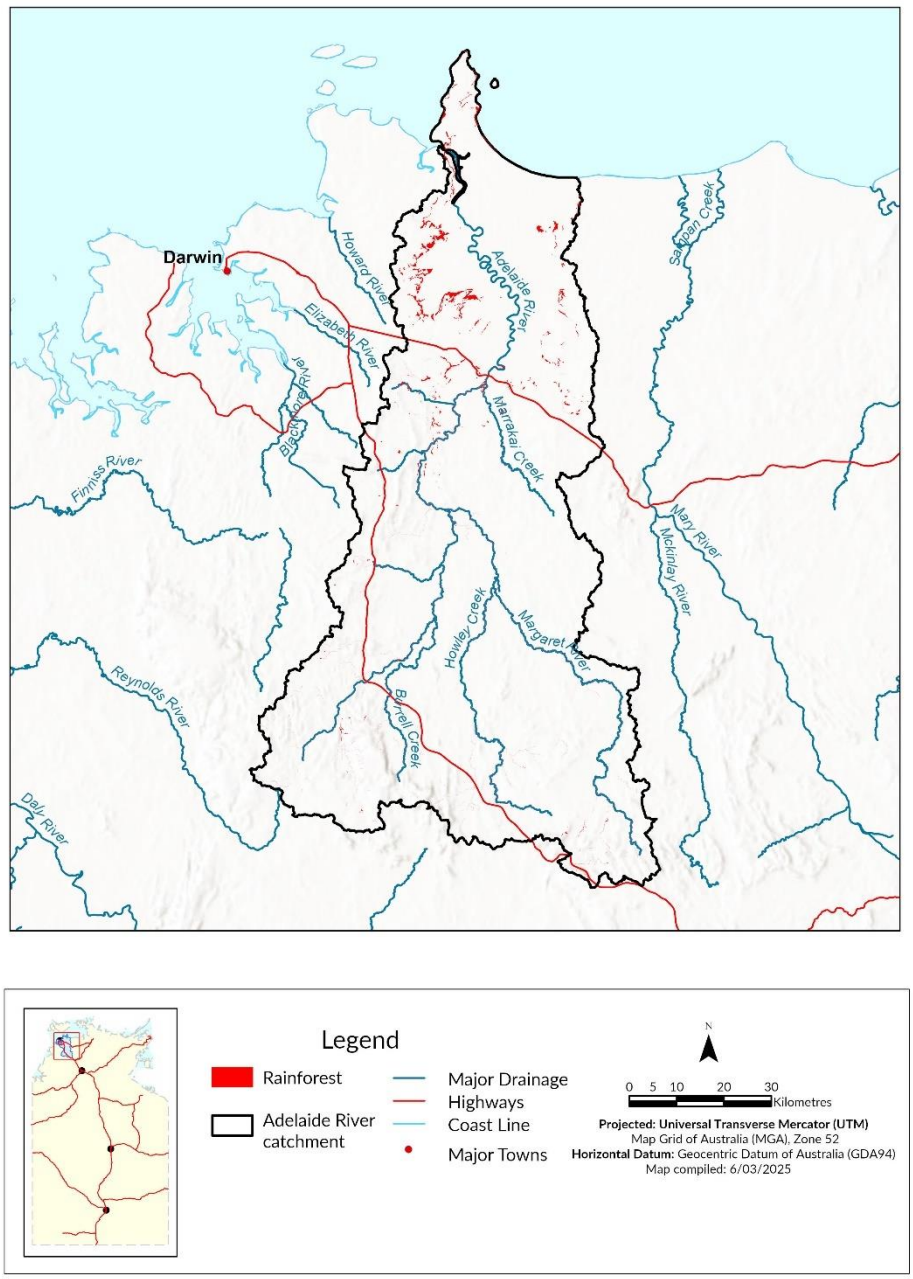


**Figure 13.** Distribution of monsoon rainforest in the Adelaide River catchment.

# 5. Spatial variation in water quality

Environmental data, including data on water quality parameters, were collected at each survey site to provide information on baseline condition, and to provide explanatory variables for the analysis of ecological data. At each site, *in situ* data was collected on physicochemical variables and water samples were collected for laboratory analysis of water quality parameters (Table 14). The timing of sample collection was standardised to control for diurnal variation. There was no assessment of diurnal or seasonal variation in water quality.

## 5.1. Methods

Data on physicochemical variables were collected from three subsites at each site using a YSI field water quality meter at a depth of 0.5 m from the water surface. Field variables included water temperature, dissolved oxygen, pH and conductivity. A Hach turbidity meter was used to collect data on turbidity at each subsite. Water samples were collected from near the water surface at one subsite for the laboratory analysis of chlorophyll *a* concentration, total nutrients (nitrogen and phosphorus), ionic composition and isotopic composition. Nutrient samples were frozen in the field; ionic composition and general parameters samples were refrigerated. Chlorophyll samples were filtered and then frozen in the field.

Longitudinal patterns in water quality are shown for a sequence of nine sites, including six freshwater sites from the upper most site at DRRD, and three tidal freshwater sites. Differences between riverine and off-stream channel sites are illustrated using box plots of variability of six water quality parameters at six freshwater sites and six off-stream channel sites. Piper diagrams are used to examine variability in ionic composition among sites.

**Table 14.** Water quality parameters collected at each of the 18 study sites in the Adelaide River catchment.

| Data type | Method | Laboratory | Parameters |
|---|---|---|---|
| Field measurements of physico-chemical parameters | YSI DSS<br>Hach turbidimeter | | DO, %DO<br>Temperature<br>pH<br>Electrical conductivity<br>Turbidity |
| Total nutrient concentration | | Intertek, Darwin | Total nitrogen<br>Total phosphorus |
| Ionic composition | | Intertek, Darwin | Anions Cl, $CO_3$, $HCO_3$, $SO_4$<br>Cations Ca, Mg, K, Na |
| General parameters | | Intertek, Darwin | Alkalinity<br>Hardness<br>Total dissolved solids |
| Chlorophyll concentration | | ECMU | Chlorophyll *a* |
| Isotopic composition | | | 18O VSMOW<br>2H VSMOW |

## 5.2. Results

Water quality parameters varied according to habitat class and position in the landscape (Table 15). The primary trends are longitudinal differences within freshwater reaches; differences between freshwater and tidal freshwater reaches; differences in mean values and variability of riverine and off-stream channels; and differences between non-impacted and impacted sites.

Electrical conductivity of the freshwater reach of the Adelaide River ranged from a minimum value of 78.1 µS/cm at the upper most site at site Daly River Road Crossing (DRRD), but thereafter was relatively invariable (mean value 261.4 µS/cm) from Adelaide River township, site Adelaide River Bridge Riffle (ARBR) to the tidal limit at site Marrakai Crossing (MKXG).

Values increased in the tidal freshwater reach (Figure 14). Differences in the conductivity of the upper most sites (DRRD for Adelaide River, and CMCK for Coomalie Creek) presumably reflect differences in the chemistry of groundwater sources at these sites (Figure 15). The conductivity of off-stream channels ranged from 29.7 to 56.4 µS/cm, and averaged 46.2 µS/cm. Off-stream channels are inundated by wet season floodwaters; the difference in conductivity among off-stream channel site may reflect differences in the timing of connection with floodwaters.

Chlorophyll *a* concentration tended to increase throughout the longitudinal sequence but was markedly higher at the tidal freshwater site Kaissis Creek (KSCK). Total nitrogen concentration mirrored the pattern for conductivity. Total phosphorus values tended to be low and invariable at freshwater sites, then increased markedly downstream in the tidal freshwater (Figure 14).

Values of chlorophyll *a*, total nitrogen, total phosphorus and turbidity tended to be relatively low and invariable at freshwater channel sites, but high and variable at off-stream channel sites. Electrical conductivity, as noted above, tends to be high and invariable at freshwater sites and low and invariable at off-stream channel sites (Figure 16).

The single impacted floodplain lagoon site featured high values of chlorophyll *a*, high total nitrogen and turbidity, and low percentage dissolved oxygen. Maps of the spatial variability of water quality parameters are presented in Figures 17 to 21.

**Table 15.** Data for six water quality parameters at 18 sites in the Adelaide River catchment, ordered by habitat class.

| Site | Date | Time | Chlorophyll *a* (µg/L) | Electrical conductivity (µS/cm) | Total nitrogen (mg/L) | Total phosphorus (mg/L) | Turbidity (NTU) | % dissolved oxygen |
|---|---|---|---|---|---|---|---|---|
| **Freshwater main channel sites in longitudinal sequence (classes 1, 2.1 and 2.2)** | | | | | | | | |
| DRRD | 23/08/24 | 10:09 | 0.5 | 78.1 | 0.03 | 0.005 | 2.8 | 67.9 |
| ARBR | 12/08/24 | 14:52 | 1.3 | 279.2 | 0.19 | 0.02 | 2.1 | 92.4 |
| STRD | 13/08/24 | 10:03 | 3.2 | 271.5 | 0.18 | 0.01 | 9.6 | 68.4 |
| ARDD | 06/08/24 | 11:12 | 1.7 | 247.4 | 0.21 | 0.01 | 3.0 | 56.7 |
| DDRF | 17/08/24 | 11:37 | 2.5 | 248.0 | 0.18 | 0.005 | 2.8 | 64.5 |
| MKXG | 12/08/24 | 9:16 | 3.1 | 260.9 | 0.17 | 0.005 | 3.1 | 69.4 |
| **Tidal freshwater sites in longitudinal sequence (class 6)** | | | | | | | | |
| MRJN | 16/08/24 | | 4.4 | 273.4 | 0.17 | 0.01 | 5.6 | 59.1 |
| KSCK | 14/08/24 | 10:12 | 20.4 | 330.1 | 0.24 | 0.035 | 90.2 | 96.7 |
| BTCK | 15/08/24 | 10:07 | 6.6 | 495.1 | 0.46 | 0.1 | 211.5 | 92.2 |
| **Riverine lagoon on tributary stream, headwaters (Coomalie Creek) (class 2.1)** | | | | | | | | |
| CMCK | 22/08/24 | 9:08 | 11.9 | 424.7 | 0.25 | 0.035 | 6.1 | 58.4 |
| **Freshwater non-main channel** | | | | | | | | |
| **Upper (class 3.1)** | | | | | | | | |
| MKBB | 10/08/24 | 9:46 | 19.9 | 48.8 | 1.06 | 0.035 | 5.6 | 53.1 |
| DLDD | 05/08/24 | 10:55 | 4.2 | 29.7 | 0.38 | 0.01 | 3.5 | 87.2 |
| **Middle (class 3.2)** | | | | | | | | |
| AR03 | 09/08/24 | 9:27 | 4.4 | 40.3 | 0.35 | 0.015 | 1.8 | 57.0 |
| AR01 | 20/08/24 | 9:40 | 4.6 | 51.0 | 0.38 | 0.015 | 1.4 | 76.1 |
| **Lower (class 3.3)** | | | | | | | | |
| AULD | 07/08/24 | 9:42 | 5.3 | 51.2 | 0.43 | 0.025 | 7.3 | 40.3 |
| DNLG | 08/08/24 | 9:22 | 11.3 | 56.4 | 0.76 | 0.055 | 13.6 | 72.9 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Riverine lagoon on tributary stream, adjacent to floodplain (Manton Creek) (class 4)** | | | | | | | | |
| AGLN | 19/08/24 | 9:20 | 3.5 | 148.6 | 0.18 | 0.01 | 2.0 | 65.9 |
| **Impacted floodplain channel (class 5)** | | | | | | | | |
| BHRF | 21/08/24 | 10:31 | 24.9 | 176.7 | 1.04 | 0.105 | 241.3 | 13.2 |

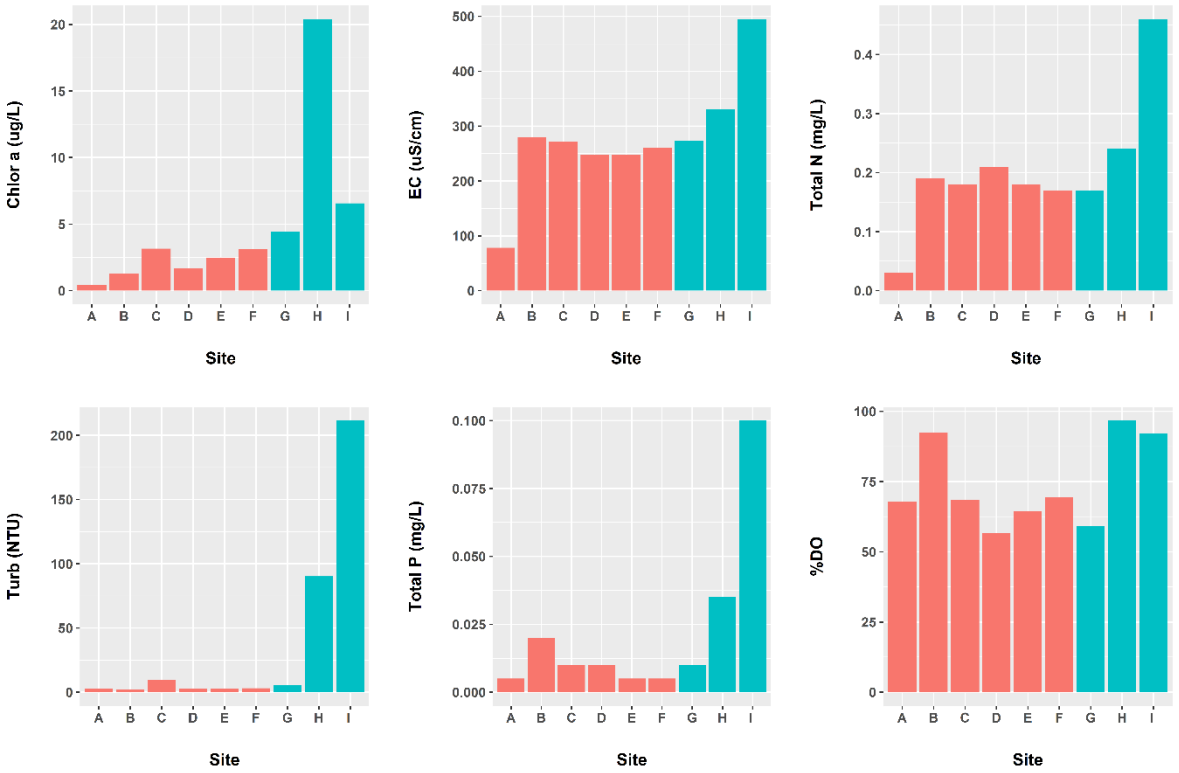


**Figure 14.** Longitudinal variability in data for six water quality variables in freshwater reach (red) and tidal freshwater reach (blue) of the Adelaide River.

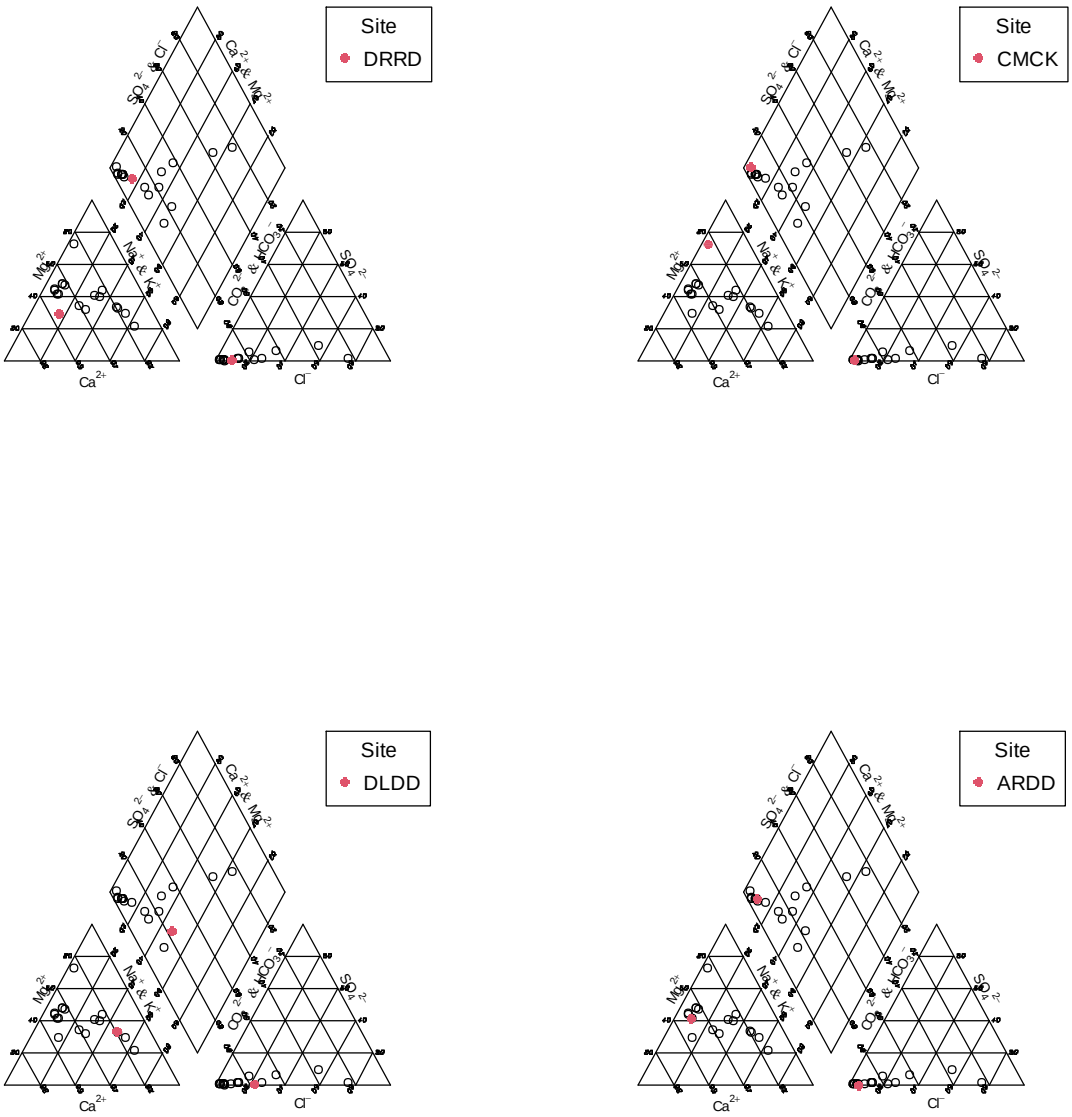


**Figure 15.** Piper diagrams of variation in ionic composition between sites with different groundwater sources, (sites DRRD and CMCK); and between sites with wet season (DLDD) and dry season (ARDD) characteristics.

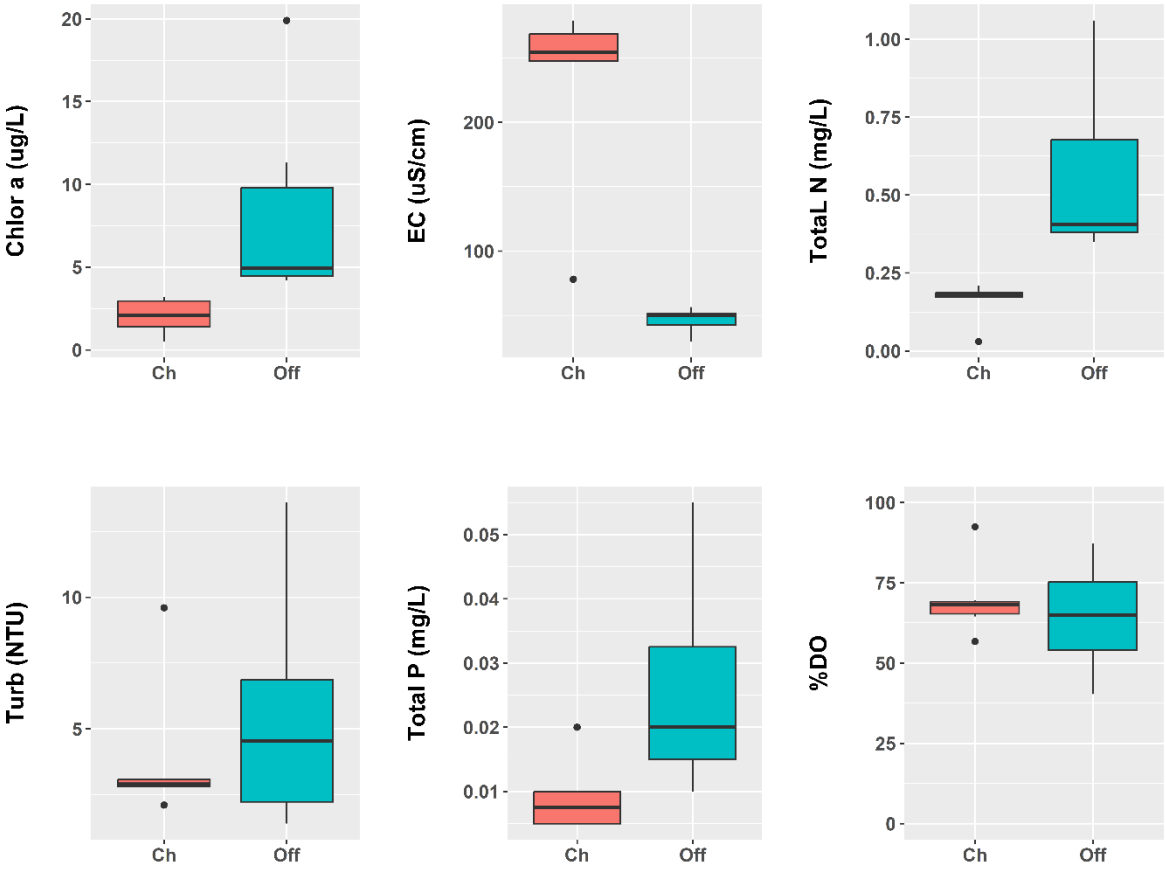


**Figure 16.** Boxplots of data for six water quality parameters of freshwater riverine and off-stream channel sites.

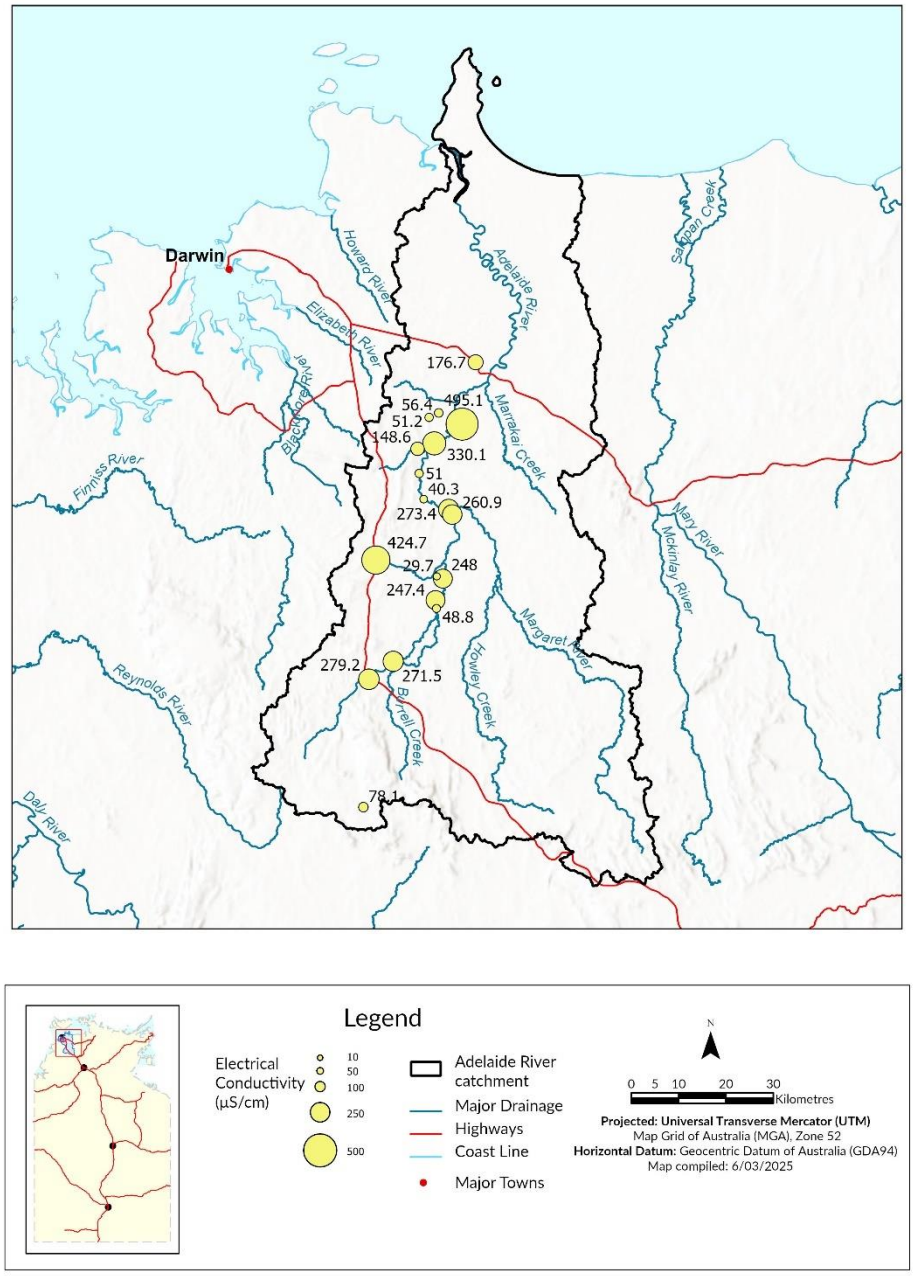


**Figure 17.** Spatial variability of values of electrical conductivity (µS/cm) at 18 sites in the Adelaide River catchment. Sites were sampled from 5 to 23 August 2024.

