## One river - many Journeys: fish and drought refuges in the Finke


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**Keywords**: water, river, arid-zone, ecosystem, fish, refuge


### Abstract


The Finke is often touted as the oldest river on earth. The veracity of this is hard to quantify, as are statements about the Finke's significant biodiversity. Until recently, limited biological data was virtually all from the rocky headwaters and there had been no systematic population surveys of fish. This was a glaring knowledge gap, given that the fish species diversity is among the highest for strictly arid zone Australian rivers. This diversity has been attributed to the abundance of drought refuge waterholes, yet there was inadequate documentation of waterhole location and persistence. Now four years of effort has lifted the veil on the refuge ecology of the Finke fishes, using an innovative combination of methods. The cornerstone has been the Lake Eyre Basin Rivers Assessment (LEBRA) which applies consistent methods across the Basin in monitoring fish, hydrology and water chemistry. This is an unusual interstate collaboration of multiple jurisdictions. In the Finke catchment, the NT Government has supplemented LEBRA with several other projects involving many partners and diverse funding sources. This has substantially improved capacity to determine environmental requirements of future economic activities such as fossil fuel resource development. Previously undocumented drought refuges have been surveyed in areas of the catchment where science was previously blind. Local knowledge and Aboriginal participation have been key ingredients. Understanding of drought refuge function has blossomed, with groundwater and natural salinity now regarded as critical drivers. However, LEBRA monitoring has not yet achieved an adequate baseline for fish dynamics. We are yet to establish the drivers for changes in assemblage and abundance at some monitoring sites, and are yet to document repeating patterns in response to major wet/dry phases. Chaotic and hard to predict population dynamics may be a natural feature of the system but we will only find out through longer-term monitoring.



**Keywords:** water, river, arid-zone, ecosystem, fish, refuge


### Introduction

The past four years have seen significant advances in knowledge of waterholes and native fish in the Finke River of central Australia. Prior to this, ecological knowledge was poor for many fundamental aspects of this desert river system. The Finke River only runs intermittently and so fish populations predominantly reside in the waterholes that remain after flows cease. In 2010 plans were developed for monitoring the health of rivers in the Lake Eyre Basin, including the Finke, using fish populations, hydrology and water quality. In the Finke there had been no previous fish population survey or monitoring, and biodiversity and taxonomic sampling that had been done was mostly in a small part of the large catchment (Duguid et al 2005 and Duguid 2013). An even bigger limitation for monitoring was the very poor knowledge of the location and characteristics of drought refuges.

This paper presents an overview of the recent advances in knowledge of fish and drought refuges in the Finke catchment. Several distinct projects were undertaken involving a considerable variety of partnerships. The associated surveys involved 'many journeys' as referred to in the title of this paper, echoing the past importance of the Finke as a travel route for early European explorers and settlers. For millennia the Finke has been travelled by Aboriginal peoples and we acknowledge their traditional ownership and knowledge. Some of the projects contributing to this paper have been completed and the results reported, while others are ongoing with only preliminary publication of data. The aim here is to explore the importance of a very collaborative approach and present a selection of the key results, including: fish species distribution, population dynamics, the distribution of drought refuge waterholes and aspects of their ecological characteristics.

**Geographical and ecological context**

The Finke River rises in the MacDonnell Ranges of central Australia. Gaps and gorges occur where the river and its tributaries have eroded through the ranges over millennia, and most of the better studied waterholes are sheltered in such gaps. Sedimentary bedrock restricts the Finke's path through the MacDonnell Ranges and continues to restrict the river to a narrow alluvial valley well beyond the ranges (Read 2011). This is the basis for the Finke's reputation as the 'oldest river on earth'.

