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Indigenous fish traps and fish weirs on the Darling (Baaka) River, south-eastern Australia, and their influence on the ecology and morphology of the river and floodplains

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ABSTRACT

*Fish traps and fish weirs built by Indigenous people in the Barwon-Darling River system of the Murray Darling Basin (MDB), south-eastern Australia, are an important component of their traditional social, spiritual and economic systems. The celebrated Brewarrina stone fish traps (*Ngunnhu*) on the Barwon River are the largest and best documented stone fish traps in the Basin. However, there has been minimal research on the many other stone fish traps in this system. This paper focusses on the in-stream stone fish traps downstream of Brewarrina along the Darling (Baaka) River, some still partly extant, remembered, or documented in historical material. Wooden and earthen bank fish traps and weirs, while not as enduring and archaeologically visible as stone fish traps, were frequently used on the Darling (Baaka) floodplain lakes, swamps and billabongs. Archaeological evidence, traditional cultural knowledge and historical materials are utilised to document the complex social processes and modification of landscapes associated with fish traps and weirs. By demonstrating that Barkandji were active and successful managers of the river and its ecology prior to colonisation, and that much of this cultural knowledge is retained by current generations, the authors make a case for them to renew their custodianship and a decision-making role in water management.*

Keywords: barkandji, darling baaka river, indigenous fish traps, fish weirs, water and ecological management , Darling Baaka River, Barkandji, pièges à poissons indigènes, fascines à poissons, gestion de l'eau et de l'écologie

RÉSUMÉ

*Des pièges à poissons et des petits barrages à poissons furent construits, par les peuples aborigènes, dans la rivière Barwon-Darling, qui fait partie du bassin Murray Darling, au sud-est de l'Australie. Ils constituaient une composante importante de leurs systèmes sociaux, spirituels et économiques traditionnels. Les célèbres pièges à poissons, construits en pierre, Brewarrina (*Ngunnhu*) sur la rivière Barwon sont les pièges à poissons en pierre les plus grands et les mieux documentés du bassin. Cependant, il y a eu peu de recherches sur de nombreux autres pièges à poissons en pierre dans ce système. Cet article se concentre sur les pièges à poissons en pierre, en aval de Brewarrina, le long de la rivière Darling (Baaka), dont certains existent encore, au moins en partie, dont on se souvient, ou qui sont documentés dans des documents historiques. Les pièges à poissons et les petits barrages en bois et en terre, bien qu'ils ne soient pas aussi durables, et archéologiquement visibles, que les pièges à poissons en pierre, étaient fréquemment utilisés sur les lacs, les marécages et les billabongs de la plaine inondable de la Darling (Baaka). Des preuves archéologiques, des connaissances culturelles traditionnelles et des matériaux historiques sont utilisés pour documenter les processus sociaux complexes et la modification des paysages associés aux pièges à poissons et aux barrages. En démontrant que les Barkandji étaient des gestionnaires actifs et efficaces du fleuve et de son écologie avant la colonisation, et qu'une grande partie de ces connaissances culturelles ont été conservées par les générations actuelles, les auteurs plaident pour que les Barkandji reprennent leur un rôle décisionnel dans la gestion de l'eau.*

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INTRODUCTION

This paper presents new research into Indigenous stone fish traps and wooden and earthen fish traps and fish weirs of the Darling (Baaka) River, south-eastern Australia. The Barwon-Darling River and its tributaries form the longest river system of the Murray Darling Basin (MDB), Australia's largest riverine basin (Figure 1). Despite the size and importance of the MDB waterways and flood plains and their social, economic, and spiritual importance to Indigenous people, there has been minimal archaeological survey of fish traps and fish weirs in the MDB. Previous research has focussed on historical material predominantly from the Murray River and its tributaries (Humphries, 2007; Kelly, 2014). The Brewarrina Fish Traps (*Ngunnhu*), located on the Barwon-Darling system upstream from the study area, are the exception as they have been extensively described in historical materials from the 1860s, mapped (Figure 2), surveyed, researched, and listed on the National and State Heritage Registers (discussed in more detail in later sections).This paper is the first step in addressing the gap in information on the technical, ecological and social aspects of fish traps and fish weirs on the Darling (Baaka) River.