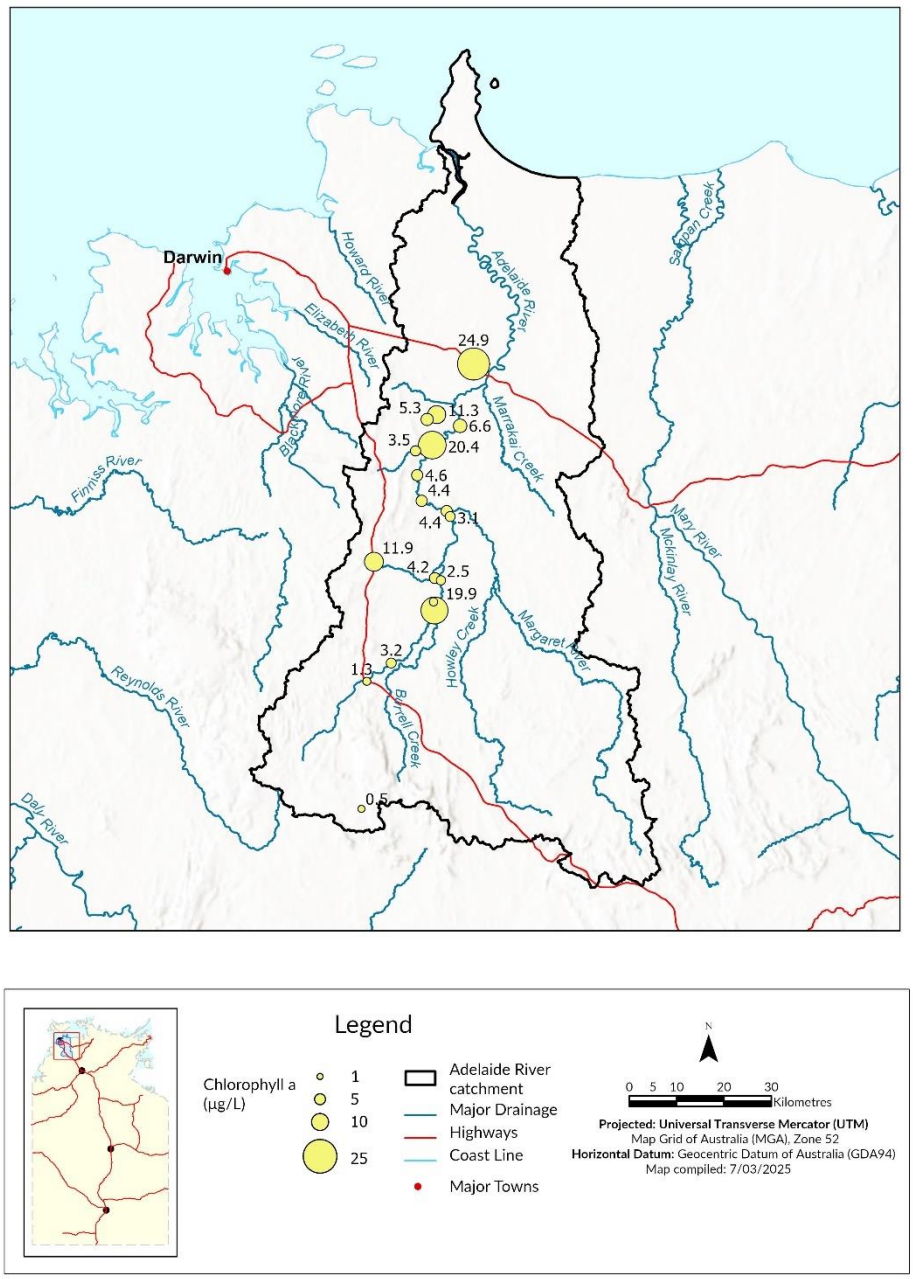


**Figure 18.** Spatial variability of values of chlorophyll *a* (µg/L) at 18 sites in the Adelaide River catchment. Sites were sampled from 5 to 23 August 2024.

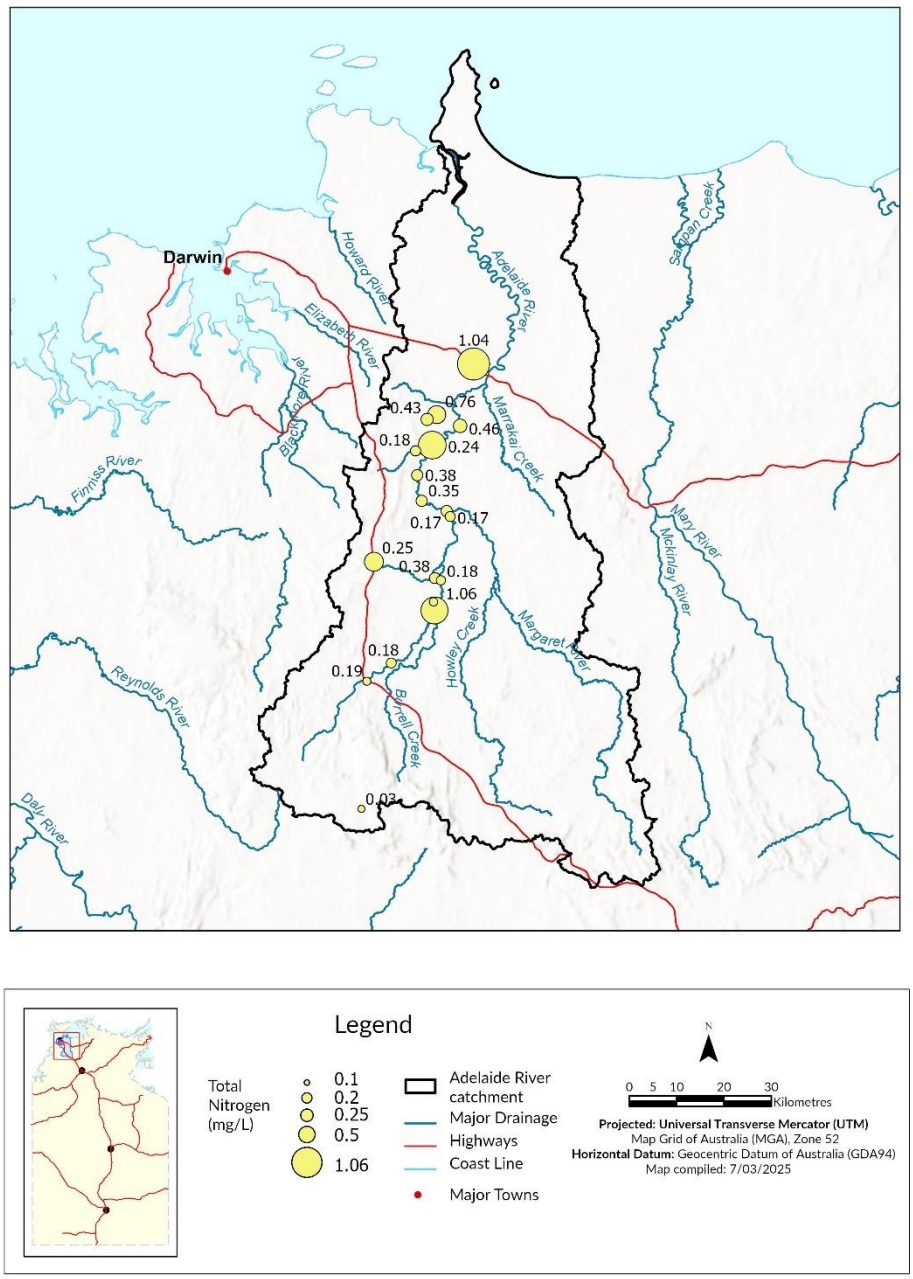


**Figure 19.** Spatial variability of values of total nitrogen (mg/L) at 18 sites in the Adelaide River catchment. Sites were sampled from 5 to 23 August 2024.

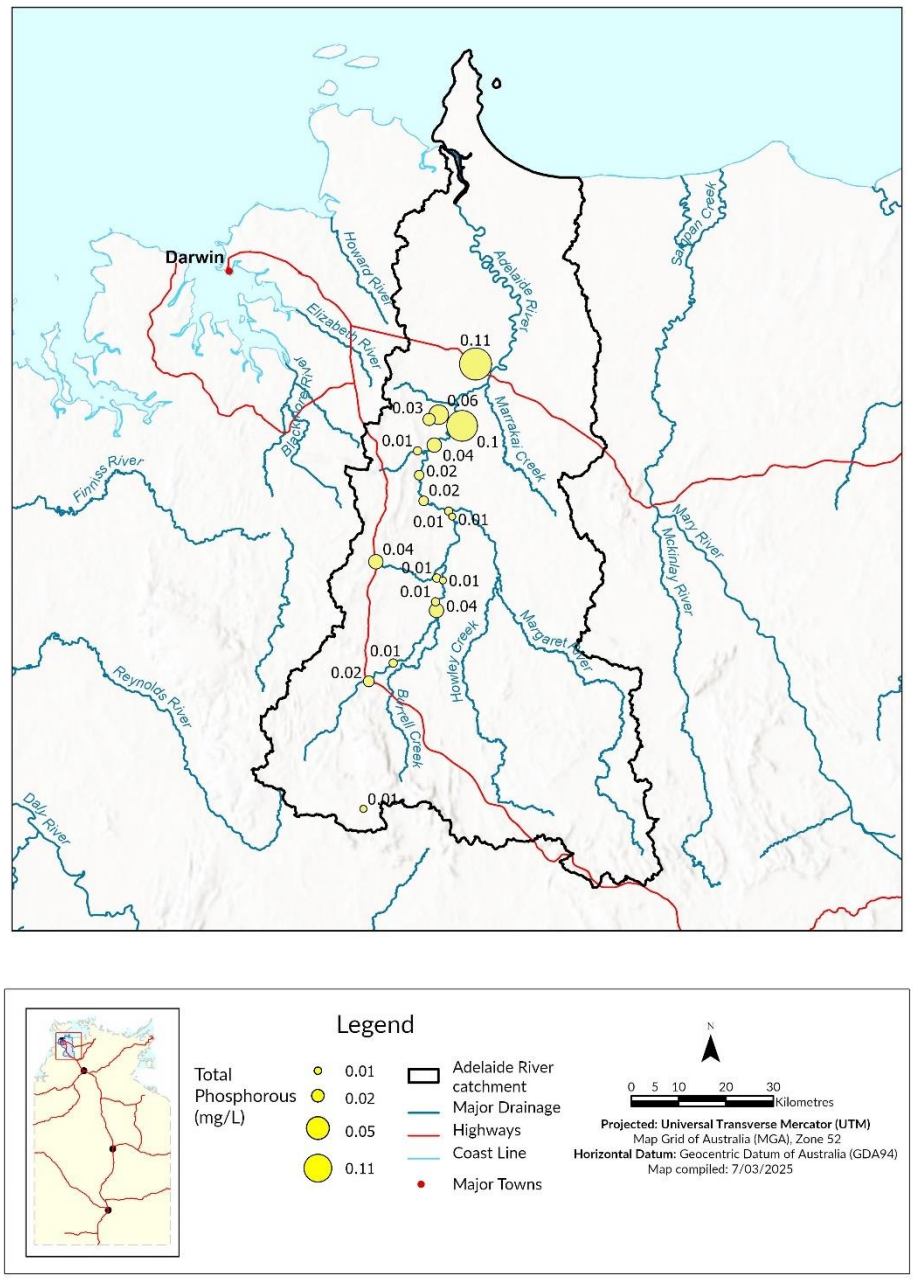


**Figure 20.** Spatial variability of values of total phosphorus (mg/L) at 18 sites in the Adelaide River catchment. Sites were sampled from 5 to 23 August 2024.

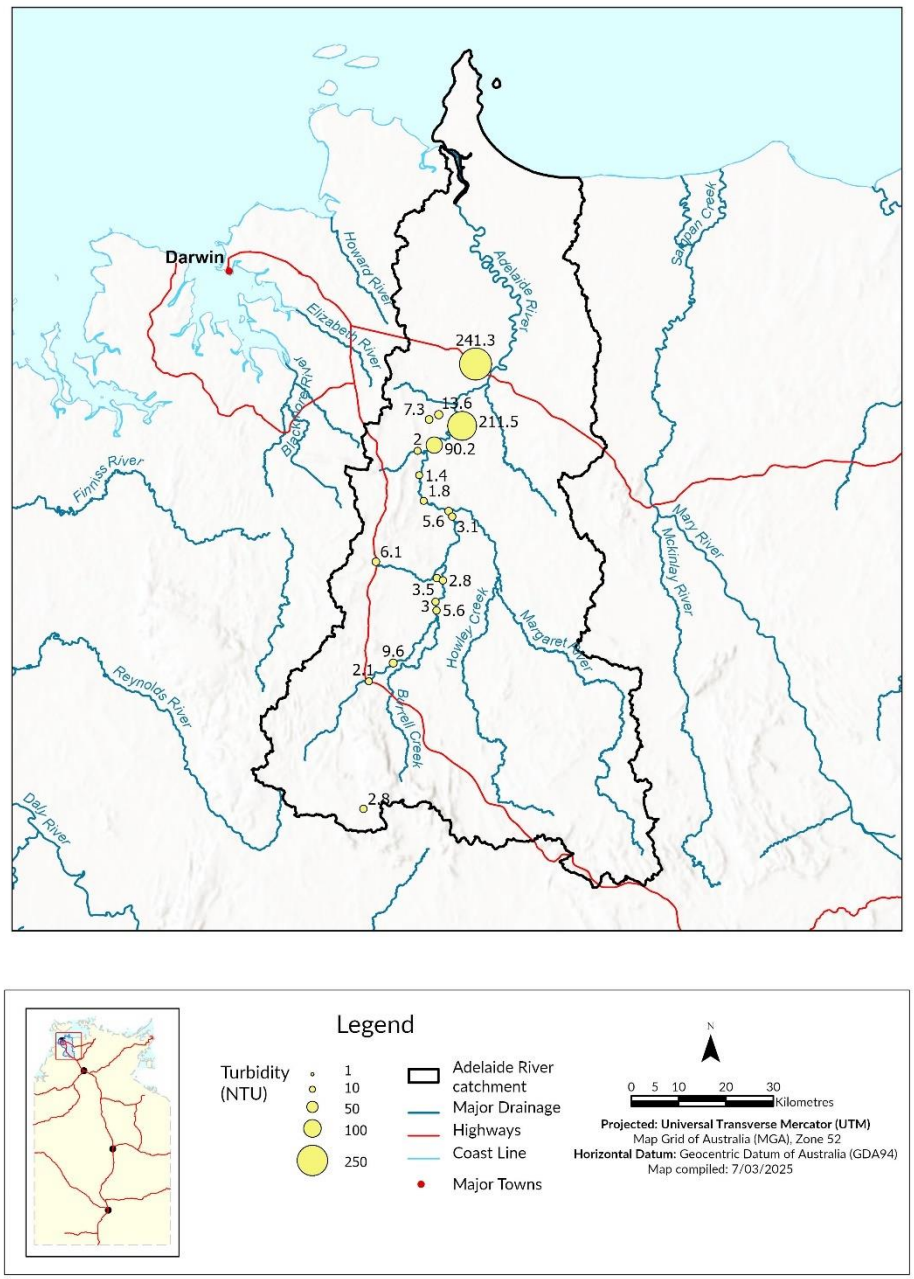


**Figure 21.** Spatial variability of values of turbidity (NTU) at 18 sites in the Adelaide River catchment. Sites were sampled from 5 to 23 August 2024.

# 6. Spatial variation in aquatic biodiversity

## 6.1. Introduction

There have been few previous surveys of the aquatic fauna of the Adelaide River catchment. Midgley (1984) recorded 24 fish taxa from six sites in the Adelaide and Margaret Rivers, however, several taxa were not identified to species level. The most recent surveys were conducted for a study of trait variation across a hydrological gradient (Luiz *et al*. 2022) which included four sites in the Adelaide River catchment. This survey found 37 taxa, two of which were only identified to genus. For the NT, the only catchment wide study of spatial variation, and associated environmental correlates, was undertaken at 55 sites in the Daly River catchment over two years (Pusey *et al*. 2020).

This chapter presents data on spatial variation in richness, abundance and composition of the aquatic biota of the study area. Target taxa include fish, aquatic and semiaquatic reptiles, and decapod crustacea. Aquatic and semiaquatic reptiles include file snakes, semiaquatic snakes, turtles, crocodiles, and aquatic varanids. Decapods include the carid shrimp families Atyidae and Palaemonidae.

## 6.2. Methods

### 6.2.1. Study design

The study sought to describe aquatic faunal assemblages at representative sites spanning gradients of riverine and non-riverine wetland habitats available for sampling in the mid-dry season. In particular, the study was designed to examine differences between (i) freshwater and tidal freshwater habitats, (ii) pool and riffle habitats in riverine channels, and (iii) among off-stream non-channel habitats in a longitudinal sequence from upper, mid and lower portions of the river.

Systematic sampling of aquatic biodiversity was conducted at 18 sites across the study area (Figure 22). Nine sites were located within the main channel of the Adelaide River; seven sites were located in off-stream channels or billabongs; and a further two sites were located in tributary streams of the Adelaide River. Site CMCK was located in the upstream portion of Coomalie Creek, and site Acacia Gap Lagoon (AGLN) was located in the downstream portion of Manton Creek. Orthomosaic images of 11 sample sites were derived from aerial imagery captured by a Mavic 3M UAV (Figure 23, Figure 24, and Figure 25).

Sites were allocated to six habitat classes, with subclasses for two classes based on landscape position. Subclasses of riverine channel are distinguished by landscape position and dominant riparian species; subclasses of off-stream channel are distinguished by landscape position, channel morphology and the relative dominance of emergent, submerged and floating macrophytes (Table 16).

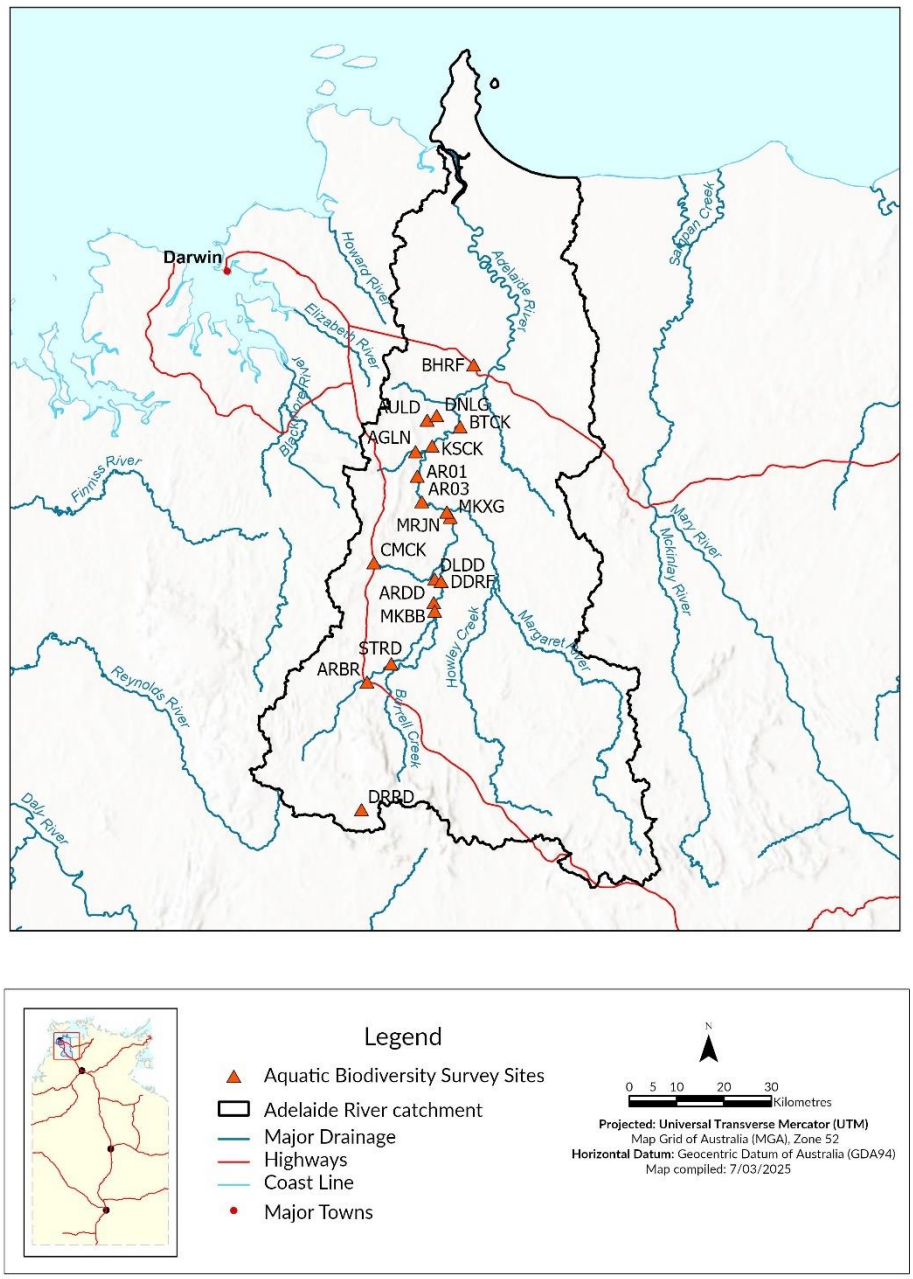


**Figure 22.** Distribution of 18 aquatic biodiversity survey sites in the Adelaide River catchment.

**Table 16.** Habitat classes of 18 survey sites in Adelaide River catchment.

| Class | Subclass | Sites | Habitat type | Features |
|---|---|---|---|---|
| 1 | | ARBR, DDRF, MKXG | stream riffle | shallow, flowing, rocky substrates with complex microhabitats |
| 2 | 1 | DRRD, CMCK | pool in river channel (upper) | *Pandanus aquatica* dominant riparian vegetation, mean max. depth 4.6 m |
| 2 | 2 | STRD, ARRD | pool in river channel (lower) | *Bambusa arnhemica* dominant riparian vegetation, mean max. depth 4.1 m |
| 3 | 1 | MKBB, DLDD | off-stream channel (upper) | no macrophyte cover, mean max. depth 5.9 m |
| 3 | 2 | AR01, AR03 | off-stream channel (middle) | AR03 moderate *Nymphaea* cover; AR01 high submerged macrophyte cover, mean max. depth 4.7 m |
| 3 | 3 | AULD, DNLG | off-stream channel (lower) | shallow, high macrophyte cover, mean max. depth 2.4 m |
| 4 | | AGLN | riverine lagoon | adjacent to floodplain, high *Nymphaea* cover |
| 5 | | BHRF | floodplain channel | impacted by invasive pasture grasses |
| 6 | | MRJN, KSCK, BTCK | tidal freshwater | Tidal, increasing salinity and turbidity |

DRRD (class 2.1)

CMCK (class 2.1)

STRD (class 2.2)

ARDD (class 2.2)

**Figure 23.** Orthomosaic images of four riverine channel survey sites in the Adelaide River.

MKBB (class 3.1)

DLDD (class 3.1)

AR03 (class 3.2)

AR01 (class 3.2)

**Figure 24.** Orthomosaic images of four off-stream channel survey sites in the Adelaide River.

AULD (class 3.3)

DNLG (class 3.3)

BHRF (class 5)

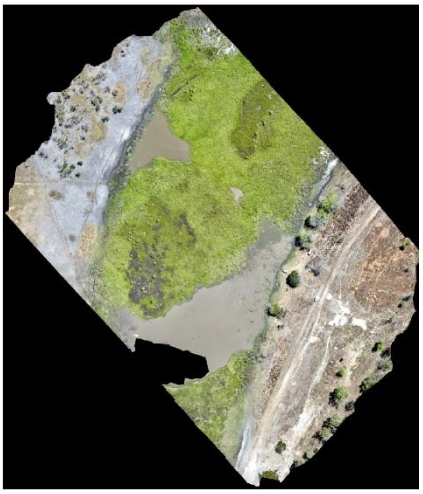

**Figure 25.** Orthomosaic images of four off-stream channel/floodplain lagoon survey sites in the Adelaide River.

### 6.2.2. Sampling methods

Aquatic surveys were conducted over an 18 day period from 5 to 23 August 2024. Most of the 18 sites were visited for a period of up to eight hours from mid-morning to mid-afternoon. There was no opportunity to deploy sampling equipment during the crepuscular period from late afternoon to early evening; nor an opportunity to conduct active searches of aquatic animals using spotlighting.