The Finke River and its tributaries (the Finke River system) have an extensive catchment. It is the most westerly river of the immense Lake Eyre Basin (LEB), which covers almost one sixth of mainland Australia. One of the defining characteristics of the LEB is that it is internally draining with no connection to the sea (athalassic and endorheic). The Finke differs from other major LEB rivers in the height of the mountainous headwaters, in its hydrology and in the biota. Natural salinity is such a prevailing feature of parts of the river that the Arrernte Aboriginal name for the Finke is lhere pirnte which can be translated as 'salty river' (Brim Box et al 2008). It is the longest and has the largest catchment of LEB rivers that are completely within the arid-zone (the other long rivers all rise in higher rainfall areas). The Finke River is also the largest isolated river system in central Australia. The hydrological isolation of the Finke is of particular ecological significance. It has not been documented as connecting to the Macumba River in the 150 years since non-Aboriginal settlement (Williams 1970, Bourke 1998, Duguid 2013). During past times of wetter climates, the Finke would have regularly connected to Lake Eyre and other LEB rivers via the Macumba, however, at present there is no defined channel between the two and connection would likely require mega-floods down the Finke and locally in the area between the modern Finke and the Macumba catchment (Duguid 2013). This hydrological isolation indicates that the fish fauna of the Finke is self-sustaining, relying on persistent waterholes during periodic severe droughts. In contrast, most other LEB rivers connect to each other and although connection is infrequent it allows the opportunity for fish species to colonise between normally separated river systems.

The extant fishes of the river are all native, which is an example of the relatively natural condition of the ecosystem in a national and global context. The fish fauna is also relatively diverse in the context of strictly arid zone rivers and the Finke is the most species diverse of rivers in the arid part of the Northern Territory. The list of fish species in the river was uncertain until relatively recently when taxonomic studies and rechecking of museum specimens resulted in the current list of nine species (see Wager and Unmack 2000 and Unmack 2001a). The distribution of those fishes within the river system was poorly known at the outset of the work described here. Duguid et al (2005) summarised knowledge at that time which included the results of their surveys in 2001 and review of earlier survey data and museum records. At that time the large sub-catchment of the Finke system that generates the Palmer River was virtually unsurveyed with few species recorded; one from an incidental specimen collection and others observed on the Horn Expedition (Spencer 1896). Likewise the Hugh catchment and the mid and lower sections of the Finke River were poorly known.

The Finke has distinct biodiversity including endemic and relictual species of both fauna and flora (e.g. Davis 1997, White et al 2000, Duguid et al 2005, Duguid 2013, Brim Box et al 2014). The fish diversity and lack of introduced fish species are important biodiversity values that should be conserved. Furthermore, three of the nine Finke species are endemic to the Finke, based on currently published taxonomy. Each has a closely related allopatric species in other parts of the LEB. It is likely that both isolation and the characteristics of the habitat contribute to evolutionary processes in the Finke. It is also likely that research using genetic techniques will greatly advance both taxonomic and ecological understanding of all the Finke fish species in the next few years (see Hammer et al 2013, and Huey et al 2014 with respect to *Ambassis* in the LEB).

The abundance and nature of drought refuge waterholes in the Finke River system are presumed to be key factors that sustain the relatively diverse fish fauna. It was already known that these waterholes vary in characteristics such as depth and salinity.  Duguid (2005) listed the known large permanent waterholes of which only eight had been identified and noted that various smaller permanent waterholes occur in the greater MacDonnell Ranges. Unmack (2001b) used the limited data for the Finke to analyse mechanisms for the persistence of fish in arid systems, providing valuable insights to the probable processes and highlighting the need for better information in the Finke system.  The previously inadequate data on drought refuge locations and characteristics not only constrained the selection of monitoring sites but also limited interpretation of monitoring data. Recorded knowledge of the existence and characteristics of drought refuge waterholes in the Palmer and Hugh catchments was minimal and was little better for many parts of the main Finke River. This situation highlights the disconnection between 'local knowledge' and knowledge recorded in written publications and scientific data sets. 'Local knowledge' is used here to include traditional Aboriginal knowledge and that of other local residents and landholders. Common sense indicated that local knowledge would be important in filling some gaps in 'scientific' knowledge (e.g. see Duguid et al 2005 with respect to central Australian wetlands).

**Methods**

The Lake Eyre Basin Rivers Assessment (LEBRA) aims to assess the environmental condition of rivers in the Basin. In 2011, LEBRA monitoring sites were established across the Basin, with annual or biannual visits to record information on fish, water quality and hydrology. These attributes were selected as the most effective use of available funds and the method is specified in McNeil and Cockayne (2011) and Cockayne et al (2012a). Five sites were chosen in the Finke as long-term LEBRA monitoring sites and a further eight waterholes have been sampled with the full LEBRA methods, six of these with some repeat monitoring. The LEBRA monitoring is a partnership of the state, territory and federal governments in accordance with the LEB Intergovernmental Agreement. In the Finke it has also involved a successful partnership with the Tjuwanpa Rangers, an Aboriginal ranger group run by the Central Land Council.