The Darling (Baaka) River is known as the Baaka to the Barkandji Indigenous people, Barkandji (various spellings) translating as people belonging to the Baaka (various spellings) (Hercus, 2011). References to the use of the word Baaka by Barkandji to describe the river include early written documentation (e.g., Pechey, 1872) to current use. It is, therefore, referred to as Baaka in the rest of the paper as it focusses on Barkandji cultural knowledge and historical documentation referring to Barkandji people. This does not preclude other groups having cultural association with the river and using different language to describe it. Barkandji living along the river from Bourke to Wentworth are people born in their country, still practising their traditional fishing culture and retaining detailed knowledge about the rivers and floodplains.

This paper also aims to draw attention to aspects of Barkandji traditional water management knowledge through analysis of information on fish traps and weirs, and discussion of their influence on the ecology and morphology of the river and floodplains. This will (again) inform water governance bodies that Indigenous science is both legitimate and important (Grafton et al., 2020:20). Pardoe and Hutton (2020) have provided an example on the

FIGURE 1. Map of the Darling River (Baaka) and Murray Darling Basin (MDB) adapted from the MDB website maps. MDB outlined in dashed line.

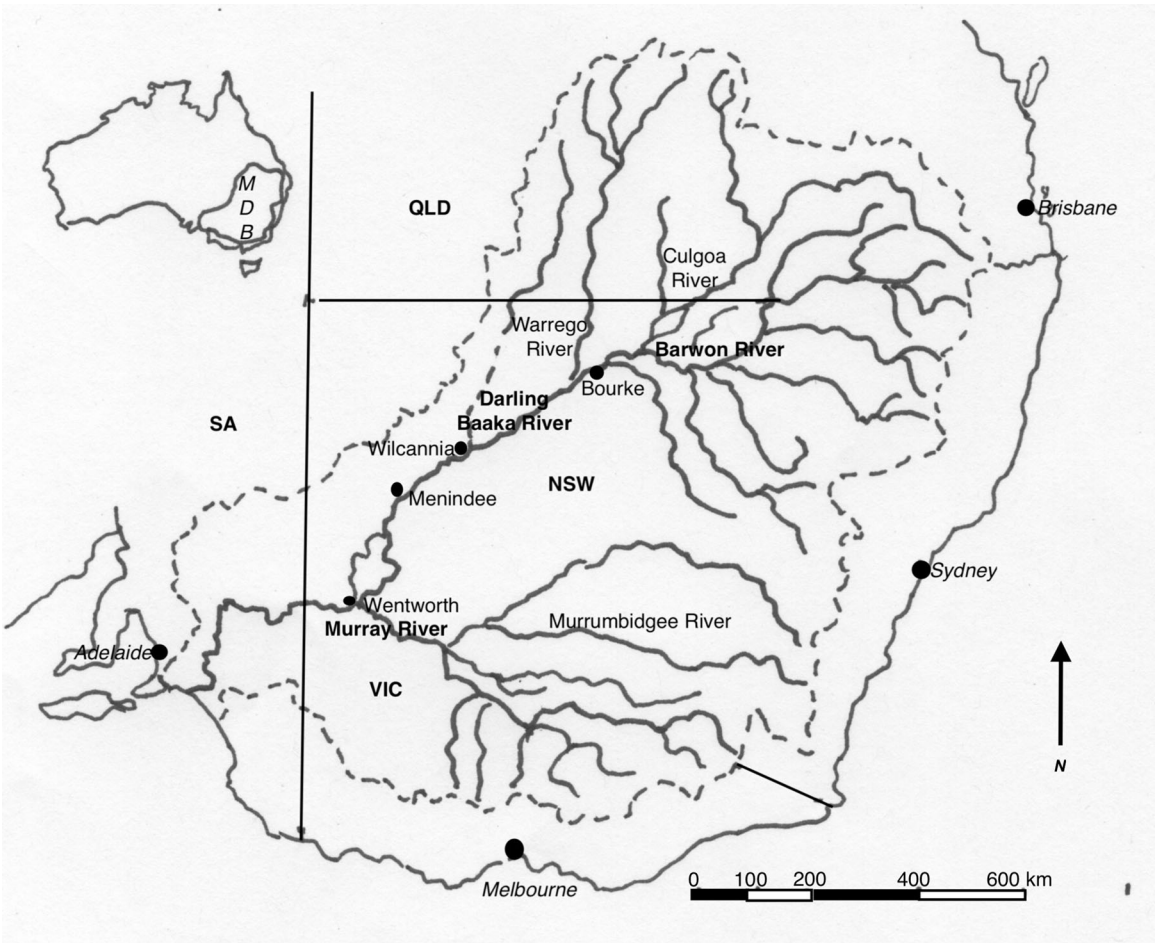
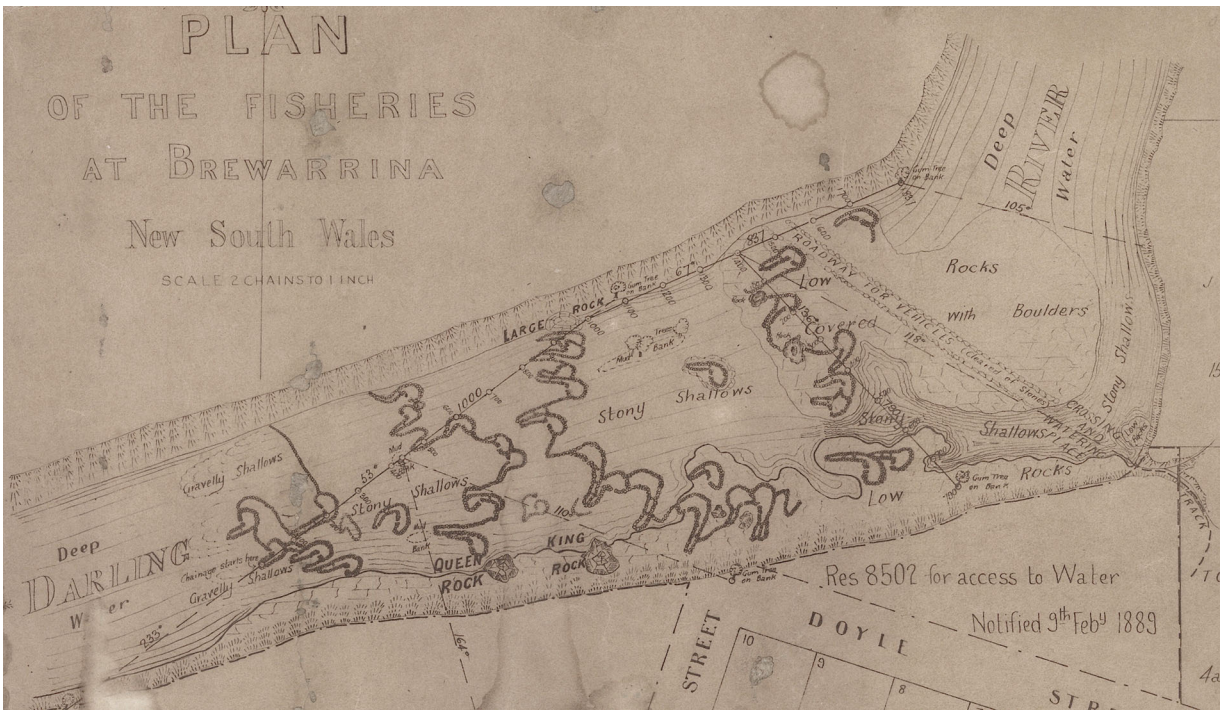


FIGURE 2. Plan of Brewarrina fish traps drawn in 1906 by A. W. Mullen, surveyor to the Western Lands Board (in North, 1916 Plate XXVII). Water flows from right to left.