To sample aquatic vertebrates, multiple sampling methods were deployed at each site, though not all methods could be deployed at all sites. Sampling methods included:

1. small bait traps deployed in edge habitats
2. modified cathedral-style turtle traps baited with meat
3. cast net throws
4. fyke nets set in shallow water
5. gill nets
6. backpack electro-fishing
7. boat electro-fishing.

Backpack electro-fishing used eight replicated sampling units of 150 seconds in duration; boat electro-fishing used up to 15 replicated sampling units of 90 seconds in duration. The actual number of boat electro-fishing shots depended on the physical dimensions of the site. Most captured specimens were released at the point of capture, though some fish and decapods were retained as voucher specimens. Tissue samples for genetic analysis were collected from the webbing of the rear foot of some turtle specimens and preserved in 100% analytical grade ethanol.

Decapods were collected using a scoop net in shallow littoral habitats, and as by-catch from vertebrate sampling methods. Specimens were preserved in 80% ethanol for later identification using published taxonomic keys.

### 6.2.3. Specimen identification and taxonomy

Most specimens were identified in the field and released unharmed. Fish retained as voucher specimens were lodged with the fishes section of MAGNT in Darwin, for identification, general QA/QC and DNA analysis. Special effort was made to ensure correct identification for a historically problematic group of gobies in the genus *Glossogobius* based on a recent field key developed for the region (Hammer *et al*. 2021). Fish nomenclature generally follows the convention followed by Atlas of Living Australia, although some ‘older’ genus names for forktail catfish (Ariidae) were retained for stability given their systematic placement is still not settled, and we followed use of the name *Denariusa bandata* for pennyfish following Pusey *et al*. (2017).

### 6.2.4. Data analysis

The adequacy of the electro-fishing sampling effort at each site was assessed using rarefaction analysis in the software package EstimateS (Colwell 2013). Richness-effort curves are used to assess whether species richness is asymptotic at a given level of sampling effort. For each site, the number of species detected using all methods, and the number of species detected using electro-fishing, were used to calculate the mean percentage of species not detected using electro-fishing.

The frequency of occurrence (that is the number of sites at which each species was detected) and the percentage frequency of occurrence was tabulated for each species.

Spatial patterns in aquatic biodiversity were analysed using three methods:

(i) plots and maps of species richness

(ii) box-plots of variation in abundance of individual species

(iii) multivariate analyses of variation in patterns of species abundance.

The numbers of species detected at each site were tallied by taxa group and presented as a bar-plot. The number of species of fish detected at a site, and of all aquatic species detected at a site, were mapped to show the distribution of species richness across the study area. Box-plots were calculated for the 16 top ranked species using caught and observed data from electro-fishing, and for the eight top ranked species using caught data from electro-fishing. Box-plots were also calculated for total numbers of both caught and observed and caught data and for species richness of both caught and observed and caught data. Box-plots show median values, the 25 and 75 percentiles, and either maximum value or 1.5 times the interquartile range of the data, whichever is the smaller. Points more than 1.5 times the interquartile range above the third quartile and points more than 1.5 times the interquartile range below the first quartile are defined as outliers and plotted individually.

Multivariate analysis was used to examine spatial patterns in species composition using the software package PRIMER version 7.0.13 (Clarke and Gorley 2015). The analysis used caught data from electro-fishing corrected for the number of electro-fishing shots per site. Data was square root transformed prior to analysis to down weight the contribution of high values. Discrete groups of sites and species were identified using the SIMPROF test in the CLUSTER classification procedure. Results are presented as a shade plot showing patterns of abundance of 42 species, ordered by classification group, across 18 sites. Characteristic species within groups were identified using SIMPER (similarity percentages). This procedure examines the contribution each species makes to the average similarity within a group. Abundant species within a group will contribute to the intragroup similarities. These species may not be good discriminator species and may be typical of a number of groups (Clarke *et al*. 2014). Species contributing up to 70% of cumulative similarity are listed.

## 6.3. Results

### 6.3.1. Adequacy of sampling

Species richness approached asymptotic values for eight of the 18 survey sites, suggesting that for the remaining sites survey effort was not sufficient to estimate species richness (Figure 26). The survey effort at the most intensively surveyed site (AGLN, with 15 sampling units) could not be replicated at all sites. Additional sampling may fail to detect those species with a low probability of detection by electro-fishing. On average, two additional species were detected only by methods other than electro-fishing (Table 17). In general, detection failures involved small-bodied species of the shallow littoral zone, and large-bodied species of deepwater habitats.

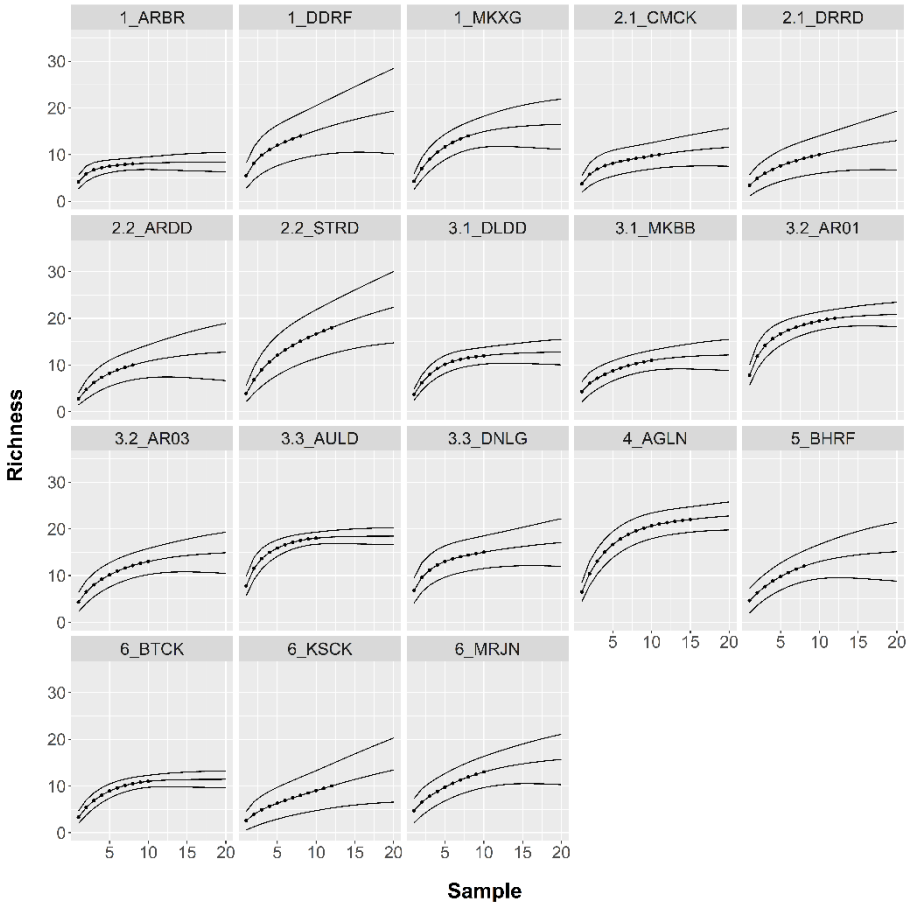


**Figure 26.** Rarefaction curves showing relationship between sampling effort and species richness for electro-fishing data comprising multiple sampling units.

**Table 17.** Number of species of fish collected by electro-fishing, and by all methods at each site, and percent difference of the number of species.

| Site | Electro-fishing type | All methods | Electro-fishing | Δ | %Δ |
|---|---|---|---|---|---|
| AGLN | boat | 25 | 22 | 3 | 12.0 |
| AR01 | boat | 21 | 20 | 1 | 4.8 |
| AR03 | boat | 16 | 13 | 3 | 18.8 |
| ARBR | backpack | 12 | 8 | 4 | 33.3 |
| ARDD | boat | 14 | 10 | 4 | 28.6 |
| AULD | boat | 22 | 18 | 4 | 18.2 |
| BHRF | boat | 13 | 12 | 1 | 7.7 |
| BTCK | boat | 13 | 11 | 2 | 15.4 |
| CMCK | boat | 12 | 10 | 2 | 16.7 |
| DDRF | backpack | 16 | 14 | 2 | 12.5 |
| DLDD | boat | 16 | 12 | 4 | 25.0 |
| DNLG | boat | 18 | 15 | 3 | 16.7 |
| DRRD | boat | 11 | 10 | 1 | 9.1 |
| KSCK | boat | 11 | 10 | 1 | 9.1 |
| MKBB | boat | 12 | 11 | 1 | 8.3 |
| MKXG | backpack | 17 | 14 | 3 | 17.6 |

| Site | Electro-fishing type | All methods | Electro-fishing | Δ | %Δ |
|---|---|---|---|---|---|
| MRJN | boat | 13 | 13 | 0 | 0.0 |
| STRD | boat | 19 | 18 | 1 | 5.3 |
| Mean | | 15.6 | 13.4 | 2.2 | 14.4 |

## 6.3.2. Composition of sampled fauna

### 6.3.2.1. Fish

Forty-five fish species were detected during surveys of 18 sites. The most frequently recorded fish species were chequered rainbowfish *Melanotaenia splendida inornata*, 16 sites, 88.9%; mouth almighty *Glossamia aprion*, 16 sites, 88.9%; sleepy cod *Oxyeleotris lineolata*, 14 sites, 77.8%; barred grunter *Amniataba percoides*, 14 sites, 77.8%; and sevenspot archerfish *Toxotes chatareus*, 14 sites, 77.8%. Nine species were recorded at one site only: warrior catfish *Hemiarius dioctes* (site BTCK); crimsontip gudgeon *Butis butis* (site KSCK); smalleye gudgeon *Prionobutis microps* (site DDRF); worm goby *Caragobius rubristriatus* (site BTCK); weber's mudskipper *Periophthalmus weberi* (site KSCK); toothless catfish *Anodontiglanis dahli* (site STRD); long-jaw river garfish *Zenarchopterus caudovittatus* (site BTCK); freshwater anchovy (*Thryssa brevicauda* (site BTCK) and *T. malabarica* (site KSCK).

Surveys recorded 45 of the 83 species known or suspected to occur in the study area (Table 18); 24 of the 33 obligate freshwater species 72.7%; and 18 of the 43 euryhaline species 41.9%. The fauna of the tidal freshwater reach was relatively poorly sampled, and further work is required to elucidate the composition of fish assemblages in this part of the river.


**Figure 27.** Common species of freshwater fish captured in surveys of Adelaide River.

**Table 18.** List of fish species detected by biodiversity surveys at 18 sites in the Adelaide River catchment.

| Family | Species name | Common name | F | % F |
|---|---|---|---|---|
| Ambassidae | *Ambassis interrupta* | long-spined glassfish | 2 | 11.1 |
| Ambassidae | *Ambassis macleayi* | Macleay's glassfish | 11 | 61.1 |
| Ambassidae | *Ambassis* sp. NW | northwest glassfish | 4 | 22.2 |
| Ambassidae | *Denariusa bandata* | pennyfish | 4 | 22.2 |
| Apogonidae | *Glossamia aprion* | mouth almighty | 16 | 88.9 |
| Ariidae | *Hemiarius dioctes* | warrior catfish | 1 | 5.6 |
| Ariidae | *Neoarius graeffei* | blue catfish | 5 | 27.8 |
| Ariidae | *Neoarius leptaspis* | salmon catfish | 6 | 33.3 |
| Atherinidae | *Craterocephalus stercusmuscarum* | fly-specked hardyhead | 11 | 61.1 |
| Belonidae | *Strongylura krefftii* | freshwater longtom | 11 | 61.1 |
| Carcharhinidae | *Carcharhinus leucas* | bull shark | 2 | 11.1 |
| Clupeidae | *Nematalosa erebi* | bony bream | 14 | 77.8 |
| Eleotridae | *Butis butis* | crimsontip gudgeon | 1 | 5.6 |
| Eleotridae | *Hypseleotris compressa* | empire gudgeon | 2 | 11.1 |
| Eleotridae | *Mogurnda mogurnda* | northern purple-spotted gudgeon | 8 | 44.4 |
| Eleotridae | *Oxyeleotris lineolata* | sleepy cod | 14 | 77.8 |
| Eleotridae | *Oxyeleotris nullipora* | poreless gudgeon | 3 | 16.7 |
| Eleotridae | *Oxyeleotris selheimi* | giant gudgeon | 9 | 50.0 |
| Eleotridae | *Prionobutis microps* | smalleye gudgeon | 1 | 5.6 |
| Engraulidae | *Thryssa brevicauda* | freshwater anchovy | 1 | 5.6 |
| Engraulidae | *Thryssa malabarica* | freshwater anchovy | 1 | 5.6 |
| Gobiidae | *Caragobius rubristriatus* | worm goby | 1 | 5.6 |
| Gobiidae | *Glossogobius aureus* | golden flathead goby | 2 | 11.1 |
| Gobiidae | *Glossogobius munroi* | square blotch goby | 5 | 27.8 |
| Gobiidae | *Periophthalmus weberi* | Weber's mudskipper | 1 | 5.6 |
| Kurtidae | *Kurtus gulliveri* | nurseyfish | 2 | 11.1 |
| Latidae | *Lates calcarifer* | barramundi | 12 | 66.7 |
| Megalopidae | *Megalops cyprinoides* | oxeye herring | 13 | 72.2 |
| Melanotaeniidae | *Melanotaenia nigrans* | blackbanded rainbowfish | 3 | 16.7 |
| Melanotaeniidae | *Melanotaenia splendida inornata* | chequered rainbowfish | 16 | 88.9 |
| Mugilidae | *Planiliza ordensis* | Ord River mullet | 13 | 72.2 |
| Osteoglossidae | *Scleropages jardinii* | northern saratoga | 9 | 50.0 |
| Plotosidae | *Anodontiglanis dahli* | toothless catfish | 1 | 5.6 |
| Plotosidae | *Neosilurus ater* | black catfish | 8 | 44.4 |
| Plotosidae | *Neosilurus hyrtlii* | Hyrtl's catfish | 4 | 22.2 |
| Plotosidae | *Porochilus rendahli* | Rendahl's catfish | 4 | 22.2 |
| Soleidae | *Leptachirus darwinensis* | Darwin sole | 3 | 16.7 |
| Synbranchidae | *Ophisternon gutturale* | swamp eel | 3 | 16.7 |
| Terapontidae | *Amniataba percoides* | barred grunter | 14 | 77.8 |

| Family | Species name | Common name | F | % F |
|---|---|---|---|---|
| Terapontidae | *Hephaestus fuliginosus* | sooty grunter | 6 | 33.3 |
| Terapontidae | *Leiopotherapon unicolor* | spangled perch | 7 | 38.9 |
| Terapontidae | *Syncomistes butleri* | sharpnose grunter | 6 | 33.3 |
| Toxotidae | *Toxotes chatareus* | sevenspot archerfish | 14 | 77.8 |
| Toxotidae | *Toxotes lorentzi* | primitive archerfish | 6 | 33.3 |
| Zenarchopteridae | *Zenarchopterus caudovittatus* | long-jaw river garfish | 1 | 5.6 |

### 6.3.2.2. Aquatic and semiaquatic reptiles

Seven species of aquatic and semiaquatic reptiles were recorded at survey sites in the study area (Table 19). Turtles were not well sampled, with only 17 individuals recorded from ten survey sites, a result largely attributable to the suboptimal timing of the sampling effort. There is some uncertainty associated with the identification of captured turtles belonging to the genus *Elseya*. They were tentatively identified as *Elseya flaviventralis*, based on the yellow coloration and lack of dark markings on the plastron (Figure 28). The Flora and Fauna Division database includes a single record of Worrell's turtle *Emydura subglobosa worrelli* from Fogg Dam photographed on 12 November 2009 (iNaturalist record 341962). All *Emydura* specimens captured in the present survey were identified as northern yellow-faced turtle *E. tanybaraga*. These species, *E. subglobosa worrelli* and *E. tanybaraga*, are difficult to distinguish consistently in the field (Georges and Thomson 2010).

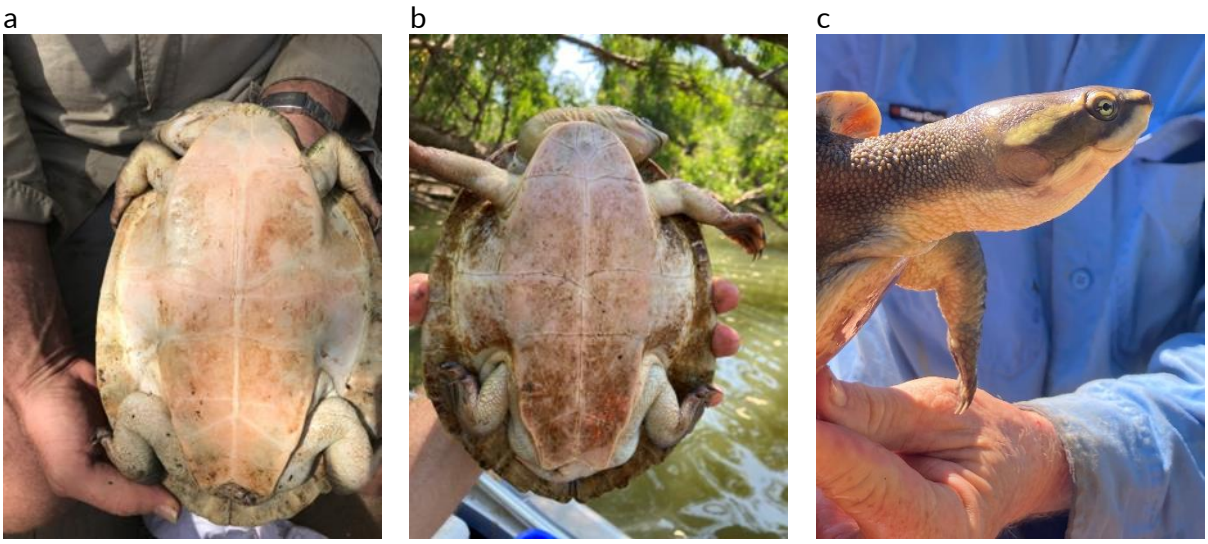


**Figure 28.** (a) and (b) plastron of yellow-bellied snapping turtle *Elseya flaviventralis*; (c) facial features of northern yellow-faced turtle *Emydura tanybaraga* showing yellow facial stripe; note iris with leading and trailing dark spots.

**Table 19.** List of aquatic and semiaquatic reptiles detected during biodiversity surveys of 18 sites in the Adelaide River catchment.

| Family | Species name | Common name | F | % F |
|---|---|---|---|---|
| Acrochordidae | *Acrochordus arafurae* | Arafura file snake | 1 | 5.6 |
| Chelidae | *Chelodina rugosa* | northern snake-necked turtle | 1 | 5.6 |
| Chelidae | *Elseya flaviventralis* | yellow-bellied snapping turtle | 4 | 22.2 |
| Chelidae | *Emydura tanybaraga* | northern yellow-faced turtle | 6 | 33.3 |
| Crocodylidae | *Crocodylus johnstoni* | freshwater crocodile | 1 | 5.6 |
| Crocodylidae | *Crocodylus porosus* | saltwater crocodile | 7 | 38.9 |
| Varanidae | *Varanus mertensi* | Mertens' water monitor | 1 | 5.6 |

#### 6.3.2.3. Decapod crustacea

Eight species of decapod crustacea were recorded in the study area, including four species in the atyid genus *Caridina*, and three species in the palaemonid genus *Macrobrachium* (Table 20). The most frequently recorded species were northern river prawn *Macrobrachium bullatum*, 14 sites, 77.8%; and the cherabin *Macrobrachium spinipes*, 10 sites, 55.6%. Cherabin are a marker for connectivity with estuarine waters: larvae are shed from ovigerous females in freshwater and are transported to saline reaches for development in the wet season. Juveniles undertake a recruitment migration in late March and April. The Atlas of Living Australia includes records of three species of *Macrobrachium* in the Adelaide River catchment, including the freshwater species *M. spinipes*, *M. bullatum*, and the estuarine species *M. equidens*. There are no records of Handschin's river prawn *M. handschini* (they have been recorded in the adjacent Daly and Darwin river catchments).

**Table 20.** List of decapod species detected during biodiversity surveys of 18 sites in the Adelaide River catchment.

| Family | Species name | Common name | F | % F |
|---|---|---|---|---|
| Atyidae | *Caridina magnovus* | | 8 | 44.4 |
| Atyidae | *Caridina nilotica* | | 8 | 44.4 |
| Atyidae | *Caridina wilkinsi* | | 8 | 44.4 |
| Atyidae | *Caridina wilsoni* | | 8 | 44.4 |
| Palaemonidae | *Macrobrachium spinipes* | cherabin | 10 | 55.6 |
| Palaemonidae | *Macrobrachium bullatum* | northern river prawn | 14 | 77.8 |
| Palaemonidae | *Macrobrachium* sp. | | 1 | 5.6 |
| Parastacidae | *Cherax quadricarinatus* | redclaw crayfish | 5 | 27.8 |

### 6.3.3. Spatial patterns of species richness

For fish, species richness per site ranged from 11 to 25 (Table 21), with a median site richness of 15. Three sites featured a fish species tally of more than 20 species, including site AR01 (21 species, class 3.2), site AULD (22 species, class 3.3) and site AGLN (25 species, class 4). For each of these, the rarefaction curve of sampling effort and richness approached the asymptote (Figure 26), suggesting that few additional species would have been detected with additional sampling effort by electro-fishing. At each of these, additional species were detected primarily by sampling in shallow edge habitats with a scoop net. For site AGLN, additional species include *Hypseleotris compressa*, *Oxyeleotris nullipora*, and *Mogurnda mogurnda*; for site AULD, additional species include *Mogurnda mogurnda*, *Oxyeleotris nullipora* and *Toxotes chatareus*; and for site AR01 *Mogurnda mogurnda*.