The LEBRA monitoring program has been the cornerstone around which several related projects have been built. These have included mapping and rapid survey of waterholes in the mid-section of the Finke, application of guidelines for delineating and describing High Ecological Value Aquatic Ecosystems (HEVAE), waterhole surveys in the Palmer sub-catchment of the Finke, the Bush Blitz survey at Henbury Station, waterhole mapping and survey in the lower Finke and field work to provide Finke data in wider-scale projects . The work has been led by the Northern Territory Government Department of Land Resource Management. Some of the important partners have been the Central Land Council, Aboriginal traditional owners, landholders on cattle stations, the South Australian Research Development Institute, Territory Natural Resource Management, the Parks and Wildlife Commission of the Northern Territory, and the Australian Government.

Local knowledge was incorporated into the selection of survey sites, and landholders participated in field work in many cases. Additional community participation in survey work has included residents and visitors at national parks and the Alice Springs Field Naturalists Club. In addition to existing hydrographic gauging stations, a depth and water chemistry logging device was deployed at one site. Landholder knowledge was obtained to supplement sparse gauging data on river flow patterns and on the persistence of some waterholes.

In addition to on-ground survey work, aerial reconnaissance included the use of fixed wing aircraft and helicopters. Data were recorded using video and still cameras as well position devices and surveying equipment. GIS tools and Google Earth were used in mapping location and size of waterholes. The depths of waterholes were measured using manual tapes and rulers and also electronic bathymetric mapping equipment. Helicopters were also used to access some remote sites for on-ground survey. Fish survey included overnight sampling with the LEBRA method and also rapid survey using seine nets and dip nets, supplemented with visual survey, both by day and at night with torches and spot lights.

**Selected results**

An overview of results is presented here. Other results can be found in project reports (Cockayne et al 2012a & 2012b, Duguid 2013, Duguid et al 2013a & 2013b, Sternberg et al 2014, Mathwin 2015 in prep.). Some specific results are presented as examples.

Some of the important outcomes achieved from the suite of related projects are:

- commencement of long-term monitoring with substantial progress towards a data baseline for fish, water quality, water levels and hydrological connection (flows);
- collection of monitoring data from a substantial range of rainfall/hydrological conditions (including the tail-end of a very wet ecological ‘boom’ time and a moderate drought in which the river did not flow at some monitored sites for two years);
- mapping of previously unmapped waterholes that function as drought refuges for fish;
- correction to the incorrect locations for some waterholes marked on topographic maps;
- identification of several previously undocumented permanent and near-permanent waterholes;
- a list of fish species in the Palmer River and Hugh River catchments;
- evidence of the importance of the mid-Finke and the Palmer catchment as locations of permanent drought refuges;
- evidence of the importance of many non-permanent but long-lasting mid-Finke waterholes as fish refuges;
- evidence that the mid-Finke is particularly important in sustaining two of the endemic fishes (goby and hardyhead);
- evidence that there are no permanent waterholes in the lower Finke;
- evidence of assemblage differences between the larger permanent riverine waterholes, especially during droughts;
- evidence of a distinct fish assemblage for upland springs with permanently running water;
- identification of key low salinity drought refuges for the endemic *Mogurnda*;
- improved understanding of patterns of flow and no flow, particularly in the mid-Finke;
- data correlating fish species assemblage with salinity;
- data demonstrating temporal and spatial patterns in water salinity enabling classification of waterholes into types based on salinity dynamics and mapping of better quality waterholes for cattle use;
- data indicating the importance of groundwater in sustaining waterholes and the influence of groundwater on waterhole salinity;
- data on the variation in physical and biotic habitat for fish (e.g. depth, length and width of waterholes, salinity, aquatic macrophytes).

Some associated outcomes include:

- development of terminology for waterhole persistence and flow dynamics in arid Australia (Duguid 2013);
- a summary and overview of pre-existing biophysical information for the Finke River system (Duguid 2013).