Murray River of how an understanding of cultural landscapes, in this case a series of Indigenous mound sites and associated constructed wetland ponds, when compared with fauna survey data, can provide an important environmental proxy for understanding the pre-colonial settlement hydrology and ecology. Until detailed research on traditional Barkandji water management is conducted, scientists and government water managers have no certainty about how many and what aquatic species existed prior to colonial settlement or what effect the *absence* of traditional Indigenous impacts and management practices had on depleting the aquatic resources (Humphries, 2007:110).

Barkandji are denied a meaningful role in water management and confront ongoing struggles to have their common law rights recognised and accommodated within Australian water governance regimes (Hartwig et al., 2018:1). The Murray Darling Basin Royal Commission (MDBRC) found the current governance framework under the Federal *Water Act 2007* fails to provide Indigenous people with a central decision-making role regarding water management. It also identified that Indigenous peoples of the MDB have suffered damage and loss to their culture and way of life due to the over-exploitation of water resources by governments and other sectors of Australian society (MDBRC 2019: 68, 473, 474 in Grafton et al., 2020:13). Barkandji see water managers "overruling, dismissing or ignoring their jurisdiction as governments endorse and govern in favour of powerful cotton and mining industries" (Hartwig et al., 2021:15). This paper demonstrates the capacity Barkandji cultural knowledge has to inform more sustainable management of the Baaka, its floodplains, and aquifers.

Context of fish trap research in Australia

Research into fish traps and fish weirs in Australia has concentrated on both the technical dimensions (size, shape, materials, dating, methods of use etc.) and social aspects (such as gender, social complexity and social organisation). Other aspects of fish trap research include ownership, resource enhancement, interregional gatherings, the effect on the archaeological record of construction, maintenance, disuse and dismantling of structures, see reviews by Rowland and Ulm (2011) and McNiven and Lambrides (2021). A major significance of fish trap research lies in its potential to explore the ecological and sociocultural changes associated with persistent structures such as stone fish traps (McNiven & Lambrides, 2021:1).

The fish trap complexes of south western Victoria were instrumental in the "great intensification debate" where they are seen as indicating a mid to late Holocene intensification of use of certain resources, in this case eels in their freshwater cycle that were exploited using complex stone traps, artificial channels and holding ponds (Lourandos, 1980, 1997; Lourandos & Ross, 1994, 2021). In this debate reasons why hunter-gatherers in Australia may choose to intensify exploitation of certain food resources (Balme, 1995; Lourandos, 1997) include: to maintain or increase population, to utilise smaller territories, to reduce mobility, to maximise efficiency of food procurement, to create larger

group sizes, to support large "redistribution" networks and risk minimisation.

In a slightly different interpretation of "intensification"; David and Lourandos (1998:210-212) list various changes in socio-cultural patterns that they argue occurred on Cape York in the Late Holocene including a "unified system of territoriality, land use and information exchange". Reasons for intensification include new territorial systems which may be exemplified by smaller territories, well managed crops, enlarged diet breadth, or incorporating new staple foods collected in large quantities over extended periods of time. Intensification may include risk minimisation and restricting the ranges of resource extraction and settlement to short-spaced and/or more commonly reused areas. Thus residential bases become more marked and overall mobility reduced. In this sense stone fish trap complexes, but also potentially larger wooden fish traps and weirs demonstrate that archaeologically "persistent places became prominent places" (Schroeder, 2004:822-3). However other archaeological research indicates that not all fish traps fit the intensification model. A large survey of fish traps in Queensland suggests some and particularly small fish traps were backup devices because, although they increase the chance of catching food, they do not guarantee it (Rowland & Ulm, 2011:41).

Detailed research on the fish trap complexes of south western Victoria such as Budj Bim (Lake Condah) and Toolondo Swamp have added to their archaeological significance on an international level. These traps have been shown to have enhanced fish stocks through fish farming (Lourandos, 1980, 1983) or fish aquaculture (Builth, 2014), through the construction of stone walled eel traps in conjunction with artificial channels that fed water and eels into artificial and/or natural containment ponds. This had the effect of regularizing the availability of eel stocks, which enabled flow on effects such as reduction in mobility (Lourandos, 1980).