For all aquatic taxa, species richness per site ranged from 14 to 32, with a median site richness of 20. Three sites featured a species tally of more than 25 species, including site AR01 (26 species, class 3.2), site AULD (27 species, class 3.3) and site AGLN (32 species, class 4). Site BHRF (class 5) featured the lowest values of fish (13) and total aquatic (14) species richness (Figure 29). Highest values for both fish species richness, and all aquatic taxa species richness, occur in the lower reaches in habitat classes 3.2, 3.3 and 4 (Table 21, Figure 30 and Figure 31).

**Table 21.** Number of species in three taxa groups by site and sum of all aquatic species per site.

| Site | Site code | Habitat class | Fish | Decapod | Aquatic reptile | All taxa |
|---|---|---|---|---|---|---|
| ARBR | A | 1 | 12 | 4 | 0 | 16 |
| DDRF | B | 1 | 16 | 6 | 0 | 22 |
| MKXG | C | 1 | 17 | 4 | 1 | 22 |
| CMCK | D | 2.1 | 12 | 4 | 0 | 16 |

| Site | Site code | Habitat class | Fish | Decapod | Aquatic reptile | All taxa |
|---|---|---|---|---|---|---|
| DRRD | E | 2.1 | 11 | 4 | 0 | 15 |
| STRD | F | 2.2 | 19 | 3 | 2 | 24 |
| ARDD | G | 2.2 | 14 | 6 | 0 | 20 |
| MKBB | H | 3.1 | 12 | 3 | 1 | 16 |
| DLDD | I | 3.1 | 16 | 2 | 2 | 20 |
| AR03 | J | 3.2 | 16 | 4 | 2 | 22 |
| AR01 | K | 3.2 | 21 | 4 | 1 | 26 |
| AULD | L | 3.3 | 22 | 4 | 1 | 27 |
| DNLG | M | 3.3 | 18 | 3 | 1 | 22 |
| AGLN | N | 4 | 25 | 5 | 2 | 32 |
| BHRF | O | 5 | 13 | 0 | 1 | 14 |
| MRJN | P | 6 | 13 | 3 | 3 | 19 |
| KSCK | Q | 6 | 11 | 3 | 3 | 17 |
| BTCK | R | 6 | 13 | 0 | 1 | 14 |

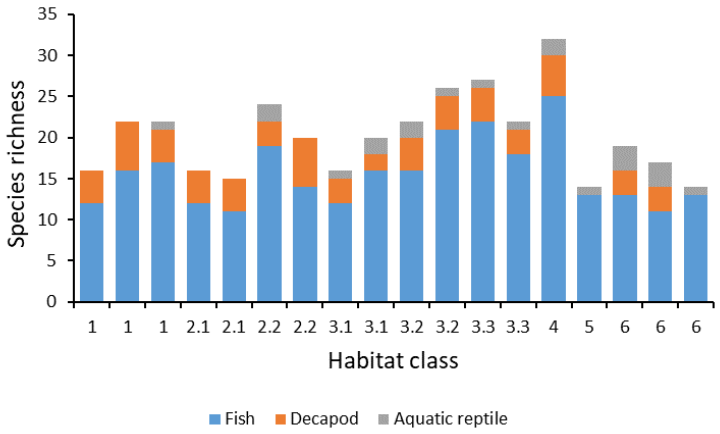


**Figure 29.** Bar-plot of number of species in three taxa groups by site.

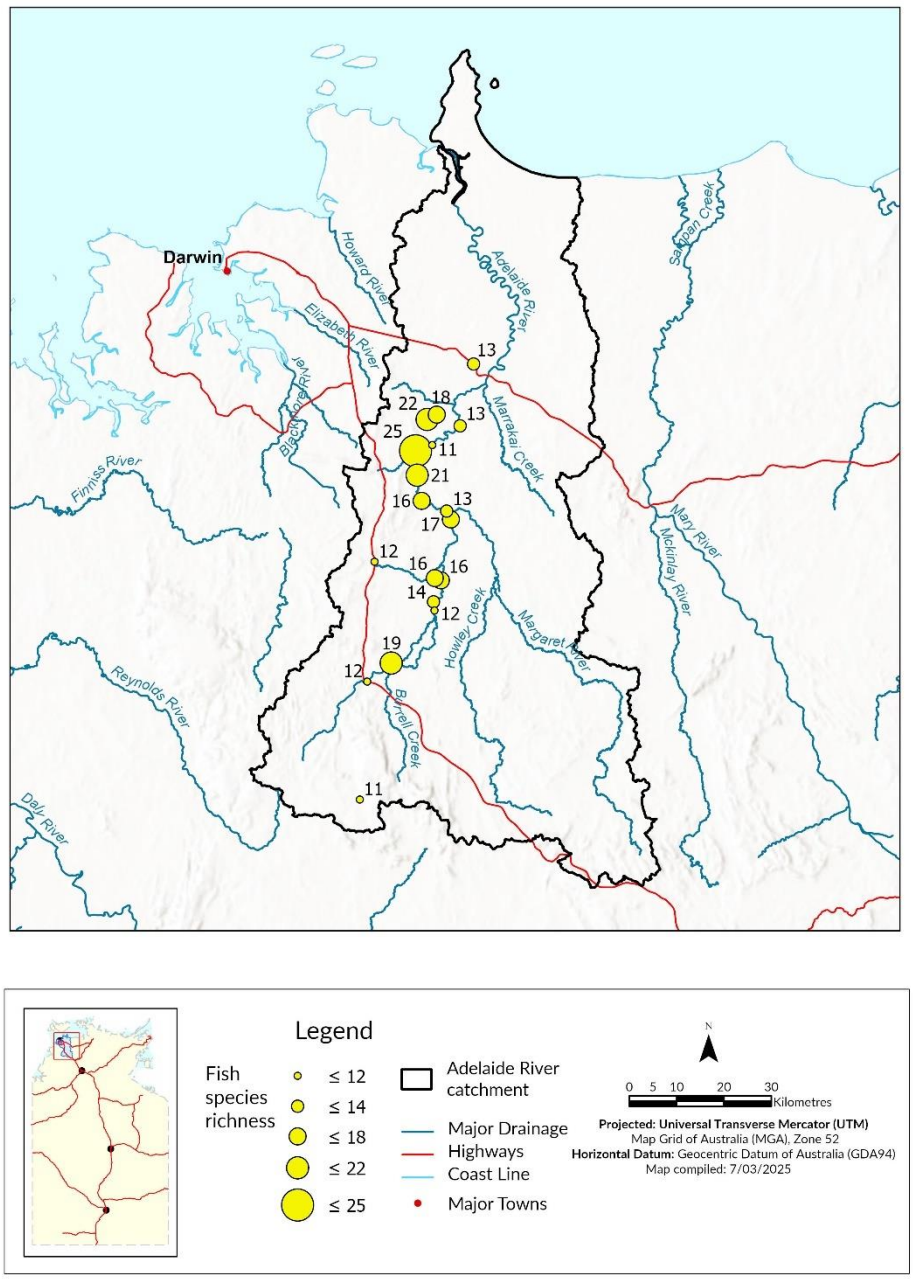


**Figure 30.** Fish species richness at 18 survey sites in the Adelaide River catchment.

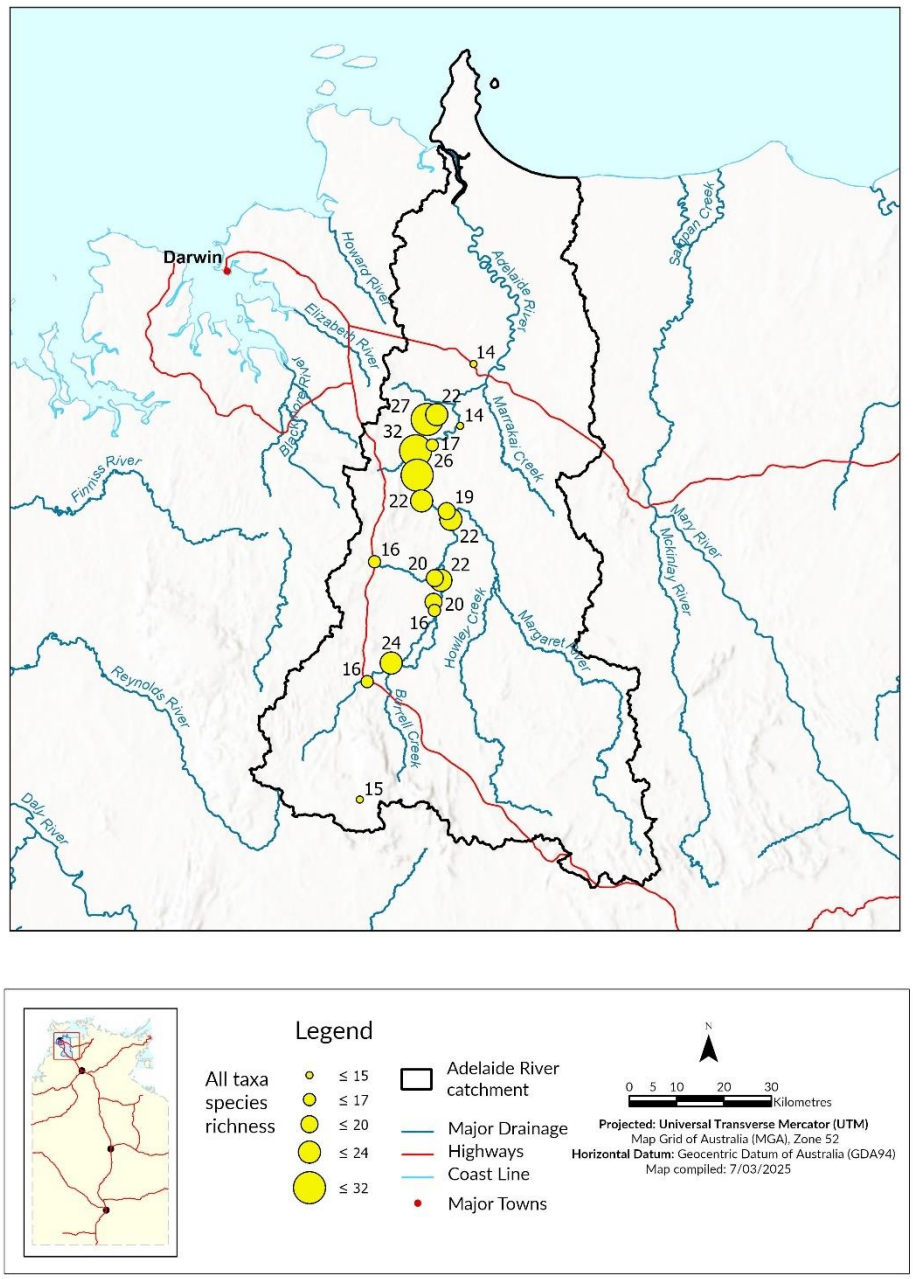


**Figure 31.** Richness of all aquatic taxa at 18 survey sites in the Adelaide River catchment.

### 6.3.4. Spatial patterns of abundance

A total of 5,314 individuals were recorded as caught and observed, and a total of 1,628 individuals were recorded as caught from the 18 survey sites (Table 22). Three species including chequered rainbowfish *Melanotaenia splendida inornata* 25.6%; mouth almighty *Glossamia aprion* 12.6%; and barred grunter *Amniataba percoides* 8.3%, contributed nearly half the tally of caught and observed data. Whilst chequered rainbowfish *M. splendida inornata* 20%; mouth almighty *G. aprion* 8.1%; and Macleay's glassfish *Ambassis macleayi* 6.9%, contributed about a third of the caught data tally.

Spatial variation in patterns of abundance were examined using box-plots for 16 top ranked species for caught and observed data, and for 8 top ranked species using caught data (Figure 32, Figure 33, and Figure 34).

For caught and observed data, some species are most abundant within a particular habitat class. For example, freshwater mullet *Planiliza ordensis* are most prevalent at tidal freshwater sites (class 6), and sooty grunter *Hephaestus fuliginosus* are most prevalent at riffle sites (class 1). There is high variability in the patterns of abundance of individual species, with several species particularly abundant at one or few sites. Examples include chequered rainbowfish *M. splendida inornata*; barred grunter *A. percoides*; fly-specked hardyhead *Craterocephalus stercusmuscarum;* and bony bream *Nematalosa erebi.* There is evidence the two larger members of the genus *Oxyeleotris* differ in habitat preference, with sleepy cod *O. lineolata* largely confined to unvegetated riverine channel habitats, and giant gudgeon *O. selheimi* largely confined to vegetated off-stream channel habitats (although the two were caught sympatrically in consecutive shots at one site). Results are broadly similar for electro-fishing caught data.

The patterns of species richness per shot for caught and observed and caught data are broadly similar, though marginally fewer species were recorded in the caught data. There is a marked difference in the patterns of catch per unit effort for caught and observed versus caught. The caught and observed data indicates high levels of abundance in habitat classes 3.2 and 3.3 which is not evident in the caught data (Figure 35).

**Table 22.** Numbers of 42 fish species caught and observed and caught by electro-fishing at 18 survey sites.

| | | caught and observed | | caught | |
|---|---|---|---|---|---|
| Family | Species name | *N* | % | *N* | % |
| Ambassidae | *Ambassis interrupta* | 34 | 0.64 | 31 | 1.90 |
| Ambassidae | *Ambassis macleayi* | 281 | 5.29 | 113 | 6.94 |
| Ambassidae | *Ambassis* sp. NW | 160 | 3.01 | 11 | 0.68 |
| Ambassidae | *Denariusa bandata* | 8 | 0.15 | 8 | 0.49 |
| Apogonidae | *Glossamia aprion* | 669 | 12.59 | 131 | 8.05 |
| Ariidae | *Neoarius graeffei* | 3 | 0.06 | 2 | 0.12 |
| Ariidae | *Neoarius leptaspis* | 4 | 0.08 | 4 | 0.25 |
| Atherinidae | *Craterocephalus stercusmuscarum* | 389 | 7.32 | 62 | 3.81 |
| Belonidae | *Strongylura krefftii* | 42 | 0.79 | 23 | 1.41 |
| Clupeidae | *Nematalosa erebi* | 421 | 7.92 | 91 | 5.59 |
| Eleotridae | *Butis butis* | 1 | 0.02 | 1 | 0.06 |
| Eleotridae | *Hypseleotris compressa* | 24 | 0.45 | 11 | 0.68 |
| Eleotridae | *Mogurnda mogurnda* | 35 | 0.66 | 33 | 2.03 |
| Eleotridae | *Oxyeleotris lineolata* | 105 | 1.98 | 78 | 4.79 |
| Eleotridae | *Oxyeleotris selheimi* | 173 | 3.26 | 73 | 4.48 |
| Eleotridae | *Prionobutis microps* | 1 | 0.02 | 1 | 0.06 |

| | | caught and observed | | caught | |
|---|---|---|---|---|---|
| Family | Species name | *N* | % | *N* | % |
| Engraulidae | *Thryssa brevicauda* | 8 | 0.15 | 7 | 0.43 |
| Engraulidae | *Thryssa malabarica* | 1 | 0.02 | 1 | 0.06 |
| Gobiidae | *Caragobius rubristriatus* | 1 | 0.02 | 1 | 0.06 |
| Gobiidae | *Glossogobius aureus* | 3 | 0.06 | 3 | 0.18 |
| Gobiidae | *Glossogobius munroi* | 22 | 0.41 | 22 | 1.35 |
| Gobiidae | *Periophthalmus weberi* | 1 | 0.02 | 1 | 0.06 |
| Hemiramphidae | *Zenarchopterus caudovittatus* | 8 | 0.15 | 2 | 0.12 |
| Kurtidae | *Kurtus gulliveri* | 4 | 0.08 | 4 | 0.25 |
| Latidae | *Lates calcarifer* | 117 | 2.20 | 55 | 3.38 |
| Megalopidae | *Megalops cyprinoides* | 233 | 4.38 | 79 | 4.85 |
| Melanotaeniidae | *Melanotaenia nigrans* | 9 | 0.17 | 4 | 0.25 |
| Melanotaeniidae | *Melanotaenia splendida inornata* | 1,362 | 25.63 | 325 | 19.96 |
| Mugilidae | *Planiliza ordensis* | 255 | 4.80 | 104 | 6.39 |
| Osteoglossidae | *Scleropages jardinii* | 21 | 0.40 | 8 | 0.49 |
| Plotosidae | *Anodontiglanis dahli* | 1 | 0.02 | 1 | 0.06 |
| Plotosidae | *Neosilurus ater* | 76 | 1.43 | 37 | 2.27 |
| Plotosidae | *Neosilurus hyrtlii* | 3 | 0.06 | 3 | 0.18 |
| Plotosidae | *Porochilus rendahli* | 36 | 0.68 | 23 | 1.41 |
| Soleidae | *Leptachirus darwinensis* | 16 | 0.30 | 11 | 0.68 |
| Synbranchidae | *Ophisternon gutturale* | 4 | 0.08 | 1 | 0.06 |
| Terapontidae | *Amniataba percoides* | 439 | 8.26 | 89 | 5.47 |
| Terapontidae | *Hephaestus fuliginosus* | 89 | 1.67 | 68 | 4.18 |
| Terapontidae | *Leiopotherapon unicolor* | 101 | 1.90 | 37 | 2.27 |
| Terapontidae | *Syncomistes butleri* | 35 | 0.66 | 25 | 1.54 |
| Toxotidae | *Toxotes chatareus* | 81 | 1.52 | 31 | 1.90 |
| Toxotidae | *Toxotes lorentzi* | 38 | 0.72 | 13 | 0.80 |
| number of species | | 42 | | 42 | |
| total abundance | | 5,314 | | 1,628 | |