Below we expand briefly on some of the points above. The rapid survey sites along the mid-Finke have revealed that saline groundwater influence occurs in particular zones along the river. Previously some groundwater experts regarded part of the headwaters as the main location of saline groundwater discharge (Read 2011). Numerous shallow pools persisted for more than a year after a flow event in the mid-Finke and some were documented as lasting two years without a flow (March 2012 to April 2014). There is preliminary evidence suggesting that in places fresh (relatively low EC) groundwater moves from bedrock aquifers into the river alluvium, influencing salinity dynamics and fish assemblage in some waterholes that remain relatively fresh between flows. Two waterholes increase in salinity rapidly after the end of a flow event; faster than the effect of evaporative concentration. The LEBRA data indicate some significant differences in the temporal patterns of fish assemblage at the long-term monitoring sites. A notable aspect of this is that after two years without a substantial flow event, the abundance of some species diminished at some waterholes to the point where they were not detected and may have been absent. Other species increased in relative abundance with time since flow, and these patterns were different for different waterholes.

Improved knowledge of the distribution of the nine fish species in the Finke River system is one of the important results, as summarised in Table 1.

Table 1. Fish species of the Finke River and their distribution

| Scientific Name | Common Names | Known Distribution | | | | | |
|---|---|---|---|---|---|---|---|
| | | Endemism | Upper Finke | mid-Finke | Hugh | Palmer | Lower Finke /Floodout |
| *Ambassis mulleri* [1] | Glassfish | | Y | Y | | Y[3] | Y[5] |
| *Amniataba percoides* | Banded Grunter, Barred Grunter | | Y | Y | Y | [?Y[4]] | Y[5] |
| *Chlamydogobius japalpa* | Finke Goby | Finke Endemic | Y | Y | | | Y[5] |
| *Craterocephalus centralis* | Finke Hardyhead | Finke Endemic | Y | Y | Y[2] | Y[3] | Y[5] |
| *Leiopotherapon unicolor* | Spangled Grunter, Spangled Perch | | Y | Y | Y | Y[3] | Y |
| *Melanotaenia splendida* subsp. *tatei* | Desert Rainbowfish | | Y | Y | Y | Y[3] | Y |
| *Mogurnda larapintae* | Finke Mogurnda, Finke Gudgeon | Finke Endemic | Y | Y | | Y[3] | Y[5] |
| *Nematalosa erebi* | Bony Bream | | Y | Y | Y | Y[3] | Y[5] |
| *Neosilurus hyrtlii* | Hytrl's Catfish | | Y | Y | Y | Y[3] | |

Superscript notes for Table 1:

1. The *Ambassis* genus in inland Australia may include undescribed species according to Allen et al. (2002). Accordingly Duguid et al. (2005) referred to all the NT LEB records as '*Ambassis* sp. Central Australia', however, for the LEBRA all *Ambassis* are currently recorded as *A. mulleri*, following Wager and Unmack (2000).
2. LEBRA survey data (Cockayne et al 2012b).
3. Palmer catchment survey (Duguid et al 2013b).
4. Banded Grunter were recorded in the Palmer sub-catchment on the Horn Expedition (Spencer 1896 p.68) but there is no modern record despite surveys in 2012 and 2014.
5. Survey data from three sites in the lower Finke in April 2013.

Survey and mapping data indicate that the only permanent pools in the Hugh catchment are among the MacDonnell Ranges. Some are associated with two permanent springs. There is good evidence that none of the lowland waterholes in the Hugh are permanent and that not all the species recorded in the Hugh persist in the mountain pools. Consequently some of the fishes recorded in the Hugh catchment may periodically recolonise during connections of the Hugh to the Finke.

**Discussion**

Having started from a situation of no previous population data, four years of monitoring have resulted in substantial new understanding. The differences in fish assemblage between waterholes have proved to be bigger than some participants expected. Likewise some of the temporal changes recorded at individual waterholes were not anticipated. Although at some sites the changes in relative abundance of different species correlate strongly with increasing salinity, this is not true at all sites. An appropriate question after four years of monitoring is "*have we achieved an adequate baseline spanning the range of natural variation?*". The answer must be *"probably not!"* . Major wet periods and associated large flow events occur at intervals of 10 to 20 years (based on long-term rainfall records and moderately long-term river stage height data). On that time scale our monitoring spans a relatively short period and does not yet include one of the very large flow events (e.g. 1974, 2000, 2010).