More recent work on the World Heritage listed Budj Bim (Lake Condah) Eel Traps complex supports and adds on to the work of Lourandos and Builth. Muldoons Trap Complex at Budj Bim is one of the only examples of fish traps in Australia that have been accurately dated. Charcoal recovered from channel infill sediments indicated initial construction began at least 6600 cal. BP, making the site one of the world's oldest known fish traps. In addition, channel excavations revealed the addition of basalt block walls dating to ca 600−800 cal. BP and subsequent excavations demonstrate that a barrier/dam feature associated with artificial ponding of flood waters and containment of eels was added to the site complex ca 300−500 cal. BP and possibly elaborated in the nineteenth century. These significant results show that Muldoons Trap Complex underwent phased redevelopment and major elaboration over the past 800 years (McNiven et al., 2015:44) and this can be related to regional increases in site establishment and occupation intensity within the last 1000 years (McNiven & Lambrides, 2021).

Research on fish traps has also looked at the relationship between fish traps, notably stone fish traps, and the Indigenous spirit-world. In northern Australia research has shown that an "archaeology of seascapes" needs to "extend beyond subsistence and technology and investigate spiritscapes and associated ritual sites used to manage and control the sea spiritually" (McNiven, 2004:330). Some examples on the South Australian coastline include the ritual singing of dolphins or sharks to herd fish into man-made or natural enclosures on Eyre Peninsula (Martin, 1988:36, 89) and Yorke Peninsula (Roberts et al., 2016:5). In the MDB an ancestral story describes the origin of a stone feature in Murrumbidgee just below Balranald, which has also been recorded through oral history as a semi-circular fish trap formed across the river (Heritage New South Wales [NSW] Aboriginal Heritage Information Management System [AHIMS] site card 47-6-1). An ancestral story describes the creation of the Brewarrina fish traps and determines the rules governing use, maintenance and resource sharing (Rando, 2007:20).

The Baaka study area

The focus of this paper is the section of the Baaka below Bourke, starting at Toorale National Park and finishing at the junction with the Murray River at Wentworth. The Baaka channel is deeply incised and carves a winding course across a relatively flat floodplain as it flows slowly through a semi-arid region that is often dry, hot and receives little rainfall, depending largely on the upper tributaries for water flows. Most Barwon-Darling tributaries that contribute water to the Baaka rise in the Great Dividing Range to the east, capturing sub-tropical summer rain from Queensland in the north, and both winter and summer rains from northern central New South Wales. Exceptions are the extremely variable Culgoa, Warrego and Paroo Rivers which rise in the semi-arid section of Queensland, intermittently capturing sub-tropical rain and delivering it to the Baaka (Thoms et al., 2004).

The Baaka provides ample opportunity for stone fish traps, given the numerous rock outcrops along its channel as noted in the 1891 and 1899 Water Commission survey reports (NSW Parliament 1891 and 1899) on locking the river, also river pilot charts (Echuca Historical Society 1880–1889a; 1880–1889b; Echuca Historical Society 1880–1918; Strom and Lindsay ca. 1870–1880), and geological maps (Resources and Geoscience NSW n.d.). An unexpected description is found in the travelogue of Dr and Mrs Clarke's 1895 canoe trip down the entire river system to the Murray mouth. They describe the numerous "rapids" they encountered, some so dangerous they had to take their canoe out of the river and walk it down to relaunch below (Clark & Clark, 1895). This description seems at odds with the modern river morphology, which may be explained by recent research indicating that the entire Barwon-Darling system has suffered extensive sediment accumulation from recent agriculture related landscape erosion and loss of flows (Pearson et al., 2020:1).