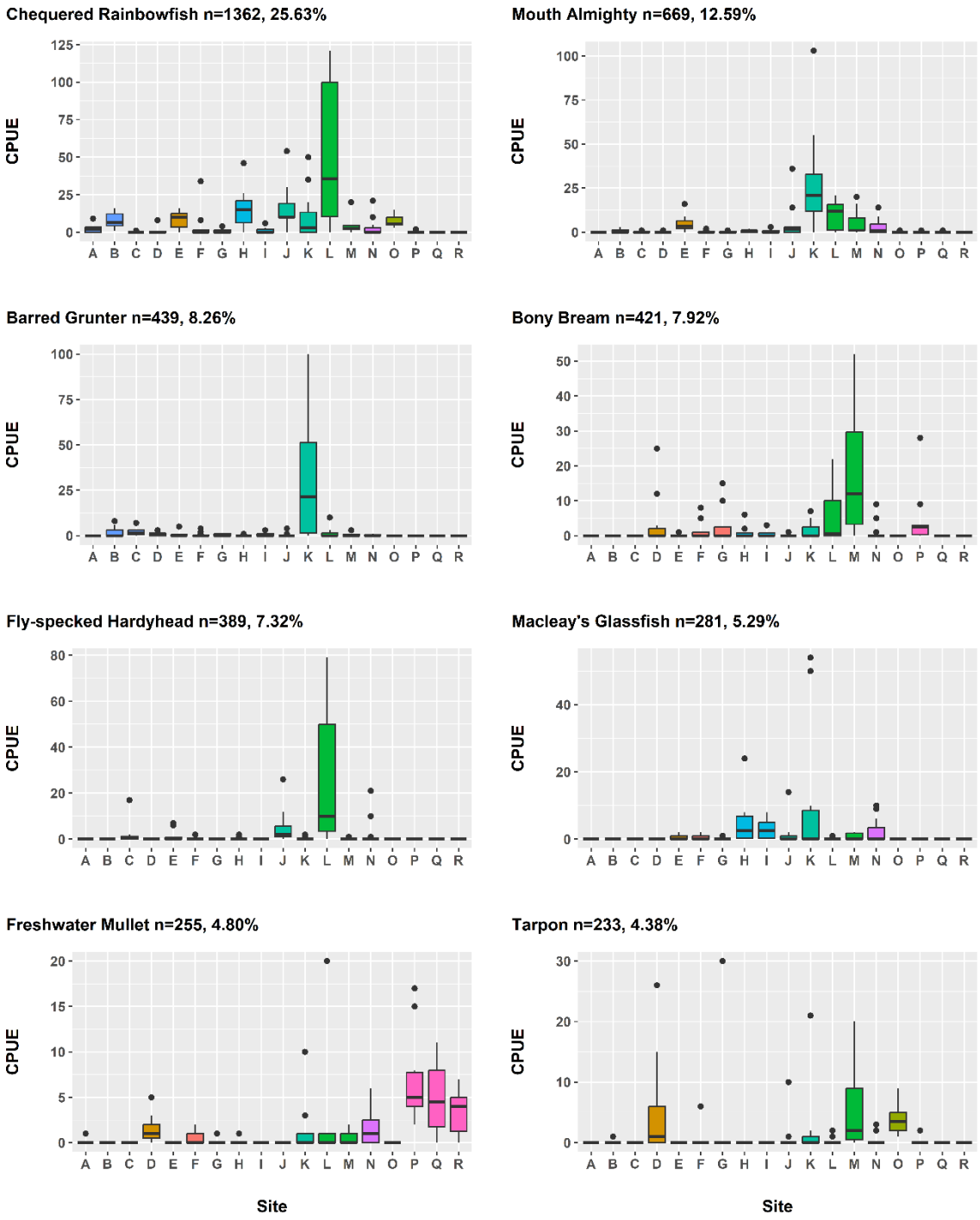


**Figure 32.** Boxplots of abundance of species ranked 1 to 8, using caught and observed electro-fishing data.

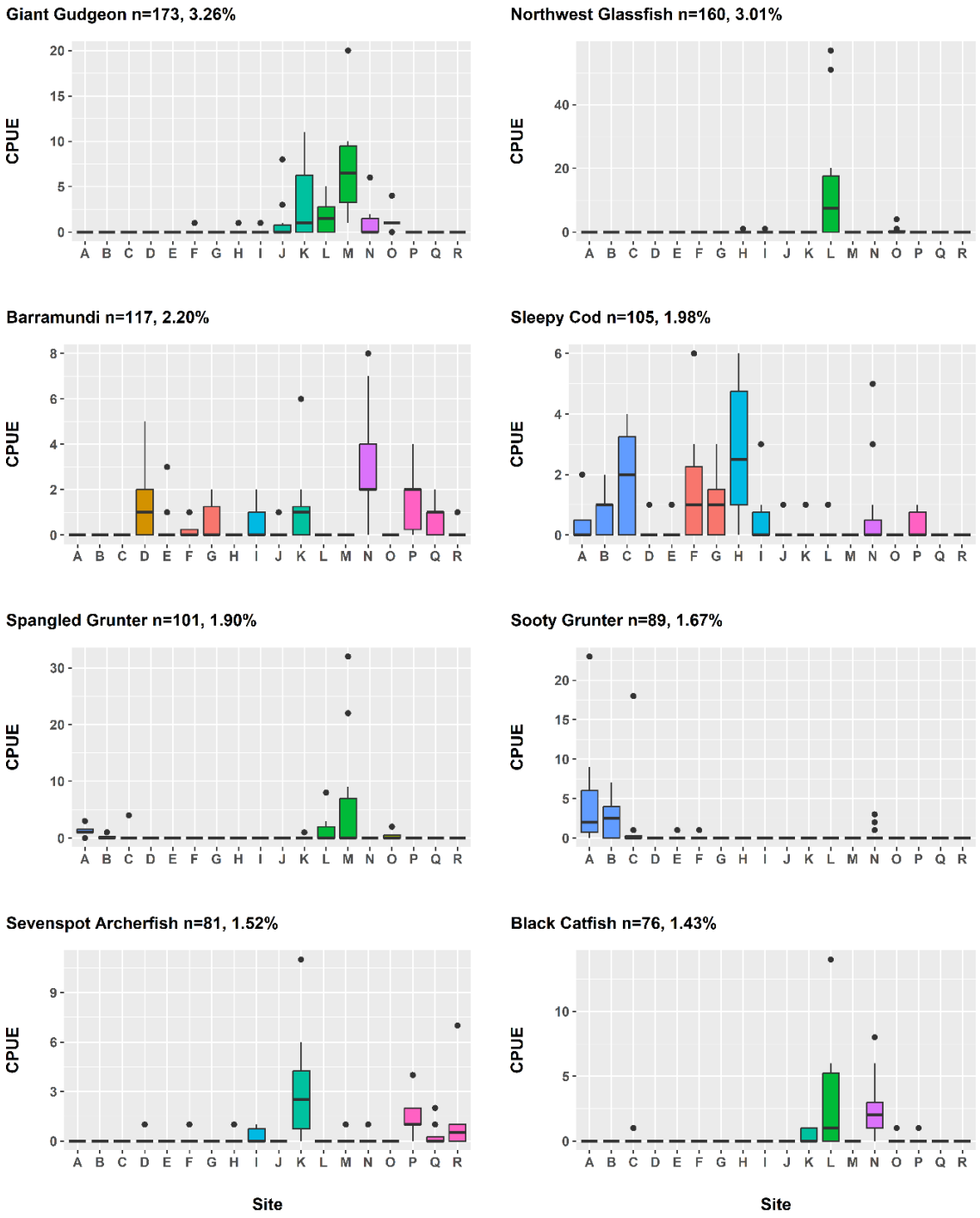


**Figure 33.** Boxplots of abundance of species ranked 9 to 16, using caught and observed electro-fishing data.

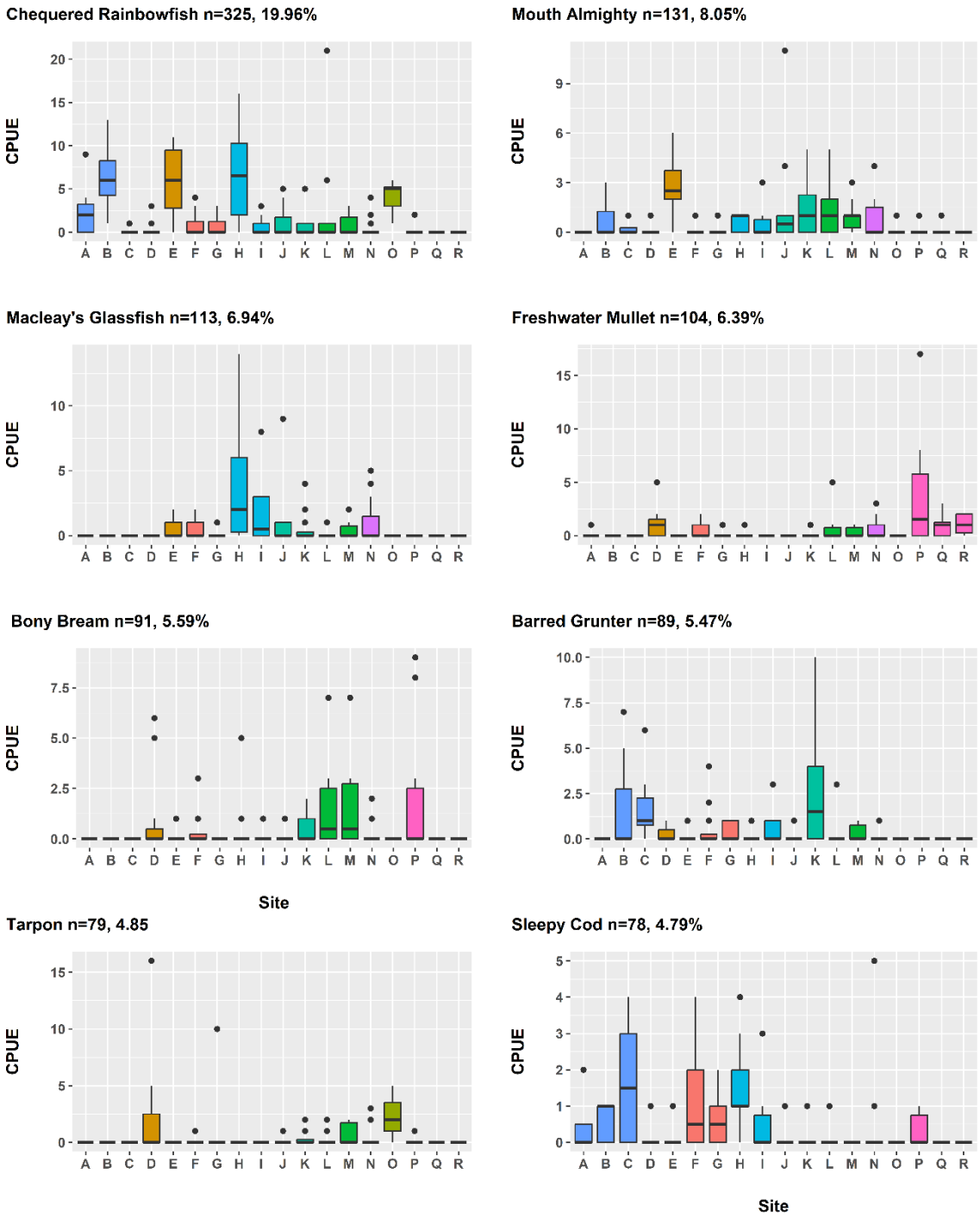


**Figure 34.** Boxplots of abundance of species ranked 1 to 8, using caught electro-fishing data.

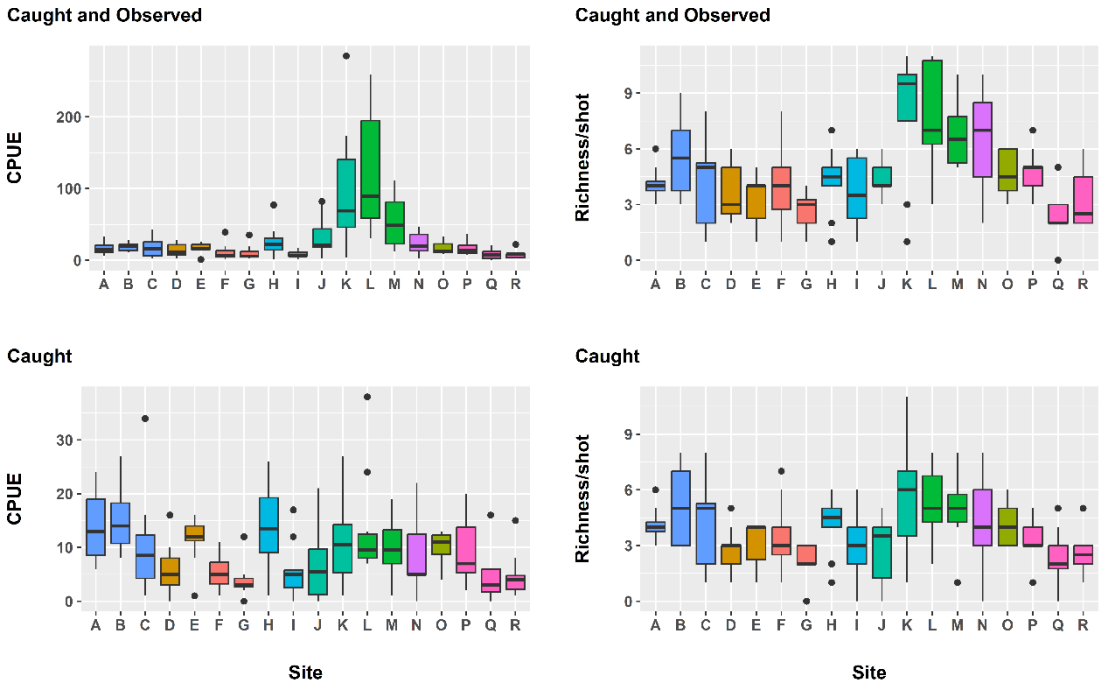


**Figure 35.** Boxplots of catch per unit effort abundance and species richness for caught and observed and caught electro-fishing data.

## 6.3.5. Multivariate analyses of spatial variation

CLUSTER classification of the catch per unit effort caught dataset identified six discrete groups, with one group represented by a single site (Figure 36).

Group 1: consists of three sites in riffle habitats in the river channel (ARBR, DDRF and MKXG). An average of 11.3 species was detected; characteristic species include sooty grunter *Hephaestus fuliginosus*, chequered rainbowfish *Melanotaenia splendida inornata* and sleepy cod *Oxyeleotris lineolata*.

Group 2: consists of a single site (BHRF) on a floodplain channel with a history of use by cattle and buffalo and extensive cover of introduced pasture grasses. Eleven fish species were recorded. Water quality was poor, with high chlorophyll, total nitrogen and turbidity, and low surface dissolved oxygen levels.

Group 3: consists of five sites (AR03, DRRD, MKBB, STRD and DLDD) in habitat classes 2.1, 2.2, 3.1 and 3.2. An average of 11.8 species was detected; characteristic species include chequered rainbowfish *M. splendida inornata*, Macleay's glassfish *Ambassis macleayi*, and mouth almighty *G. aprion*.

Group 4: consists of four sites (AULD, DNLG, AR01 and AGLN) in habitat classes 3.2, .3.3 and 4. An average of 17.8 species was detected; characteristic species include mouth almighty *Glossamia aprion*, giant gudgeon *Oxyeleotris selheimi*, and chequered rainbowfish *Melanotaenia splendida inornata*. Primitive archerfish *Toxotes lorentzi* and northern saratoga *Scleropages jardinii* were recorded at all four sites.

Group 5: consists of two sites (ARDD, CMCK and MRJN) in habitat classes 2.1, 2.2 and 6. An average of 10.7 species was recorded; characteristic species include barramundi *Lates calcarifer*, oxeye herring *Megalops cyprinoides*, and freshwater mullet *Planiliza ordensis*.

Group 6: consists of two of the three tidal freshwater sites (KSCK and BTCK). An average of 10.5 species was recorded; characteristic species include freshwater mullet *Planiliza ordensis*, long-spined glassfish *Ambassis interrupta*, and sevenspot archerfish *Toxotes chatareus*.

Table 23 lists characteristic species for each CLUSTER group as identified by SIMPER analysis.

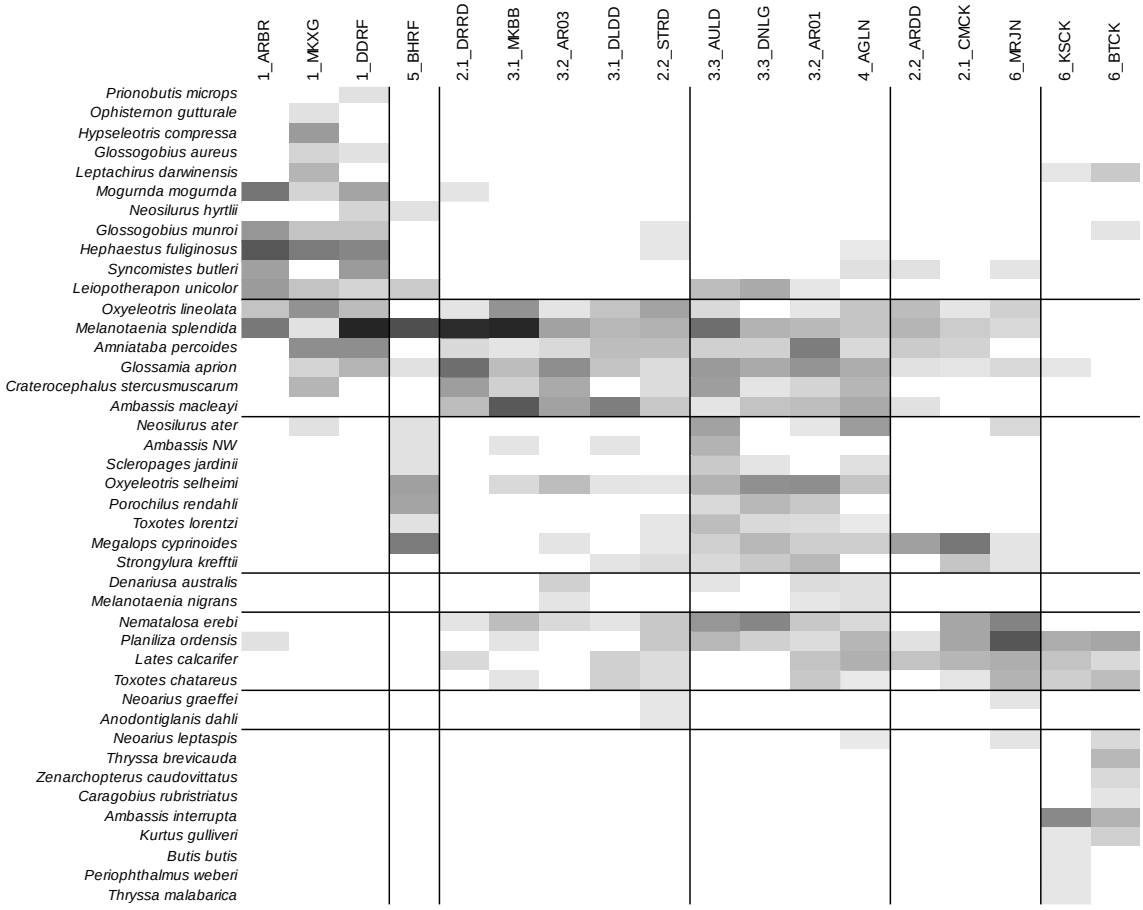


**Figure 36.** Shade-plot of abundance of fish species at 18 survey sites, based on caught electro-fishing data. Data were standardised per shot and transformed using square root prior to analysis.

**Table 23.** Characteristic species in site groups as identified from CLUSTER and SIMPER analyses of fish abundance at 18 survey sites, based on caught electro-fishing data.

| | CLUSTER group | | | | |
|---|---|---|---|---|---|
| Species name | 1 | 3 | 4 | 5 | 6 |
| *Hephaestus fuliginosus* | 1 | | | | |
| *Melanotaenia splendida* | 2 | 1 | 3 | 4 | |
| *Oxyeleotris lineolata* | 3 | 4 | | 5 | |
| *Glossamia munroi* | 4 | | | | |
| *Mogurnda mogurnda* | 5 | | | | |
| *Megalops cyprinoides* | | | 5 | 2 | |
| *Nematalosa erebi* | | | 4 | | |
| *Lates calcarifer* | | | | 1 | |
| *Ambassis macleayi* | | 2 | 6 | | |
| *Glossamia aprion* | | 3 | 1 | | |
| *Amniataba percoides* | | 5 | 8 | | |
| *Oxyeleotris selheimi* | | | 2 | | |
| *Planiliza ordensis* | | | 7 | 3 | 1 |
| *Ambassis interrupta* | | | | | 2 |
| *Craterocephalus stercusmuscarum* | | | 9 | | |

| | CLUSTER group | | | | |
|---|---|---|---|---|---|
| Species name | 1 | 3 | 4 | 5 | 6 |
| *Toxotes chatareus* | | | | | 3 |
| Number of sites | 3 | 5 | 4 | 3 | 2 |
| | 1_ARBR | 2.1_DRRD | 3.3_AULD | 2.2_ARDD | 6_KSCK |
| | 1_MKXG | 3.1_MKBB | 3.3_DNLG | 2.1_CMCK | 6_BTCK |
| | 1_DDRF | 3.2_AR03 | 3.2_AR01 | 6_MRJN | |
| | | 3.1_DLDD | 4_AGLN | | |
| | | 2.2_STRD | | | |

## 6.4. Discussion

This study represents the first systematic effort to describe patterns of fish diversity in the Adelaide River catchment. The adequacy of the sampling effort can be assessed by three measures (i) habitat representation, (ii) rarefaction curves, and (iii) proportion of expected species. The distribution of survey effort was restricted to the upper and middle reaches of the catchment, and additional sampling is required in lagoons and backswamps of the lower floodplain to build a more comprehensive view of the distribution of biodiversity values. Priority sites for sampling include Bald Hill Lagoon, Tommy Policeman Lagoon, and Scott's Creek in Djukbinj National Park. Rarefaction curves suggested that species richness was asymptotic for a given effort at 6 of the 18 sites, and that further sampling may have detected additional species. Surveys detected 45 of the 83 species known or expected to occur in freshwater or tidal freshwater reaches of the Adelaide River. Twenty-five euryhaline species were not detected, and additional targeted surveys are required.

Quantitative surveys using electro-fishing detected 42 fish species, with an additional three fish species detected by other sampling methods. Fish assemblages are structured by habitat and position in the catchment. The most diverse sites tend to be structurally diverse with a well developed macrophyte fringe and lack of extensive invasive grass cover. These results align with observations of fish diversity in floodplain lagoons of the Wet Tropics (Arthington *et al.* 2014). These lagoon habitats were regarded as in good ecological condition because of retention of riparian vegetation and frequent flushing by high stream flows. Assemblage composition differed with distance from the coast, position on the floodplain, water quality and habitat. The present study found 29 native fish species in four floodplain lagoons (AGLN, AR01, DNLG and AULD); Arthington *et al.* (2014) found 21 native fish species in ten lagoon sites.

Riffle habitats provide habitat for a small but distinctive subset of the riverine channel fish fauna. Juvenile grunters, in particular sooty grunter *Hephaestus fuliginosus*, are dependent on shallow flowing habitats (Keller *et al.* 2019, Crook *et al.* 2021). Other species frequently detected in riffle habitats include other terapontid species, and square blotch goby *Glossogobius munroi*. Riffle habitats are vulnerable to reduction in dry season flow and are eliminated under cease to flow conditions.

Exquisite rainbowfish *Melanotaenia exquisita* are known from isolated escarpment areas in the NT and the east Kimberley in Western Australia, including sites in a small area in the upper reaches of the Adelaide River (Hammer and Golding 2017), which were not sampled in this survey. Specimens of spotted blue-eye *Pseudomugil gertrudae* were collected during opportunistic sampling at Anniversary Creek in the upper portion of the catchment on 23 August 2024; another swamp specialist, Obbes' catfish *Porochilus obbesi*, has been previously recorded from this site (MAGNT records). Similarly, specimens of delicate blue-eye *Pseudomugil tenellus* were collected during opportunistic sampling in a remnant channel on Beatrice Hill Research Farm on 21 August 2024.

The genus *Ophisternon* is a species-complex and genetic identification is required to confirm species identity. There are two species present in the Adelaide River, and consequently the identification of specimens as *Ophisternon gutturale* requires DNA confirmation. Similarly, the identification of juvenile engraulids from site BTCK as *Thryssa brevicauda* requires DNA confirmation.

# 7. Environmental DNA

## 7.1. Introduction

The detection of DNA fragments in environmental samples offers a cost effective and rigorous method of biodiversity inventory (Baird and Hajibabaei 2012, Huerlimann *et al*. 2020). The method depends on the availability of reference DNA gene sequences for accurate identification of species, and on the ability of reference sequences to discriminate among closely related species. Building the DNA reference library for Top End aquatic fauna is currently the focus of a funded research collaboration between Charles Darwin University and the MAGNT. The present study conducted eDNA sampling at each site to allow assessment of the current capacity of the method, and to identify gaps in species coverage.

Specifically, this study sought to:

(i) detect species of aquatic vertebrates and decapods using metabarcoding assays

(ii) detect threatened largetooth sawfish *Pristis pristis* using qPCR

(iii) compare results for different methods of sample collection.

## 7.2. Methods

Environmental DNA samples were collected at 18 sites prior to the commencement of other sampling activities. On each sampling occasion, 3 or 4 filtered samples were collected using 5 $\mu$m self-preserving Smith Root filters and an extendable sampling pole. Samples were collected from undisturbed water in advance of a small boat moving forward at low speed. A control sample using ultrapure water was collected using the same sampling equipment prior to the collection of other samples. Filters were refrigerated after collection until delivery to a commercial laboratory.

Vertebrate and decapod metabarcoding assays were used to screen eDNA samples. The decapod assay used miDeca primers for the 16S rRNA gene (Komai *et al*. 2019). DNA was extracted from filters using a Qiagen PowerSoil Kit that minimises compounds that can inhibit PCR reactions in environmental samples. Library construction involved two rounds of PCR, whereby the first round employed gene-specific primers to amplify the target region and the second round incorporated sequencing adapters and unique barcodes for each sample-amplicon combination included in the library. Negative controls were included during library construction. Negative controls consisted of the extraction negative as well as PCR negatives, in which nuclease-free water was used in place of DNA during both rounds of PCR. Sequencing was carried out on an Illumina sequencing platform.

Following quality control filtering to remove primer sequences, truncated reads, and low-frequency reads, DNA sequences were clustered into OTU's on the basis of sequence similarity. Taxonomic assignment was performed with VSEARCH software (Rognes *et al*. 2016), whereby each OTU cluster was assigned a species identity using a threshold of 95% by comparing against a reference sequence database. Where a species could not be assigned (that is reference database was deficient or taxa were poorly-characterised), taxonomic assignments were manually vetted by first obtaining a list of possible species through BLASTN searches against the public repository Genbank, followed by elimination of species on the basis of their geographic distributions, using information from the Atlas of Living Australia. In cases where an OTU could not be adequately resolved to a single species (for example due to shared haplotypes), either a list of multiple species is included, or the OTU is assigned to the lowest taxonomic rank without further classification. Separate bioassays were conducted for the detection of largetooth sawfish *Pristis pristis* using qPCR.

Environmental DNA samples were collected on two separate occasions from Dash Lagoon (site DLDD) using a Smith-Root backpack sampler. On 6 August 2024 samples were collected from the bank at three discrete points along the waterbody ('point'); on 17 August 2024 three samples were collected mid-stream from a small boat moving slowly forward ('composite'). An extendable sampling pole was used on both occasions.

Data are presented on the frequency of detection of OTU's identified by eDNA, truncated to the level of family. Fish species detected by concurrent biodiversity survey and not detected by eDNA are listed.

## 7.3. Results

eDNA metabarcoding bioassays identified 94 taxa from 18 sites in the Adelaide River catchment (Table 24). Fifty-eight taxa were identified to species-level, 61.7%; though six taxa are only identified to species 'type'. Twenty-three of 45 fish species detected by biodiversity surveys were not detected by eDNA (Table 26). Of these, eight of 23: 34.8%, were obligate freshwater species, and 15 of 23: 65.2%, were euryhaline species.

eDNA failed to discriminate the common terapontid species spangled perch *Leiopotherapon unicolor*, and barred grunter *Amniataba percoides*; as well as the melanotaeniid species chequered rainbowfish *Melanotaenia splendida inornata*, and blackbanded rainbowfish *M. nigrans*. Other problem taxa include ariid catfish, which were detected at the level of family at 14 of 18 sites. Two of the six ariidae species, known or suspected to occur in the catchment, were detected by eDNA, that is *Neoarius graeffei* and *N. berneyi*. The presence of *N. berneyi* in the catchment however is yet to be confirmed and may be an artefact of the current reference library; *N. leptaspis* was not detected; and smallmouth catfish *Cinetodes froggatti* have been recorded from previous biodiversity surveys in the catchment but were not detected.

There were detections of 44 OTU's of non-fish vertebrates, including 22 birds and 12 mammals (Table 25). There were species-level detections of three species of cormorant, but no species-level detections of egrets. Detections for three species (wood duck *Chenonetta jubata*; painted honeyeater *Grantiella picta*; and bearded mudskipper *Scartelaos histophorus*) are likely to be erroneous based on known habitat and distribution. Other questionable detections include sheep *Ovis aries*, and chicken *Gallus gallus*. There was no evidence of in-field contamination in control samples.