Another unexpected result was the number of waterholes persisting in the mid-Finke for more than one year without flow and in some cases at least two years (between March 2012 and April 2014). This was contrary to some of the information provided by a landholder on the longevity of the minor waterholes. However, that may be an example of the difficulty in establishing a common language for the surprisingly complex task of describing and determining waterhole persistence. Shallow saline pools may not rate the term 'waterhole' for a cattle manager. Another likely factor is the longevity of the very wet conditions in 2010 to mid-2011. These resulted in continuous flows down the mid-Finke, akin to base-flow, lasting for more around 18 months in places. These flows and the rains that initiated them are believed to have raised the water table in the alluvial aquifer of the mid-Finke (Duguid 2013). The mid-Finke waterholes are now regarded as 'windows on the water table' so the water table may have remained raised for several years (e.g. from mid-2011 when the 'base-flow' event ceased). Accordingly minor waterholes may have persisted for longer without a flow (from March 2012 to April 2014) than was typical in the experience of the landholder (who has now left).

Water scientists have long had general awareness that the salinity of Finke waterholes is influenced by groundwater discharge and varies substantially within and between waterholes (G. Ride pers. comm., Jolly 2005, Duguid et al 2005) but with scarce quantitative data and from few sites. The conductivity data collected at numerous sites since 2010 provide much firmer evidence of the importance of groundwater in the ecology of the river. The data allow the longer-lasting pools to be characterised according to their salinity including how that changes through time. However caution is required in the interpretation of the influence of groundwater because the groundwater aquifers are yet to be quantitatively studied.

Some of the Finke fish species were known to have substantial tolerance of salinity, mainly from work in other catchments and closely related species (see Duguid et al 2005), but there was no data to quantify the influence of salinity on fish distribution and abundance in the Finke. Data from our surveys confirm that the goby and hardyhead are the only species present in the higher salinity pools and provide a basis for modelling the relationship between salinity and the relative abundance of the different species. At the other end of the spectrum, the gudgeon is confirmed as the least tolerant of salinity. Several lower salinity waterholes and springs are now regarded as critical refuges for this species.

The mapping component of the work has been an important aspect of the overall ecological results. A moderately rigorous approach was taken to the mapping work including documenting various data sources. This resulted in a substantial overhead of spatial data management and the magnitude of that task was not anticipated.

Although the Finke catchment is a relatively natural landscape on a global scale it is not unaffected by modern human usage and new developments, such as petroleum resource development, could lead to new pressures. Until recently, biological survey had focussed on the upper catchment of the main Finke River implying that the rest of the large catchment has less important for species conservation. The inconsistency in the spatial distribution of biodiversity survey creates challenges for quantifying the significance of biodiversity in specific ecosystems and the Finke is an example of this (see Hale 2010). The survey and mapping work reported here have generated datasets that will enable more quantitative conservation assessment and planning.

**Conclusions**

Fish have been chosen as key indicators of ecosystem health in rivers of the Lake Eyre Basin. The drought refuge waterholes are key sites. The natural variation in flows, water quality and fish dynamics need to be understood if monitoring is to be a successful tool for assessing ecosystem health. This is basic information that is required if the potential impacts of anthropogenic pressures are to be predicted and managed. Adequate knowledge of the location and ecology of refuge waterholes is equally fundamental to monitoring, to condition assessment and to risk management. In the Finke River system, the LEBRA monitoring program became the cornerstone for various other projects. Collectively they have substantially improved knowledge of: where the long-term waterholes are, ecological function of specific waterholes, the distribution of fish species and the natural variations in abundance of the nine fish species. Long-term monitoring must be cost effective so there is a clear incentive to get the maximum information from the minimum of sites. The use of a variety of methods at a large number of waterholes has establishing the context for interpreting monitoring data from the 5 long-term sites. Involving Aboriginal people and other locals added considerably to both formal and informal outcomes. Their involvement and that of various project partners is not cost free to either themselves or to the agency leading the work. Therefore it is important to not only recognise benefits but set aside the necessary resources for facilitating community involvement.

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