The Baaka has a tendency to evolve new channels in areas of wide floodplains, while in other areas the channel is confined and has remained largely unchanged in location. The radical shift in the middle to lower Baaka from the old Talyawalka/Great Darling Anabranch channel to the modern Baaka channel has been dated using OSL to around 7500 BP (Lawrie et al., 2012:183), which gives a maximum possible date for in-stream stone fish traps in these sections of the river. Future research should investigate the potential for using river channel, lake and billabong ages for establishing a maximum possible date for associated fish traps and fish weirs. The evolving river channels, especially on the mid to lower Baaka, are related to the many billabongs, swamps, lakes and anabranch creeks, that characterise this system. These landforms provide additional potential locations for fish traps and weirs, particularly wooden and earthen structures. The many lakes and larger billabongs provide nursery areas for fish (Stuart & Sharpe, 2020:683) and this generates the possibility of enhancement of fish stocks and containment of fish through the use of fish weirs.

METHODS

Historical Materialism has provided a theoretical framework for archaeologists to study the dynamic relationships between socio-cultural factors and environment, technology, and demography. It recognises that the beliefs of a society play a primary role, thus society does not passively adapt to environmental and/or technological changes but plays out conflicting needs and strategies of groups within societies and the relations between groups (David & Lourandos, 1998; Huchet, 1991:45-6). The three imperatives of ecology, agency and historical processes can be intertwined to provide an exploration of the complex processes, including modification of landscapes by creating enduring assets such as fish traps for a range of social reasons (Schroeder, 2004:820-3). Interpretative Archaeology theory asserts that material culture can also have agency and "act back" on its makers and users (Dobres & Robb, 2005:161; Gosden, 2005:194) thus opening up the possibility that fish traps themselves influence social relations, for example by creating possibilities for large gatherings and ceremonies. This paper utilises both concepts to study the relationships between the people, fish traps and the Baaka river and floodplain.

Following a review of previous work, information on fish traps and weirs along the Baaka has been collated from historical sources such as maps, photos and manuscripts, and historic published accounts and unpublished heritage reports. Historical material includes primary evidence from writers who lived alongside Barkandji people in the nineteenth century exploration and early settler history, and wrote extensively about them, for example, Krefft (1866), Newland (1890), and Sturt (1849 [2001]). These writers document use of fish traps over a season or many seasons, whereas other writers describe a single point in time that gives only a partial account of the fish traps. This essentially European view has been balanced by oral history accounts that demonstrate Barkandji traditional knowledge has been retained. Oral history projects undertaken by author Sarah Martin involved recording Barkandji elder's knowledge about history and ways of living, including evidence of existing or remembered fish traps along the Baaka and relevant cultural and ecological knowledge (Bates & Martin, 2010; Harris, 2018; Martin, 2020; Martin & Kurnu Baakandji Elders 2014; The Elders and Martin 2011). These projects were all instigated and managed by local Indigenous organisations (Wilcannia Local Aboriginal Land Council, Kurnu Baakandji Joint Management Committee, or in the case of Bates & Martin, 2010, by Badger Bates telling his own personal history); and undertaken with due regard to cultural protocol policies and procedures (NSW National Parks and Wildlife Service, Heritage NSW, and Australian Institute of Aboriginal and Torres Strait Islander Studies ethics committee).

The archaeological evidence for stone fish traps includes actual remains of dry stone wall enclosures, and short stone walls placed in openings of natural rock pools, some of which have been recorded and entered into the Heritage NSW AHIMS database. A search of AHIMS revealed very few fish traps or weirs have been recorded and registered in the NSW Barwon-Darling system. Three stone fish traps are registered on the Narran River north of Brewarrina, and on the Barwon River only the Brewarrina fish traps are registered. On the Baaka, five stone fish traps are registered as a result of field surveys carried out by authors Sarah Martin and Badger Bates. Additional field survey of fish traps was undertaken near Newfoundland Station and Tilpa but not registered at the adjacent land-owners request. This field survey work was instigated by Badger Bates as a way of revisiting places to which he travelled with his grandmother, the Kurnu Barkandji matriarch Granny Moysey (Bates & Martin, 2010).