Some OTU names can be matched to species with high probability (Table 27).

**Table 24.** List of taxa identified using eDNA analysis of samples from 18 sites in the Adelaide River catchment.

| Taxon | Family | Genus | Species | Common name | F |
|---|---|---|---|---|---|
| amphibians | Bufonidae | *Rhinella* | *Rhinella marina* | cane toad | 10 |
| amphibians | Hylidae | *Litoria* | *Litoria inermis* | bumpy rocketfrog | 1 |
| amphibians | Hylidae | *Litoria* | | genus of Australasian tree frogs | 2 |
| amphibians | Hylidae | *Litoria* | *Litoria nasuta* | striped rocket frog | 2 |
| amphibians | Myobatrachidae | | | family of Australian ground frogs | 3 |
| birds | Acanthizidae | *Gerygone* | | genus of peep-warblers | 1 |
| birds | Alcedinidae | | | family of kingfishers | 1 |
| birds | Anatidae | | | order of waterbirds that includes ducks, geese and swans | 4 |
| birds | Anatidae | *Chenonetta* | *Chenonetta jubata* | Australian wood duck | 1 |
| birds | Anatidae | *Dendrocygna* | *Dendrocygna arcuata* | wandering whistling-duck | 2 |
| birds | Anhingidae | | | order of Australian darter | 1 |

| Taxon | Family | Genus | Species | Common name | F |
|---|---|---|---|---|---|
| birds | Anseranatidae | *Anseranas* | *Anseranas semipalmata* | magpie goose | 1 |
| birds | Ardeidae | *Ardea* | | genus of herons | 1 |
| birds | Ardeidae | *Bubulcus* | *Bubulcus ibis* | cattle egret | 3 |
| birds | Ardeidae | *Ixobrychus* | *Ixobrychus flavicollis* | black bittern | 1 |
| birds | Ardeidae | *Nycticorax* | *Nycticorax caledonicus* | nankeen night heron | 5 |
| birds | Cacatuidae | *Cacatua* | *Cacatua galerita* | sulphur-crested cockatoo | 2 |
| birds | Meliphagidae | | | family of honeyeaters | 2 |
| birds | Meliphagidae | *Grantiella* | *Grantiella picta* | painted honeyeater | 1 |
| birds | Meliphagidae | *Myzomela* | | genus of honeyeaters | 1 |
| birds | Monarchidae | | | family of shrikebills, paradise flycatchers, magpie-larks | 1 |
| birds | Phalacrocoracidae | | | family of cormorants | 1 |
| birds | Phalacrocoracidae | *Microcarbo* | *Microcarbo melanoleucos* | little pied cormorant | 6 |
| birds | Phalacrocoracidae | *Phalacrocorax* | *Phalacrocorax sulcirostris* | little black cormorant | 1 |
| birds | Phalacrocoracidae | *Phalacrocorax* | *Phalacrocorax varius* | pied cormorant | 1 |
| birds | Phasianidae | *Gallus* | *Gallus gallus* | chicken | 2 |
| birds | Threskiornithidae | *Threskiornis* | | genus of ibis | 2 |
| decapods | Atyidae | *Caridina* | *Caridina wilkinsi* | freshwater atyid shrimp | 3 |
| decapods | Atyidae | *Caridina* | *Caridina* sp. | freshwater atyid shrimp | 4 |
| decapods | Atyidae | *Caridina* | *Caridina* sp. Gulf1 | freshwater atyid shrimp | 1 |
| decapods | Atyidae | *Caridina* | *Caridina* sp. WA4 | freshwater atyid shrimp | 6 |
| decapods | Atyidae | *Caridina* | | genus of freshwater atyid shrimp | 3 |
| decapods | Palaemonidae | *Macrobrachium* | *Macrobrachium* sp. Blackmore | freshwater prawns and shrimps | 1 |
| decapods | Palaemonidae | *Macrobrachium* | *Macrobrachium spinipes* | giant freshwater prawn | 4 |
| decapods | Palaemonidae | *Macrobrachium* | *Macrobrachium bullatum* | northwest Australian river prawn | 3 |
| decapods | Parastacidae | *Cherax* | | genus of yabbies | 3 |
| decapods | Parastacidae | *Cherax* | *Cherax quadricarinatus* | redclaw crayfish | 2 |
| decapods | Parastacidae | *Cherax* | *Cherax* sp.1 | species of yabby | 5 |
| decapods | Sesarmidae | | | | 1 |
| fish | Ambassidae | *Ambassis* | | genus of glassfish | 4 |
| fish | Ambassidae | *Ambassis* | *Ambassis* sp. | genus of glassfish | 7 |
| fish | Ambassidae | *Ambassis* | *Ambassis macleayi* | Macleay's glass fish | 15 |
| fish | Ambassidae | *Denariusa* | | genus of glassfish | 4 |
| fish | Apogonidae | *Glossamia* | *Glossamia aprion* | mouth almighty | 17 |
| fish | Ariidae | | | family of catfish | 14 |
| fish | Ariidae | *Neoarius* | *Neoarius graeffei* | blue salmon catfish | 4 |
| fish | Ariidae | *Neoarius* | *Neoarius berneyi* | highfin catfish | 8 |

| Taxon | Family | Genus | Species | Common name | F |
|---|---|---|---|---|---|
| fish | Atherinidae | *Craterocephalus* | | genus of silversides, hardyheads | 8 |
| fish | Belonidae | *Strongylura* | | genus of needlefish | 14 |
| fish | Clupeidae | *Nematalosa* | *Nematalosa erebi* | bony bream | 16 |
| fish | Eleotridae | *Hypseleotris* | | genus of carp gudgeons | 4 |
| fish | Eleotridae | *Mogurnda* | *Mogurnda mogurnda* | northern purple spotted gudgeon | 9 |
| fish | Eleotridae | *Oxyeleotris* | *Oxyeleotris selheimi* | blackbanded gudgeon | 9 |
| fish | Eleotridae | *Oxyeleotris* | *Oxyeleotris nullipora* | poreless gudgeon | 2 |
| fish | Eleotridae | *Oxyeleotris* | *Oxyeleotris lineolata* | sleepy cod | 13 |
| fish | Eleotridae | *Prionobutis* | *Prionobutis microps* | smalleye gudgeon | 3 |
| fish | Engraulidae | *Thryssa* | | genus of anchovy | 1 |
| fish | Gobiidae | | | family of goby | 1 |
| fish | Gobiidae | *Glossogobius* | | genus of goby | 10 |
| fish | Gobiidae | *Glossogobius* | *Glossogobius aureus* | golden flathead goby | 7 |
| fish | Gobiidae | *Scartelaos* | *Scartelaos histophorus* | bearded mudskipper | 1 |
| fish | Latidae | *Lates* | *Lates calcarifer* | barramundi | 15 |
| fish | Megalopidae | *Megalops* | *Megalops cyprinoides* | oxeye herring | 15 |
| fish | Melanotaeniidae | *Melanotaenia* | | genus of rainbowfishes | 15 |
| fish | Mugilidae | *Planiliza* | *Planiliza ordensis* | diamond mullet | 15 |
| fish | Osteoglossidae | *Scleropages* | *Scleropages jardinii* | northern saratoga | 3 |
| fish | Plotosidae | *Neosilurus* | *Neosilurus ater* | black catfish, narrow-fronted tandan | 16 |
| fish | Plotosidae | *Neosilurus* | | genus of catfish | 10 |
| fish | Plotosidae | *Neosilurus* | *Neosilurus hyrtlii* | hyrtl's catfish | 7 |
| fish | Plotosidae | *Porochilus* | *Porochilus rendahli* | rendahl's catfish | 4 |
| fish | Soleidae | | | family of soles | 4 |
| fish | Synbranchidae | *Ophisternon* | *Ophisternon gutturale* | Australian swamp eel | 4 |
| fish | Synbranchidae | *Ophisternon* | | genus of swamp eel | 10 |
| fish | Terapontidae | *Hephaestus* | *Hephaestus fuliginosus* | sooty grunter | 10 |
| fish | Terapontidae | *Syncomistes* | *Syncomistes butleri* | sharpnose grunter | 13 |
| fish | Terapontidae | | | family of grunters | 15 |
| fish | Toxotidae | *Toxotes* | *Toxotes chatareus* | sevenspot archerfish | 13 |
| mammals | Bovidae | | | family of ruminants including cattle | 2 |
| mammals | Bovidae | *Bos* | *Bos taurus* | cattle | 2 |
| mammals | Bovidae | *Bubalus* | *Bubalus bubalis* | water buffalo | 6 |
| mammals | Bovidae | *Ovis* | *Ovis aries* | sheep | 1 |
| mammals | Canidae | *Canis* | *Canis lupus* | dog or dingo | 1 |
| mammals | Macropodidae | *Notamacropus* | | genus of small marsupials | 8 |

| Taxon | Family | Genus | Species | Common name | F |
|---|---|---|---|---|---|
| mammals | Macropodidae | *Osphranter* | *Osphranter antilopinus* | antilopine kangaroo | 1 |
| mammals | Macropodidae | *Osphranter* | | genus of large kangaroos | 1 |
| mammals | Muridae | *Melomys* | *Melomys burtoni* | grassland melomys | 2 |
| mammals | Pteropodidae | *Pteropus* | | genus of flying foxes | 3 |
| mammals | Suidae | *Sus* | *Sus scrofa* | pig | 1 |
| mammals | Vespertilionidae | *Nyctophilus* | | genus of Australian big-eared bats | 1 |
| reptiles | Acrochordidae | *Acrochordus* | *Acrochordus arafurae* | Arafura file snake | 2 |
| reptiles | Chelidae | *Chelodina* | *Chelodina oblonga* | northern snake-necked turtle | 2 |
| reptiles | Chelidae | *Elseya* | | Australian snapping turtles | 6 |
| reptiles | Chelidae | *Emydura* | | Australian short-necked turtles | 4 |
| reptiles | Crocodylidae | *Crocodylus* | *Crocodylus porosus* | saltwater crocodile | 3 |

**Table 25.** Numbers of OTU's derived from eDNA analysis, number of species-level identifications, and percentage of species-level identifications.

| Taxon | OTU | Species-level | % |
|---|---|---|---|
| amphibians | 5 | 3 | 60 |
| birds | 22 | 12 | 55 |
| decapods | 12 | 9 | 75 |
| fish | 38 | 24 | 63 |
| mammals | 12 | 7 | 58 |
| reptiles | 5 | 3 | 60 |
| total | 94 | 58 | 62 |

**Table 26.** List of fish species collected during biodiversity surveys of 18 sites in Adelaide River catchment in August 2024, and not detected by eDNA.

| Family | Species name | Common name |
|---|---|---|
| Ambassidae | *Ambassis interrupta* | long-spined glassfish |
| Ambassidae | *Ambassis* sp. NW | northwest glassfish |
| Ariidae | *Hemiarius dioctes* | warrior catfish |
| Ariidae | *Neoarius leptaspis* | salmon catfish |
| Atherinidae | *Craterocephalus stercusmuscarum* | fly-specked hardyhead |
| Belonidae | *Strongylura krefftii* | freshwater longtom |
| Carcharhinidae | *Carcharhinus leucas* | bull shark |
| Eleotridae | *Butis butis* | crimsontip gudgeon |
| Eleotridae | *Hypseleotris compressa* | empire gudgeon |
| Engraulidae | *Thryssa brevicauda* | freshwater anchovy |
| Engraulidae | *Thryssa malabarica* | freshwater anchovy |
| Gobiidae | *Caragobius rubristriatus* | worm goby |
| Gobiidae | *Glossogobius munroi* | square blotch goby |
| Gobiidae | *Periophthalmus weberi* | Weber's mudskipper |

| | | |
|---|---|---|
| Kurtidae | *Kurtus gulliveri* | nurseryfish |
| Melanotaeniidae | *Melanotaenia nigrans* | blackbanded rainbowfish |
| Melanotaeniidae | *Melanotaenia splendida inornata* | chequered rainbowfish |
| Plotosidae | *Anodontiglanis dahli* | toothless catfish |
| Soleidae | *Leptachirus darwinensis* | Darwin sole |
| Terapontidae | *Amniataba percoides* | barred grunter |
| Terapontidae | *Leiopotherapon unicolor* | spangled perch |
| Toxotidae | *Toxotes lorentzi* | primitive archerfish |
| Zenarchopteridae | *Zenarchopterus caudovittatus* | long-jaw river garfish |

**Table 27.** List of OTU names from eDNA analysis and probable species-level identifications.

| Taxon | OTU name | Probable species name |
|---|---|---|
| birds | Anhingidae | *Anhinga novaehollandiae* |
| fish | *Denariusa* | *Denariusa bandata* |
| fish | *Strongylura* | *Strongylura krefftii* |
| mammals | *Notamacropus* | *Notamacropus agilis* |
| reptiles | *Elseya* | *Elseya flaviventralis* |

### 7.3.1. qPCR bioassay for largetooth sawfish

There were no positive qPCR detections for largetooth sawfish *Pristis pristis*, with the exception of an equivocal result for one replicate at site DRRD.

### 7.3.2. Comparison of eDNA collection method

Thirty-one taxa were identified in samples batches collected by point and composite sampling in Dash Lagoon (Table 28). Twenty of 31 OTU's were identified to species-level. Twenty-five taxa were identified from three bankside point samples; twenty-seven taxa were identified from three roaming composite samples; twenty-one taxa were detected by both methods. Bankside point sample collection can substitute for mid-stream boat-based sample collection, though this may depend on habitat structure.

**Table 28.** List of operational taxonomic units identified in bank-side point eDNA samples, and in roaming composite eDNA samples at site DLDD.

| Family | Genus | Species | Common name | Point | Comp. |
|---|---|---|---|---|---|
| Bufonidae | *Rhinella* | *Rhinella marina* | cane toad | 1 | |
| Myobatrachidae | | | family of Australian ground frogs | | 1 |
| Ambassidae | *Ambassis* | *Ambassis* sp. | genus of glassfish | | 1 |
| Ambassidae | *Ambassis* | *Ambassis macleayi* | Macleay's glass fish | 1 | 1 |
| Apogonidae | *Glossamia* | *Glossamia aprion* | mouth almighty | 1 | 1 |
| Ariidae | | | family of catfish | 1 | 1 |
| Atherinidae | *Craterocephalus* | | genus of silversides, hardyheads | 1 | 1 |
| Belonidae | *Strongylura* | | genus of needlefish | 1 | 1 |
| Clupeidae | *Nematalosa* | *Nematalosa erebi* | bony bream | 1 | 1 |
| Eleotridae | *Mogurnda* | *Mogurnda mogurnda* | northern purple spotted gudgeon | 1 | |
| Eleotridae | *Oxyeleotris* | *Oxyeleotris selheimi* | blackbanded gudgeon | 1 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| Eleotridae | *Oxyeleotris* | *Oxyeleotris lineolata* | sleepy cod | 1 | 1 |
| Gobiidae | *Glossogobius* | | genus of goby | 1 | 1 |
| Gobiidae | *Glossogobius* | *Glossogobius aureus* | golden flathead goby | 1 | 1 |
| Latidae | *Lates* | *Lates calcarifer* | barramundi | 1 | 1 |
| Megalopidae | *Megalops* | *Megalops cyprinoides* | oxeye herring | 1 | 1 |
| Melanotaeniidae | *Melanotaenia* | | genus of rainbowfishes | 1 | 1 |
| Osteoglossidae | *Scleropages* | *Scleropages jardinii* | northern saratoga | 1 | 1 |
| Plotosidae | *Neosilurus* | *Neosilurus ater* | black catfish, narrow-fronted tandan | 1 | 1 |
| Synbranchidae | *Ophisternon* | *Ophisternon gutturale* | Australian swamp eel | | 1 |
| Synbranchidae | *Ophisternon* | | genus of swamp eel | | 1 |
| Terapontidae | *Hephaestus* | *Hephaestus fuliginosus* | sooty grunter | 1 | 1 |
| Terapontidae | *Syncomistes* | *Syncomistes butleri* | sharpnose grunter | 1 | 1 |
| Terapontidae | | | family of grunters | 1 | 1 |
| Toxotidae | *Toxotes* | *Toxotes chatareus* | sevenspot archerfish | 1 | 1 |
| Bovidae | | | family of ruminants incl. cattle | 1 | |
| Bovidae | *Bos* | *Bos taurus* | cattle | | 1 |
| Bovidae | *Bubalus* | *Bubalus bubalis* | water buffalo | 1 | 1 |
| Chelidae | *Elseya* | | Australian snapping turtles | 1 | |
| Chelidae | *Emydura* | | Australian short-necked turtles | 1 | 1 |
| Crocodylidae | *Crocodylus* | *Crocodylus porosus* | saltwater crocodile | | 1 |

## 7.4. Discussion

DNA based methods are likely to assume a prominent role in monitoring aquatic and terrestrial biodiversity in northern Australia. These methods offer several advantages over conventional field-sampling methods. These advantages include cost effectiveness, reduced exposure to field hazards, and whole of waterbody sampling not influenced by method bias. This present study featured a high proportion of unassigned taxa which could not be identified to species-level. Several taxa were frequently identified only to the level of genus, for example *Melanotaenia* and *Glossogobius*; or family, for example Ariidae and Terapontidae. Three species of freshwater crayfish in the genus *Cherax* are known to occur in the Top End (Hammer *et al.* 2024), these being *C. quadricarinatus*, *C. bicarinatus* and *C. nucifraga*. The decapod metabarcoding assay identified the taxon *Cherax* sp. 1. It is unclear whether this represents an additional species, or failure to match existing described species (only *C. quadricarinatus* has been previously recorded in the Adelaide River).

The study failed to detect 23 of 45 fish species known to occur from concurrent biodiversity surveys. There are four potential factors which may account for detection failure:

(i) the lack of reference sequence data

(ii) shared haplotypes preventing species discrimination

(iii) low DNA shedding by some species groups

(iv) environmental factors.

Vertebrate bioassays using the 12S gene cannot discriminate between rainbowfish species chequered rainbowfish *Melanotaenia splendida inornata*, and black-banded rainbowfish *M. nigrans*; and between the terapontid species spangled grunter *Leiopotherapon unicolor*, barred grunter *Amniataba percoides*, and yellowtail trumpeter *Amniataba caudavittata.*

Other problematic genera include *Neoarius*, *Ambassis*, *Neosilurus* and *Hypseleotris*. Some taxa, including aquatic reptiles and elasmobranchs, shed relatively low amounts of DNA and consequently have a low probability of detection. As an example, *Carcharhinus leucas* is a relatively common species in the tidal freshwater reach of the Adelaide River but was not detected by eDNA.

qPCR analyses failed to detect largetooth sawfish *Pristis pristis*. juvenile sawfish were observed in the lower freshwater reach of the Margaret River, are known to occur in the upper reaches of the Adelaide River (D. Wedd, *pers. comm.*), and were detected by metabarcoding in samples from the Dirty Lagoon gauge station site on the Adelaide River on 18 April 2024.

# 8. Summary

## 8.1. Composition of vertebrate fauna

The vertebrate species records dataset for the Adelaide River catchment includes 171,758 individual records. Of these, 942 (<1%), were records of fish species. The dataset includes records of 243 aquatic vertebrate species and 15 threatened aquatic vertebrate species. The list of threatened aquatic vertebrate species includes seven migratory shorebird species, three elasmobranch species and three varanid species. The three elasmobranch species are potentially vulnerable to impacts from water resource development in the catchment.

## 8.2. Review of ecological assets

The attributes and values of ten ecological assets of the Adelaide River catchment are listed in Table 29.

**Table 29.** Summary of key ecological assets of aquatic systems of Adelaide River catchment.

| Ecological asset | Attributes and values |
|---|---|
| saltwater crocodile | localised high-density nesting habitat<br>monitoring of population in Adelaide River since 1977 |
| magpie geese | floodplains of Adelaide and Mary important nesting areas<br>consistent monitoring of geese numbers and nests since 2011<br>8.2% of Top End magpie geese numbers<br>14.7% of Top End magpie geese nests |
| euryhaline elasmobranchs | Euryhaline species threatened globally<br>Adelaide River is a stronghold for three threatened elasmobranch species |
| migratory birds | habitat for nationally significant numbers of migratory shorebirds<br>42 JAMBA/CAMBA listed species |
| colonial breeding waterbirds | 76 breeding sites for 15 colonial breeding waterbird species in Top End<br>3 active colonies in Adelaide River catchment, including potentially largest regular egret colony in Australia |
| monsoon rainforest | 2% of NT rainforest estate<br>one of six clusters of patches required to capture rare endemic rainforest species |

| | |
|---|---|
| tidal freshwater fish | 83 known or probable species from freshwater and tidal freshwater<br>50 of 83 fish species euryhaline or diadromous<br>characteristic suite of tidal freshwater species; salinity requirements of early life stages of these species mostly unknown |
| migratory aquatic species | 7 diadromous fish species including barramundi, oxeye herring, and largetooth sawfish<br>diadromous decapods including cherabin and some *Caridina* species<br>several species undertake large-scale within-system movements |
| frogs | 26 species in Adelaide River catchment<br>threatened Howard River toadlet restricted to sandsheet heath<br>16 year survey of four frog species in Fogg Dam Reserve found abrupt and asynchronous changes not clearly linked to rainfall patterns |
| water python and dusky rat | long-term studies from 1991 of predator-prey system in Fogg Dam Reserve area<br>population dynamics driven by rainfall pattern<br>catastrophic system collapse after flood events in 2007 and 2011 |

## 8.3. Spatial variation in water quality

Data on water quality parameters were collected concurrently with surveys of aquatic biodiversity at 18 sites in the Adelaide River catchment. Differences in electrical conductivity and ionic composition reflect differences in hydrogeology across the catchment. Conductivity of the Adelaide River within the freshwater reach from Adelaide River township to the tidal limit at Marrakai Crossing averaged 261.4 µS/cm. The conductivity of off-stream channels averaged 46.2 µS/cm, reflecting the influence of wet season floodwaters on these waterbodies. Values of chlorophyll *a*, total nitrogen, total phosphorus and turbidity tended to be relatively low and invariable in freshwater riverine sites, but high and variable at off-stream channel sites. The single site with a history of substantial impacts from domestic stock featured high values of chlorophyll *a*, total nitrogen and turbidity, and low values of dissolved oxygen. The historic baseline of water quality data for much of the catchment is meagre and therefore insufficient to assess long-term temporal trends.

## 8.4. Spatial variation in aquatic biodiversity

The composition of the aquatic vertebrate and decapod crustacean fauna was systematically surveyed at 18 sites in the Adelaide River catchment. Sites spanned the range of available habitats that could be accessed. Forty-five of the 83: 54.2%, fish species known or thought to occur in the freshwater and tidal freshwater reaches of the Adelaide River were detected by this survey. This included 24 primarily freshwater species, 18 euryhaline species, and three diadromous species. The most frequently recorded species were chequered rainbowfish *Melanotaenia splendida inornata*, 16 sites: 88.9%, and mouth almighty *Glossamia aprion*, 16 sites: 88.9%. Further work is required to elucidate the composition and distribution of fish species in the tidal freshwater reach, and of lagoons of the lower floodplain.

Seven of the eighteen known aquatic and semiaquatic reptile species were detected by the survey, and eight species of decapod crustacea including four atyid species in the genus *Caridina*, and three palaemonid species in the genus *Macrobrachium*.

Spatial patterns in aquatic biodiversity were described using data on species richness at each site; data on abundance of individual fish species; and multivariate analysis of spatial variation in fish abundance. Highest values of summed species richness were recorded in off-stream channel sites in habitat classes 3.3 and 4.

Catch per unit effort data using caught and observed and caught electro-fishing data were plotted for several fish species. Catch per unit effort abundance of all fish species, and species richness per shot was highest in habitat classes 3.2 and 3.3 for caught and observed data.

Multivariate classification revealed spatial patterning in fish assemblages. CLUSTER classification identified six discrete groups corresponding to riffle sites, tidal freshwater sites, riverine and off-stream sites with little or no fringing macrophytes, off-stream channel sites with submerged and floating macrophytes, and an impacted floodplain lagoon site. The SIMPER procedure identified characteristic species of each group.

## 8.5. Environmental DNA

eDNA samples collected concurrently with biodiversity surveys at 18 sites identified 94 operational taxonomic units including 38 fish, 22 birds, 12 mammals and 12 decapods. Twenty-three of 45 fish species detected by biodiversity surveys were not detected by eDNA. Further work is required to discriminate fish species within the families Melanotaeniidae and Terapontidae. There were no detections of largetooth sawfish *Pristis pristis*. A trial of two eDNA sample collection methods found minimal differences in species detection.

# 9. Conclusions

The Adelaide River floodplain system provides a major breeding area for magpie goose *Anseranas semipalmata*, a major breeding area for saltwater crocodile *Crocodylus porosus*, a major breeding area for herons and allies, a major dry season refuge area for waterbirds, and a significant migration stop-over area for shorebirds. Major breeding sites for saltwater crocodile occur in freshwater swamps on the lower Marrakai Creek, in swamps between tidal channels in the far north-west, and along Melacca Creek. Melacca Swamp provides important habitat for nesting in dense, permanently inundated tall sedgeland of *Thoracostachyum sumatranum* (Jaensch 1993). The floodplains encompass the most important nesting habitat for magpie goose in the NT (Bayliss and Yeomans 1990). The site includes three waterbird breeding colonies, including two in mangroves in the lower reaches of the Adelaide River (Chatto 2000). One colony supported an estimated 30,000 birds in 1994. It is believed to be the largest waterbird colony in the NT, and possibly the largest, regular egret colony in Australia. Lake Finniss is identified as an internationally important site for migratory shorebirds in the East Asian-Australasian Flyway (Bamford *et al*. 2008). Maximum counts of species that are internationally significant, that is >1% global population, include 12,000 little curlew (Jaensch 1994), 3,000 red-necked avocet (Chatto 2006), and 2,000 black-tailed godwits (Chatto 2003). Coastal mudflats and nearby areas support internationally significant numbers of shorebirds, and thousands of oriental pratincole *Glareola maldivarum* occur on the floodplain prior to the wet season.

The present study reviewed vertebrate species records for the Adelaide River catchment. The extracted dataset included 171,758 records comprising 588 vertebrate species. There were 30 threatened vertebrate species and 15 threatened aquatic vertebrate species; including three elasmobranch species which are potentially vulnerable to water resource development in the catchment. The Adelaide River is regarded as a stronghold for speartooth shark *Glyphis glyphis*, Northern river shark *Glyphis garricki*, and largetooth sawfish *Pristis pristis*.

There are long-term studies of several ecological assets which provide information on species-specific responses to climatic variation. The nature of the response varies by taxa. For the magpie goose, nesting density and timing is correlated with variation in the timing of the onset of the wet season. For the file snake, and presumably most fish, production is related to high late wet season rainfall causing prolonged inundation of the floodplain. For the water python-dusky rat predator-prey system, rat breeding and python condition, survival and recruitment are highest in years of moderate late season rainfall. Changes in frog species composition were not clearly linked to rainfall pattern.

A field survey of aquatic vertebrates including fish, and aquatic and semiaquatic reptiles, recorded 45 fish species from a known fauna of 83 species, and seven of 18 aquatic and semiaquatic reptile species, and identified spatial patterning in fish assemblages. Riverine channels, and upstream off-stream channels, provide structurally simple habitat for a core suite of a minimum of eight species. Off-stream channels with fringing macrophytes provide more structurally complex habitat for a suite of approximately 20 species. Floodplain waterbodies, through differences in hydrology, connectivity, productivity, and habitat complexity provide a heterogeneous set of habitat circumstances which underpin medium-scale diversity and resilience. Loss of heterogeneity through hydrological change and habitat modification by weed invasion may lead to loss of diversity and resilience. Effects may be multiplicative; in that reduced floodplain flows may facilitate spread and persistence of invasive grasses.

Field surveys focussed on waterbodies within and adjacent to the main channel of the Adelaide River. Large areas of aquatic habitat remain unsurveyed. The survey did not include waterbodies on the Margaret River, spring-fed streams in monsoon forest patches, grassy back-swamps on the fringes of the floodplain, nor sufficient representation of lagoons on the lower floodplain. Anecdotal information suggests that large areas of wetland habitat on the Adelaide River floodplain are dominated by invasive aquatic grasses including para grass *Urochloa mutica* and olive hymenachne *Hymenachne amplexicaulis*. Invasive pasture grasses diminish water quality, reduce fish species richness, and provide habitat for introduced fish species including siamese fighting fish *Betta splendens*.

Sampling results provide some support to the prediction that the zone of highest ecological value occurs in the middle section of the Adelaide River in an arc from Marrakai Crossing to Donald's Lagoon at the base of the floodplain. Waterbodies upstream of this arc tend to be structurally simple and resemble riverine channels; waterbodies downstream of this arc are more likely to be impacted by invasive pasture grasses. There is currently no mapping of the extent of invasive pasture grasses on the Adelaide River floodplain, nor modelling of the spatial pattern of ecological values.

The tidal freshwater reach is potentially vulnerable to the impacts of water extraction through effects on the salinity regime. Increasing salinity may cause shifts in habitat availability for fish species adapted to low salinity (Berra and Wedd 2017), increase in the upstream extent of salt-tolerant riparian vegetation, and loss of freshwater-dependent riparian vegetation. The composition and distribution of the fauna of the tidal freshwater reach is understudied and poorly known.

## 9.1. Recommendations for research and monitoring

### 9.1.1. Research

Model floodplain hydrology:

- through model simulation, establish relationships between river flow, surface run-off, and extent and duration of floodplain inundation.

Model impacts of water extraction on tidal freshwater reach:

- through modelling of flow extraction scenarios, assess consequences of water extraction on the salinity regime in the tidal freshwater reach.
- conduct comprehensive assessment of biodiversity values of the tidal freshwater reach.
- collaborate with Charles Darwin University DNA reference library project to enhance capacity for eDNA detection of tidal freshwater species.

Map floodplain vegetation:

- map floodplain plant communities with an emphasis on the distribution of the invasive pasture grasses para grass, *Urochloa mutical*, and olive hymenachne, *Hymenachne amplexicaulis*.
- investigate relationships between existing land unit mapping and recent mapping derived from classification of satellite imagery (de Mello *et al.* 2024).

Augment existing data on biodiversity values of aquatic habitats of the Adelaide River catchment:

- expand coverage of aquatic biodiversity surveys to include greater representation of floodplain and other under-represented habitats (e.g. tidal freshwater, smaller streams) with a minimum target survey effort of 30 sites.
- priority sites include lower floodplain lagoons, backswamps, waterbodies of Margaret River, and upper reaches of Adelaide River.

Investigate current status of waterbird breeding colonies:

- investigate status of waterbird breeding colonies on the Adelaide River floodplain and investigate methods for assessment of seasonal and interannual nesting activity and success.

Model spatial variability of magpie geese and magpie geese nests:

- model interannual variation in distribution of magpie geese and magpie geese nests on the Adelaide River floodplain, and patterns of floodplain inundation.

Saltwater crocodile:

- model interannual variation in recruitment, egg harvest and hydrology.

### 9.1.2. Monitoring

Long-term monitoring of ecological assets and processes provides assurance that the goals of management are met. Long-term data spanning the range of hydrological variability provides critical information on the responses of biota to hydrological variability. Rigorous flow-ecology relationships provide critical underpinning for river flow management.

Threatening processes on tropical floodplains of northern Australia have been well documented. The biodiversity values of remnant floodplain lagoons in the Wet Tropics of northern Queensland were assessed to be threatened by the loss of natural flow regimes and floodplain connectivity (Arthington *et al.* 2014). Invasive plants including para grass, *Urochloa mutica*, have significant negative effects on floodplain fish communities (Perna *et al*. 2012), and on floodplain plant and avifauna diversity (Ferdinands *et al*. 2005).

Targets for monitoring in the Adelaide River catchment include:

1. Known high conservation value sites: these occur in an arc downstream from the tidal limit from Marrakai Crossing, and include the following survey sites AR01, Acacia Gap Lagoon (AGLN), Auld's Lagoon (AULD), Donald's Lagoon (DNLG) and the unsurveyed Bald Hill Lagoon.

2. Vulnerable flow-dependent habitats: riffles within the main river channel support a distinctive suite of fish, and invertebrate, species. Flow reduction will lead to loss of available habitat; cease to flow conditions will temporarily eliminate this habitat.

3. Freshwater-dependent riparian vegetation in the tidal freshwater zone: the ingress of saline water into the upper tidal reaches may lead to community wide changes in the composition of riparian vegetation and the replacement of freshwater species with salt tolerant species.

## 9.2. Knowledge gaps

Further work is required to improve the utility of environmental DNA for routine monitoring of the biodiversity of waterbodies in the Adelaide River catchment, and elsewhere. This requires building a comprehensive reference DNA library for target taxa, including fish, molluscs, decapods and turtles: and improving the understanding of factors influencing species-specific detection rates from eDNA in order to optimise sampling design.

There are long-term datasets for several ecological assets within the Adelaide River catchment, but none specifically address the relationship between variation in flow and biodiversity assets or ecological function. There is an urgent need to establish long-term monitoring programs to describe interannual variability in ecological structure and processes in relation to variability in climate drivers.

Much of the information on biodiversity assets and mapping products are derived from surveys conducted several decades ago and may require updating or correction. More information is required on the extent and ecological impacts of invasive pasture grasses.

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# 11. Appendices

## 11.1. Appendix 1 – Site summaries

Site DLDD – Dash Lagoon

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | DLDD | EC | 29.7 µS/cm | off-stream channel | class 3.1 |
| latitude | -13.0445 | DO | 7.3 mg/L | max. depth | 5.8 m |
| longitude | 131.2364 | % DO | 87.2 | channel width | 48 m |
| date | 5/8/2024 | TN | 0.38 mg/L | % open water | 100 |
| | | TP | 0.01 mg/L | % macrophyte cover | 0 |
| | | Chlorophyll *a* | 4.21 µg/L | | |
| | | Turbidity | 3.5 NTU | | |
| | | pH | 7.22 | | |

| Fish species (n=16) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Glossamia aprion* | *Megalops cyprinoides* | *Oxyeleotris lineolata* |
| *Ambassis* sp. NW | *Lates calcarifer* | *Melanotaenia splendida* | *Oxyeleotris selheimi* |
| *Amniataba percoides* | *Scleropages jardinii* | *Nematalosa erebi* | *Syncomistes butleri* |
| *Craterocephalus stercusmuscarum* | *Strongylura krefftii* | *Neoarius leptaspis* | *Toxotes chatareus* |

| Reptile species (n=2) | Decapod species (n=2) |
|---|---|
| *Crocodylus porosus* | *Macrobrachium spinipes* |
| *Elseya flaviventralis* | *Macrobrachium bullatum* |

Site ARDD – Adelaide River, Dot and Dash

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | ARDD | EC | 247.4 µS/cm | pool in river channel | class 2.2 |
| latitude | -13.0893 | DO | 4.7 mg/L | max. depth | 5.1 m |
| longitude | 131.2345 | %DO | 56.7 % | channel width | 22 m |
| river | Adelaide River | TN | 0.21 mg/L | % open water | 100 |
| property | NT Land Corporation | TP | 0.01 mg/L | % macrophyte | 0 |
| date | 6/8/2024 | Chlorophyll *a* | 1.68 µg/L | | |
| | | Turbidity | 3.0 NTU | | |
| | | pH | 7.45 | | |

| Fish species (n=14) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Melanotaenia splendida* | *Oxyeleotris lineolata* | *Toxotes chatareus* |
| *Amniataba percoides* | *Nematalosa erebi* | *Planiliza ordensis* | *Glossamia aprion* |
| *Lates calcarifer* | *Neoarius graeffei* | *Strongylura krefftii* | |
| *Megalops cyprinoides* | *Neosilurus ater* | *Syncomistes butleri* | |

| Decapod species (n=6) | |
|---|---|
| *Caridina magnovus* | *Caridina wilsoni* |
| *Caridina nilotica* | *Macrobrachium bullatum* |
| *Caridina wilkinsi* | *Macrobrachium spinipes* |

Site AULD – Auld's Lagoon

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | AULD | EC | 51.2 S/cm | off-stream channel | class 3.3 |
| latitude | -12.7429 | DO | 3.2 mg/L | max. depth | 2.9 m |
| longitude | 131.2221 | %DO | 40.3 % | channel width | 65 m |
| river | | TN | 0.43 mg/L | % open water | 40 |
| property | Donald's Lagoon | TP | 0.025 mg/L | % macrophyte | 60 |
| date | 7/08/2024 | Chlorophyll *a* | 5.31 µg/L | | |
| | | Turbidity | 7.3 NTU | | |
| | | pH | 6.7 | | |

| Fish species (n=22) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Megalops cyprinoides* | *Oxyeleotris nullipora* | *Toxotes lorentzi* |
| *Ambassis* sp. NW | *Melanotaenia splendida* | *Oxyeleotris selheimi* | *Mogurnda mogurnda* |
| *Craterocephalus stercusmuscarum* | *Nematalosa erebi* | *Planiliza ordensis* | *Strongylura krefftii* |
| *Denariusa bandata* | *Neosilurus ater* | *Porochilus rendahli* | *Amniataba percoides* |
| *Glossamia aprion* | *Neosilurus hyrtlii* | *Scleropages jardinii* | |
| *Leiopotherapon unicolor* | *Oxyeleotris lineolata* | *Toxotes chatareus* | |

| Decapod species (n=4) | Reptile species (n=1) |
|---|---|
| *Caridina nilotica* | *Emydura tanybaraga* |
| *Caridina wilkinsi* | |
| *Caridina wilsoni* | |
| *Macrobrachium bullatum* | |

Site DNLG – Donald's Lagoon

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | DNLG | EC | 56.4 µS/cm | off-stream channel | class 3.3 |
| latitude | -12.7342 | DO | 5.9 mg/L | max. depth | 1.9 m |
| longitude | 131.2401 | %DO | 72.9 % | channel width | 138 m |
| river | | TN | 0.76 mg/L | % open water | 30 |
| property | Donald's Lagoon | TP | 0.055 mg/L | % macrophyte | 70 |
| date | 8/8/2024 | Chlorophyll *a* | 11.26 µg/L | | |
| | | Turbidity | 13.6 NTU | | |
| | | pH | 6.86 | | |

| Fish species (n=18) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Lates calcarifer* | *Nematalosa erebi* | *Strongylura krefftii* |
| *Amniataba percoides* | *Leiopotherapon unicolor* | *Neoarius leptaspis* | *Toxotes chatareus* |
| *Craterocephalus stercusmuscarum* | *Megalops cyprinoides* | *Neosilurus hyrtlii* | *Toxotes lorentzi* |
| *Glossamia aprion* | *Melanotaenia splendida* | *Porochilus rendahli* | |
| *Oxyeleotris selheimi* | *Planiliza ordensis* | *Scleropages jardinii* | |

| Decapod species (n=3) | Reptile species (n=1) |
|---|---|
| *Caridina wilkinsi* | *Emydura tanybaraga* |
| *Macrobrachium bullatum* | |
| *Macrobrachium spinipes* | |

Site AR03 – Adelaide River site 3

| Site | | Water Quality | | Habitat | |
|---|---|---|---|---|---|
| code | AR03 | EC | 40.3 µS/cm | off-stream channel | class 3.2 |
| latitude | -12.8976 | DO | 4.7 mg/L | max. depth | 6 m |
| longitude | 131.2119 | DO | 57 % | channel width | 83 m |
| river | | TN | 0.35 mg/L | % open water | 80 |
| property | Koolpinyah | TP | 0.015 mg/L | % macrophyte | 20 |
| date | 9/8/2024 | Chlorophyll *a* | 4.43 µg/L | | |
| | | Turbidity | 1.8 NTU | | |
| | | pH | 6.64 | | |

| Fish species (n=16) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Glossamia aprion* | *Melanotaenia splendida* | *Oxyeleotris selheimi* |
| *Amniataba percoides* | *Lates calcarifer* | *Nematalosa erebi* | *Oxyeleotris nullipora* |
| *Craterocephalus stercusmuscarum* | *Megalops cyprinoides* | *Neosilurus ater* | *Scleropages jardinii* |
| *Denariusa bandata* | *Melanotaenia nigrans* | *Oxyeleotris lineolata* | *Strongylura krefftii* |

| Decapod species (n=4) | Reptile species (n=2) |
|---|---|
| *Caridina wilkinsi* | *Crocodylus porosus* |
| *Caridina wilsoni* | *Varanus mertensi* |
| *Cherax quadricarinatus* | |
| *Macrobrachium bullatum* | |

Site MKBB – Mt Keppler Billabong

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | MKBB | EC | 48.8 µS/cm | off-stream channel | class 3.1 |
| latitude | -13.1056 | DO | 4.4 mg/L | max. depth | 6 m |
| longitude | 131.2363 | %DO | 53.1 | channel width | 42 m |
| river | | TN | 1.06 mg/L | % open water | 100 |
| property | | TP | 0.035 mg/L | % macrophyte | 0 |
| date | 10/8/2024 | Chlorophyll *a* | 19.86 µg/L | | |
| | | Turbidity | 5.6 NTU | | |
| | | pH | 6.69 | | |

| Fish species (n=12) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Craterocephalus stercusmuscarum* | *Nematalosa erebi* | *Planiliza ordensis* |
| *Ambassis* sp. NW | *Glossamia aprion* | *Oxyeleotris lineolata* | *Scleropages jardinii* |
| *Amniataba percoides* | *Melanotaenia splendida* | *Oxyeleotris selheimi* | *Toxotes chatareus* |

| Decapod species (n=3) | Reptile species (n=1) |
|---|---|
| *Caridina magnovus* | *Elseya flaviventralis* |
| *Caridina wilkinsi* | |
| *Macrobrachium bullatum* | |

Site MKXG – Marrakai Crossing

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | MKXG | EC | 260.0 µS/cm | stream riffle | class 1 |
| latitude | -12.9273 | DO | 6.0 mg/L | max. depth | no data |
| longitude | 131.2659 | %DO | 69.4 mg/L | channel width | 18 m |
| river | Adelaide River | TN | 0.17 mg/L | % open water | 100 |
| property | | TP | 0.005 mg/L | % macrophyte | 0 |
| date | 12/8/2024 | Chlorophyll *a* | 3.09 µg/L | | |
| | | Turbidity | 3.1 NTU | | |
| | | pH | 7.32 | | |

| Fish species (n=17) | | | |
|---|---|---|---|
| *Amniataba percoides* | *Hephaestus fuliginosus* | *Mogurnda mogurnda* | *Planiliza ordensis* |
| *Craterocephalus stercusmuscarum* | *Hypseleotris compressa* | *Nematalosa erebi* | *Toxotes chatareus* |
| *Glossamia aprion* | *Leiopotherapon unicolor* | *Neosilurus ater* | |
| *Glossogobius aureus* | *Leptachirus darwinensis* | *Ophisternon gutturale* | |
| *Glossogobius munroi* | *Melanotaenia splendida* | *Oxyeleotris lineolata* | |

| Decapod species (n=4) | Reptile species (n=1) |
|---|---|
| *Caridina magnovus* | *Chelodina rugosa* |
| *Caridina nilotica* | |
| *Cherax quadricarinatus* | |
| *Macrobrachium spinipes* | |

Site ARBR – Adelaide River Bridge Riffle

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | ARBR | EC | 279.2 µS/cm | stream riffle | class 1 |
| latitude | -13.2401 | DO | 7.7 mg/L | max. depth | no data |
| longitude | 131.1079 | %DO | 92.4 % | channel width | no data |
| river | Adelaide | TN | 0.19 mg/L | % open water | no data |
| property | | TP | 0.02 mg/L | % macrophyte | no data |
| date | 12/8/2024 | Chlorophyll *a* | 1.3 µg/L | | |
| | | Turbidity | 2.1 NTU | | |
| | | pH | 7.84 | | |

| Fish species (n=12) | | | |
|---|---|---|---|
| *Amniataba percoides* | *Hephaestus fuliginosus* | *Melanotaenia splendida* | *Planiliza ordensis* |
| *Craterocephalus stercusmuscarum* | *Leiopotherapon unicolor* | *Mogurnda mogurnda* | *Strongylura krefftii* |
| *Glossogobius munroi* | *Megalops cyprinoides* | *Oxyeleotris lineolata* | *Syncomistes butleri* |

| Decapod species (n=4) | |
|---|---|
| *Caridina magnovus* | *Macrobrachium bullatum* |
| *Cherax quadricarinatus* | *Macrobrachium spinipes* |

Site STRD – Strickland Road

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | Strickland Road | EC | 271.5 µS/cm | pool in river channel | class 2.2 |
| latitude | -13.2055 | DO | 5.7 mg/L | max. depth | 3 m |
| longitude | 131.1539 | %DO | 68.4 % | channel width | 39 m |
| river | Adelaide | TN | 0.18 mg/L | % open water | 100 |
| property | | TP | 0.01 mg/L | % macrophyte | 0 |
| date | 13/8/2024 | Chlorophyll *a* | 3.15 µg/L | | |
| | | Turbidity | 9.6 NTU | | |
| | | pH | 7.42 | | |

| Fish species (n=19) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Glossogobius munroi* | *Nematalosa erebi* | *Planiliza ordensis* |
| *Amniataba percoides* | *Hephaestus fuliginosus* | *Neoarius graeffei* | *Strongylura krefftii* |
| *Anodontiglanis dahli* | *Lates calcarifer* | *Neoarius leptaspis* | *Toxotes chatareus* |
| *Craterocephalus stercusmuscarum* | *Megalops cyprinoides* | *Oxyeleotris lineolata* | *Toxotes lorentzi* |
| *Glossamia aprion* | *Melanotaenia spendida* | *Oxyeleotris selheimi* | |

| Decapod species (n=3) | Reptile species (n=2) |
|---|---|
| *Caridina magnovus* | *Crocodylus porosus* |
| *Caridina wilsoni* | *Emydura tanybaraga* |
| *Macrobrachium bullatum* | |

Site KSCK – Kaissis Creek

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | KSCK | EC | 330.1 µS/cm | tidal freshwater | class 6 |
| latitude | -12.792 | DO | 7.9 mg/L | max. depth | 3.6 m |
| longitude | 131.2315 | %DO | 96.7 % | channel width | 30 m |
| river | Kaissis Creek | TN | 0.24 mg/L | % open water | 100 |
| property | | TP | 0.035 mg/L | % macrophyte | 0 |
| date | 14/8/2024 | Chlorophyll *a* | 20.4 µg/L | | |
| | | Turbidity | 90.2 NTU | | |
| | | pH | 7.87 | | |

| Fish species (n=11) | | | |
|---|---|---|---|
| *Ambassis interrupta* | *Glossamia aprion* | *Leptachirus darwinensis* | *Thryssa malabarica* |
| *Butis butis* | *Kurtus gulliveri* | *Periophthalmus weberi* | *Toxotes chatareus* |
| *Carcharhinus leucas* | *Lates calcarifer* | *Planiliza ordensis* | |

| Decapod species (n=3) | Reptile species (n=3) |
|---|---|
| *Caridina nilotica* | *Acrochordus arafurae* |
| *Macrobrachium bullatum* | *Crocodylus porosus* |
| *Macrobrachium* sp. | *Emydura tanybaraga* |

Site BTCK – Beatrice Creek

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | BTCK | EC | 495.1 µS/cm | tidal freshwater | class 6 |
| latitude | -12.7554 | DO | 7.5 mg/L | max. depth | 2 m |
| longitude | 131.2845 | %DO | 92.2 % | channel width | 30 m |
| river | Beatrice Creek | TN | 0.46 mg/L | % open water | 100 |
| property | | TP | 0.1 mg/L | % macrophyte | 0 |
| date | 15/8/2024 | Chlorophyll *a* | 6.56 µg/L | | |
| | | Turbidity | 211.5 NTU | | |
| | | pH | 7.69 | | |

| Fish species (n=13) | | | |
|---|---|---|---|
| *Ambassis interrupta* | *Hemiarius dioctes* | *Neoarius leptaspis* | *Zenarchopterus caudovittatus* |
| *Caragobius urolepis* | *Kurtus gulliveri* | *Planiliza ordensis* | |
| *Carcharhinus leucas* | *Lates calcarifer* | *Thyssa brevicauda* | |
| *Glossogobius munroi* | *Leptachirus darwinensis* | *Toxotes chatareus* | |

| Reptile species (n=1) |
|---|
| *Crocodylus porosus* |

Site MRJN – Margaret River junction

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | MRJN | EC | 273.4 µS/cm | tidal freshwater | class 6 |
| latitude | -12.9172 | DO | 4.9 mg/L | max. depth | no data |
| longitude | 131.2594 | %DO | 59.1 % | channel width | 34 m |
| river | Adelaide | TN | 0.17 mg/L | % open water | no data |
| property | | TP | 0.01 mg/L | % macrophyte | no data |
| date | 16/8/2024 | Chlorophyll *a* | 4.44 µg/L | | |
| | | Turbidity | 5.6 NTU | | |
| | | pH | 7.6 | | |

| Fish species (n=13) | | | |
|---|---|---|---|
| *Glossamia aprion* | *Nematalosa erebi* | *Oxyeleotris lineolata* | *Toxotes chatareus* |
| *Lates calcarifer* | *Neoarius graeffei* | *Planiliza ordensis* | |
| *Megalops cyprinoides* | *Neoarius leptaspis* | *Strongylura krefftii* | |
| *Melanotaenia splendida* | *Neosilurus ater* | *Syncomistes butleri* | |

| Decapod species (n=3) | Reptile species (n=3) |
|---|---|
| *Caridina nilotica* | *Crocodylus johnstoni* |
| *Caridina wilsoni* | *Elseya flaviventralis* |
| *Macrobrachium spinipes* | *Emydura tanybaraga* |

Site DDRF – Dot and Dash Riffle

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | DDRF | EC | 248 µS/cm | stream riffle | class 1 |
| latitude | -13.0489 | DO | 5.4 mg/L | max. depth | no data |
| longitude | 131.2485 | %DO | 64.5 | channel width | 14 m |
| river | Adelaide | TN | 0.18 mg/L | % open water | 100 |
| property | | TP | 0.005 mg/L | % macrophyte | 0 |
| date | 17/8/2024 | Chlorophyll *a* | 2.49 µg/L | | |
| | | Turbidity | 2.8 NTU | | |
| | | pH | 7.49 | | |

| Fish species (n=16) | | | |
|---|---|---|---|
| *Amniataba percoides* | *Hephaestus fuliginosus* | *Mogurnda mogurnda* | *Oxyeleotris lineolata* |
| *Glossamia aprion* | *Leiopotherapon unicolor* | *Nematalosa erebi* | *Prionobutis microps* |
| *Glossogobius aureus* | *Megalops cyprinoides* | *Neosilurus hyrtlii* | *Syncomistes butleri* |
| *Glossogobius munroi* | *Melanotaenia splendida* | *Ophisternon gutturale* | *Toxotes chatareus* |

| Decapod species (n=6) | |
|---|---|
| *Caridina magnovus* | *Cherax quadricarinatus* |
| *Caridina nilotica* | *Macrobrachium bullatum* |
| *Caridina wilsoni* | *Macrobrachium spinipes* |

Site AGLN – Acacia Gap Lagoon

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | AGLN | EC | 148.6 µS/cm | riverine lagoon | class 4 |
| latitude | -12.8026 | DO | 5.3 mg/L | max. depth | 5.4 m |
| longitude | 131.2 | %DO | 65.9 % | channel width | 67 m |
| river | Manton | TN | 0.18 mg/L | % open water | no data |
| date | 19/8/2024 | TP | 0.01 mg/L | % macrophyte | no data |
| | | Chlorophyll *a* | 3.5 µg/L | | |
| | | Turbidity | 2.0 NTU | | |
| | | pH | 7.19 | | |

| Fish species (n=25) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Lates calcarifer* | *Neoarius leptaspis* | *Strongylura krefftii* |
| *Amniataba percoides* | *Megalops cyprinoides* | *Neosilurus ater* | *Syncomistes butleri* |
| *Craterocephalus stercusmuscarum* | *Melanotaenia nigrans* | *Oxyeleotris lineolata* | *Toxotes chatareus* |
| *Denariusa bandata* | *Melanotaenia splendida* | *Oxyeleotris nullipora* | *Toxotes lorentzi* |
| *Glossamia aprion* | *Mogurnda mogurnda* | *Oxyeleotris selhemi* | |
| *Hephaestus fuliginosus* | *Nematalosa erebi* | *Planiliza ordensis* | |
| *Hypseleotris compressa* | *Neoarius graeffei* | *Scleropages jardinii* | |

| Decapod species (n=5) | Reptile species (n=2) |
|---|---|
| *Caridina magnovus* | *Crocodylus porosus* |
| *Caridina nilotica* | *Elseya flaviventralis* |
| *Caridina wilsoni* | |
| *Macrobrachium bullatum* | |
| *Macrobrachium spinipes* | |

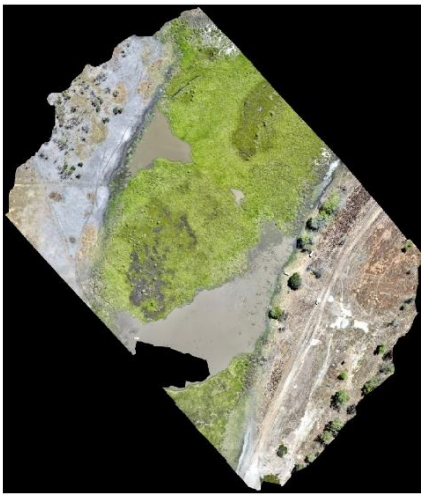
Site AR01 – Adelaide River site 1

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | AR01 | EC | 51 µS/cm | off-stream channel | class 3.2 |
| latitude | -12.8491 | DO | 6.1 mg/L | max. depth | 3.4 m |
| longitude | 131.2033 | %DO | 76.1 % | channel width | 64 m |
| river | | TN | 0.38 mg/L | % open water | 95 |
| property | | TP | 0.015 mg/L | % macrophyte | 10 |
| date | 20/8/2024 | Chlorophyll *a* | 4.57 µg/L | | |
| | | Turbidity | 1.4 NTU | | |
| | | pH | 7.27 | | |

| Fish species (n=21) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Leiopotherapon unicolor* | *Neosilurus ater* | *Strongylura krefftii* |
| *Amniataba percoides* | *Megalops cyprinoides* | *Oxyeleotris lineolata* | *Toxotes chatareus* |
| *Craterocephalus stercusmuscarum* | *Melanotaenia nigrans* | *Oxyeleotris selheimi* | *Toxotes lorentzi* |
| *Denariusa bandata* | *Melanotaenia splendida* | *Planiliza ordensis* | |
| *Glossamia aprion* | *Mogurnda mogurnda* | *Porochilus rendahli* | |
| *Lates calcarifer* | *Nematalosa erebi* | *Scleropages jardinii* | |

| Decapod species (n=4) | Reptile species (n=1) |
|---|---|
| *Caridina wilkinsi* | *Emydura tanybaraga* |
| *Macrobrachium bullatum* | |
| *Macrobrachium spinipes* | |
| *Cherax quadricarinatus* | |

Site BHRF – Beatrice Hill Research Farm



| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | BHRF | EC | 176.7 µS/cm | floodplain channel | class 5 |
| latitude | -12.638 | DO | 1 mg/L | max. depth | 1 m |
| longitude | 131.3102 | %DO | 13.2 % | channel width | no data |
| river | | TN | 1.04 mg/L | % open water | 85 |
| property | Beatrice Hill Research Farm | TP | 0.105 mg/L | % macrophyte | 15 |
| date | 21/8/2024 | Chlorophyll *a* | 24.93 µg/L | | |
| | | Turbidity | 241.3 NTU | | |
| | | pH | 5.87 | | |

| Fish species (n=13) | | | |
|---|---|---|---|
| *Ambassis* sp. NW | *Melanotaenia splendida* | *Ophisternon gutturale* | *Toxotes lorentzi* |
| *Glossamia aprion* | *Mogurnda mogurnda* | *Oxyeleotris selheimi* | |
| *Leiopotherapon unicolor* | *Neosilurus ater* | *Porochilus rendahli* | |
| *Megalops cyprinoides* | *Neosilurus hyrtlii* | *Scleropages jardinii* | |

| Reptile species (n=1) |
|---|
| *Crocodylus porosus* |

Site CMCK – Coomalie Creek

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | CMCK | EC | 424.7 µS/cm | pool in river channel | class 2.1 |
| latitude | -13.0133 | DO | 4.8 mg/L | max. depth | 5.3 m |
| longitude | 131.121 | %DO | 58.4 % | channel width | no data |
| river | Coomalie Creek | TN | 0.25 mg/L | % open water | 100 |
| property | | TP | 0.035 mg/L | % macrophyte | 0 |
| date | 22/8/2024 | Chlorophyll *a* | 11.9 µg/L | | |
| | | Turbidity | 6.1 NTU | | |
| | | pH | 7.52 | | |

| Fish species (n=12) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Lates calcarifer* | *Nematalosa erebi* | *Scleropages jardinii* |
| *Amniataba percoides* | *Megalops cyprinoides* | *Oxyeleotris lineolata* | *Strongylura krefftii* |
| *Glossamia aprion* | *Melanotaenia splendida* | *Planiliza ordensis* | *Toxotes chatareus* |

| Decapod species (n=4) | |
|---|---|
| *Caridina magnovus* | *Caridina wilsoni* |
| *Caridina wilkinsi* | *Macrobrachium bullatum* |

Site DRRD – Daly River Road Crossing

| Site | | Water quality | | Habitat | |
|---|---|---|---|---|---|
| code | DRRD | EC | 78.1 µS/cm | pool in river channel | class 2.1 |
| latitude | -13.4824 | DO | 5.4 mg/L | max. depth | 3.8 m |
| longitude | 131.0974 | %DO | 67.9 % | channel width | no data |
| river | Adelaide | TN | 0.03 mg/L | % open water | 90 |
| property | | TP | 0.005 mg/L | % macrophyte | 10 |
| date | 23/8/2024 | Chlorophyll *a* | 0.45 µg/L | | |
| | | Turbidity | 2.8 NTU | | |
| | | pH | 6.64 | | |

| Fish species (n=11) | | | |
|---|---|---|---|
| *Ambassis macleayi* | *Glossamia aprion* | *Melanotaenia splendida* | *Neoarius graeffei* |
| *Amniataba percoides* | *Hephaestus fuliginosus* | *Mogurnda mogurnda* | *Oxyeleotris lineolata* |
| *Craterocephalus stercusmuscarum* | *Lates calcarifer* | *Nematalosa erebi* | |

| Decapod species (n=4) | |
|---|---|
| *Caridina nilotica* | *Macrobrachium bullatum* |
| *Caridina wilkinsi* | *Macrobrachium spinipes* |

## 11.2. Appendix 2 - List of aquatic species

| Phylum | Class | Order | Family | Species |
|---|---|---|---|---|
| Arthropoda | Malacostraca | Decapoda | Atyidae | *Caridina magnovus* |
| Arthropoda | Malacostraca | Decapoda | Atyidae | *Caridina nilotica* |
| Arthropoda | Malacostraca | Decapoda | Atyidae | *Caridina wilkinsi* |
| Arthropoda | Malacostraca | Decapoda | Atyidae | *Caridina wilsoni* |
| Arthropoda | Malacostraca | Decapoda | Palaemonidae | *Macrobrachium bullatum* |
| Arthropoda | Malacostraca | Decapoda | Palaemonidae | *Macrobrachium* sp. |
| Arthropoda | Malacostraca | Decapoda | Palaemonidae | *Macrobrachium spinipes* |
| Arthropoda | Malacostraca | Decapoda | Parastacidae | *Cherax quadricarinatus* |
| Chordata | Actinopterygii | Perciformes | Ambassidae | *Ambassis interrupta* |
| Chordata | Actinopterygii | Perciformes | Ambassidae | *Ambassis macleayi* |
| Chordata | Actinopterygii | Perciformes | Ambassidae | *Ambassis* sp. NW |
| Chordata | Actinopterygii | Perciformes | Ambassidae | *Denariusa bandata* |
| Chordata | Actinopterygii | Perciformes | Apogonidae | *Glossamia aprion* |
| Chordata | Actinopterygii | Perciformes | Ariidae | *Hemiarius dioctes* |
| Chordata | Actinopterygii | Perciformes | Ariidae | *Neoarius graeffei* |
| Chordata | Actinopterygii | Perciformes | Ariidae | *Neoarius leptaspis* |
| Chordata | Actinopterygii | Perciformes | Atherinidae | *Craterocephalus stercusmuscarum* |
| Chordata | Actinopterygii | Perciformes | Belonidae | *Strongylura krefftii* |
| Chordata | Actinopterygii | Perciformes | Clupeidae | *Nematalosa erebi* |
| Chordata | Actinopterygii | Perciformes | Eleotridae | *Butis butis* |
| Chordata | Actinopterygii | Perciformes | Eleotridae | *Hypseleotris compressa* |
| Chordata | Actinopterygii | Perciformes | Eleotridae | *Mogurnda mogurnda* |
| Chordata | Actinopterygii | Perciformes | Eleotridae | *Oxyeleotris lineolata* |
| Chordata | Actinopterygii | Perciformes | Eleotridae | *Oxyeleotris nullipora* |
| Chordata | Actinopterygii | Perciformes | Eleotridae | *Oxyeleotris selheimi* |
| Chordata | Actinopterygii | Perciformes | Eleotridae | *Prionobutis microps* |
| Chordata | Actinopterygii | Perciformes | Engraulidae | *Thryssa brevicauda* |
| Chordata | Actinopterygii | Perciformes | Engraulidae | *Thryssa malabarica* |
| Chordata | Actinopterygii | Perciformes | Gobiidae | *Caragobius rubristriatus* |
| Chordata | Actinopterygii | Perciformes | Gobiidae | *Glossogobius aureus* |
| Chordata | Actinopterygii | Perciformes | Gobiidae | *Glossogobius munroi* |
| Chordata | Actinopterygii | Perciformes | Gobiidae | *Periophthalmus weberi* |
| Chordata | Actinopterygii | Perciformes | Kurtidae | *Kurtus gulliveri* |
| Chordata | Actinopterygii | Perciformes | Latidae | *Lates calcarifer* |
| Chordata | Actinopterygii | Perciformes | Megalopidae | *Megalops cyprinoides* |
| Chordata | Actinopterygii | Perciformes | Melanotaeniidae | *Melanotaenia nigrans* |
| Chordata | Actinopterygii | Perciformes | Melanotaeniidae | *Melanotaenia splendida* |
| Chordata | Actinopterygii | Perciformes | Mugilidae | *Planiliza ordensis* |
| Chordata | Actinopterygii | Perciformes | Osteoglossidae | *Scleropages jardinii* |

| Phylum | Class | Order | Family | Species |
|---|---|---|---|---|
| Chordata | Actinopterygii | Perciformes | Plotosidae | *Anodontiglanis dahli* |
| Chordata | Actinopterygii | Perciformes | Plotosidae | *Neosilurus ater* |
| Chordata | Actinopterygii | Perciformes | Plotosidae | *Neosilurus hyrtlii* |
| Chordata | Actinopterygii | Perciformes | Plotosidae | *Porochilus rendahli* |
| Chordata | Actinopterygii | Perciformes | Soleidae | *Leptachirus darwinensis* |
| Chordata | Actinopterygii | Perciformes | Synbranchidae | *Ophisternon gutturale* |
| Chordata | Actinopterygii | Perciformes | Terapontidae | *Amniataba percoides* |
| Chordata | Actinopterygii | Perciformes | Terapontidae | *Hephaestus fuliginosus* |
| Chordata | Actinopterygii | Perciformes | Terapontidae | *Leiopotherapon unicolor* |
| Chordata | Actinopterygii | Perciformes | Terapontidae | *Syncomistes butleri* |
| Chordata | Actinopterygii | Perciformes | Toxotidae | *Toxotes chatareus* |
| Chordata | Actinopterygii | Perciformes | Toxotidae | *Toxotes lorentzi* |
| Chordata | Actinopterygii | Perciformes | Zenarchopteridae | *Zenarchopterus caudovittatus* |
| Chordata | Chondrichthyes | Carcharhiniformes | Carcharhinidae | *Carcharhinus leucas* |
| Chordata | Reptilia | Crocodylia | Crocodylidae | *Crocodylus johnstoni* |
| Chordata | Reptilia | Crocodylia | Crocodylidae | *Crocodylus porosus* |
| Chordata | Reptilia | Squamata | Acrochordidae | *Acrochordus arafurae* |
| Chordata | Reptilia | Squamata | Varanidae | *Varanus mertensi* |
| Chordata | Reptilia | Testudines | Chelidae | *Chelodina rugosa* |
| Chordata | Reptilia | Testudines | Chelidae | *Elseya flaviventralis* |
| Chordata | Reptilia | Testudines | Chelidae | *Emydura tanybaraga* |

## 11.3. Appendix 3 – Occurrence of aquatic species by site

| Species | ARBR | DDRF | MKXG | CMCK | DRRD | STRD | ARDD | MKBB | DLDD | AR03 | AR01 | AULD | DNLG | AGLN | BHRF | MRJN | KSCK | BTCK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DECAPODA** | | | | | | | | | | | | | | | | | | |
| *Caridina magnovus* | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | | | | | | 1 | | | | |
| *Caridina nilotica* | | 1 | 1 | | 1 | | 1 | | | | | 1 | | 1 | | 1 | 1 | |
| *Caridina wilkinsi* | | | | 1 | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | | | | | |
| *Caridina wilsoni* | | 1 | | 1 | | 1 | 1 | | | 1 | | 1 | | 1 | | 1 | | |
| *Cherax quadricarinatus* | 1 | 1 | 1 | | | | | | | 1 | 1 | | | | | | | |
| *Macrobrachium bullatum* | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | |
| *Macrobrachium* sp. | | | | | | | | | | | | | | | | | 1 | |
| *Macrobrachium spinipes* | 1 | 1 | 1 | | 1 | | 1 | | 1 | | 1 | | 1 | 1 | | 1 | | |
| **FISH** | | | | | | | | | | | | | | | | | | |
| *Ambassis interrupta* | | | | | | | | | | | | | | | | | 1 | 1 |
| *Ambassis macleayi* | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | |
| *Ambassis* sp. NW | | | | | | | | 1 | 1 | | | 1 | | | 1 | | | |
| *Amniataba percoides* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | |
| *Anodontiglanis dahli* | | | | | | 1 | | | | | | | | | | | | |
| *Butis butis* | | | | | | | | | | | | | | | | | 1 | |
| *Caragobius rubristriatus* | | | | | | | | | | | | | | | | | | 1 |
| *Carcharhinus leucas* | | | | | | | | | | | | | | | | | 1 | 1 |
| *Craterocephalus stercusmuscarum* | 1 | | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | |
| *Denariusa bandata* | | | | | | | | | | 1 | 1 | 1 | | 1 | | | | |
| *Glossamia aprion* | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| *Glossogobius aureus* | | 1 | 1 | | | | | | | | | | | | | | | |
| *Glossogobius munroi* | 1 | 1 | 1 | | | 1 | | | | | | | | | | | | 1 |

| Species | ARBR | DDRF | MKXG | CMCK | DRRD | STRD | ARDD | MKBB | DLDD | AR03 | AR01 | AULD | DNLG | AGLN | BHRF | MRJN | KSCK | BTCK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Hemiarius dioctes* | | | | | | | | | | | | | | | | | | 1 |
| *Hephaestus fuliginosus* | 1 | 1 | 1 | | 1 | 1 | | | | | | | | 1 | | | | |
| *Hypseleotris compressa* | | | 1 | | | | | | | | | | | 1 | | | | |
| *Kurtus gulliveri* | | | | | | | | | | | | | | | | | 1 | 1 |
| *Lates calcarifer* | | | | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | | 1 | 1 | | 1 | 1 | 1 |
| *Leiopotherapon unicolor* | 1 | 1 | 1 | | | | | | | | 1 | 1 | 1 | | 1 | | | |
| *Leptachirus darwinensis* | | | 1 | | | | | | | | | | | | | | 1 | 1 |
| *Megalops cyprinoides* | 1 | 1 | | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| *Melanotaenia nigrans* | | | | | | | | | | 1 | 1 | | | 1 | | | | |
| *Melanotaenia splendida* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| *Mogurnda mogurnda* | 1 | 1 | 1 | | 1 | | | | | | 1 | 1 | | 1 | 1 | | | |
| *Nematalosa erebi* | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | |
| *Neoarius graeffei* | | | | | 1 | 1 | 1 | | | | | | | 1 | | 1 | | |
| *Neoarius leptaspis* | | | | | | 1 | | | 1 | | | | 1 | 1 | | 1 | | 1 |
| *Neosilurus ater* | | | 1 | | | | 1 | | | 1 | 1 | 1 | | 1 | 1 | 1 | | |
| *Neosilurus hyrtlii* | | 1 | | | | | | | | | | 1 | 1 | | 1 | | | |
| *Ophisternon gutturale* | | 1 | 1 | | | | | | | | | | | | 1 | | | |
| *Oxyeleotris lineolata* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | | |
| *Oxyeleotris nullipora* | | | | | | | | | | 1 | | 1 | | 1 | | | | |
| *Oxyeleotris selheimi* | | | | | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| *Periophthalmus weberi* | | | | | | | | | | | | | | | | | 1 | |
| *Planiliza ordensis* | 1 | | 1 | 1 | | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | | 1 | 1 | 1 |
| *Porochilus rendahli* | | | | | | | | | | | 1 | 1 | 1 | | 1 | | | |
| *Prionobutis microps* | | 1 | | | | | | | | | | | | | | | | |
| *Scleropages jardinii* | | | | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |

| Species | ARBR | DDRF | MKXG | CMCK | DRRD | STRD | ARDD | MKBB | DLDD | AR03 | AR01 | AULD | DNLG | AGLN | BHRF | MRJN | KSCK | BTCK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Strongylura krefftii* | 1 | | | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | |
| *Syncomistes butleri* | 1 | 1 | | | | | 1 | | 1 | | | | | 1 | | 1 | | |
| *Thryssa brevicauda* | | | | | | | | | | | | | | | | | | 1 |
| *Thryssa malabarica* | | | | | | | | | | | | | | | | | 1 | |
| *Toxotes chatareus* | | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | | 1 | 1 | 1 |
| *Toxotes lorentzi* | | | | | | 1 | | | | | 1 | 1 | 1 | 1 | 1 | | | |
| *Zenarchopterus caudovittatus* | | | | | | | | | | | | | | | | | | 1 |
| **REPTILES** | | | | | | | | | | | | | | | | | | |
| *Acrochordus arafurae* | | | | | | | | | | | | | | | | | 1 | |
| *Chelodina rugosa* | | | 1 | | | | | | | | | | | | | | | |
| *Crocodylus johnstoni* | | | | | | | | | | | | | | | | 1 | | |
| *Crocodylus porosus* | | | | | | 1 | | | 1 | 1 | | | | 1 | 1 | | 1 | 1 |
| *Elseya flaviventralis* | | | | | | | | 1 | 1 | | | | | 1 | | 1 | | |
| *Emydura tanybaraga* | | | | | | 1 | | | | | 1 | 1 | 1 | | | 1 | 1 | |
| *Varanus mertensi* | | | | | | | | | | 1 | | | | | | | | |