Review of previous research on fish traps and weirs on the Baaka and adjacent areas

A summary paper of Queensland fish traps and weirs concentrates on coastal structures but does discuss some fish traps inland in south-west Queensland of interest to this paper, including the stone Piastre Trap recorded on the Bulloo River (just outside the MDB), and stone fish traps on the Balonne and Nebine systems, tributaries of the Culgoa River that contributes water to the Baaka (Rowland & Ulm, 2011:34-36). These are similar in construction to three stone fish traps recorded in NSW on the adjacent Narran River, an intermittent stream with a shallow channel, consisting of low walls across the channel, walls at right angles and simple enclosures, made from large silcrete boulders abundant in the area. One fish trap recorded in 1993 consisted of about "twenty walls [that] could be delineated but had largely collapsed, stones weighed twenty to thirty pounds". Oral history was recorded from traditional knowledge holder Mr Ted Fields Snr remembering the "dam" and "wing" in approximately 1943:

> [the] wing being about one metre high … the wing and dam were at a deep hole in the … river about 3 or 4 feet deep. The hole has now silted up. Originally … was almost permanent water and dammed at the bottom end … the wall could be opened up to form a small channel … children would splash and chase the fish up stream along the channel … [the] channel would then be closed off to form a dam and the fish would be trapped (AHIMS site card 9-2-0007).

Two similar fish traps were recorded downstream on the Narran River (AHIMS 9-2-0011 and AHIMS 9-2-0013 site cards). The best preserved one is described as:

> Alignments and low walls formed from large silcrete boulders. Lines mostly go across the channel, but some at right angles as well. The channel is shallow at this point and crosses a hard silcrete substrate with river gravels and boulders deposited on top in places. Large deep waterholes upstream and downstream … lines of boulders form barriers across the channel and simple enclosures.

Katherine Langloh Parker who lived on the Narran River close to these traps notes: "To catch fish they also make small weirs and dams of stones, with narrow passages leading to them. The fish are swept by the current into these yards, and there either caught by the [Aboriginal people] with their hands, or speared" (Parker, 1905: 109).

Historical materials describe another stone fish trap upstream from Brewarrina: "The late Mr William Crowley, of Collywarry, told me there were stone fish-traps on rocks in the Barwon River near that station, about twenty-five miles above Brewarrina, but they have now disappeared" (Mullen quoted in North, 1916:127-128). This area is also described as a "rapid" by Dr and Mrs Clark who epically canoed in 1895 from Mungindi to the Murray Mouth: "we came to a very bad rapid called the Collawaral, which was about 200 yards long with a drop of about 9ft. We shot this successfully, travelling the distance at a remarkably quick pace. There was a very swift current there, which ran at the rate of about seven miles an hour" (Clark & Clark, 1895:8(3)). The explorer Charles Sturt also briefly noted a stone fish trap in the bed of the Bogan River below its junction with the Baaka, near the current site of the Gongolgan town weir: "the creek had been numerously frequented by the natives … It had a bed of coarse red granite, of the fragments of which the natives had constructed a weir for the purpose of taking fish" (Sturt, 1833:72).

A desktop review of Indigenous fish traps in the MDB by Kelly (2014) gives an overview of distribution and construction of in-stream fish traps and weirs, though it focusses on the Murray River and only discusses the Brewarrina fish traps on the Barwon-Darling system. Nearly 75% of fish traps discussed were made of organic materials such as sapling and brush, earth and timber, or logs. A small number of earthen traps are described, and the rest (less than 25%) were made of stone. This overview notes that unlike coastal and estuarine traps, which rely on daily tidal movements, inland traps must rely on fish movements that may be the result of spawning behaviour, homing patterns or related to changes in river flows such as floods (Kelly, 2014:46).

Another desktop review of Indigenous use of aquatic resources was undertaken by Humphries to assist in understanding the former and current distribution, structure and dynamics of fish communities in the MDB. It discusses the Brewarrina fish traps (*Ngunnhu*) on the Barwon River but does not specifically discuss the Baaka. The paper reviews historic materials about sustainable Indigenous use of the abundant aquatic resources, including the use of stone and wooden traps and weirs, and then documents the collapse in native fish numbers as Indigenous people were displaced and marginalised by colonial settlers. It asks the questions "what role did Aboriginal people play in the aquatic ecosystem? And what effect has their removal had on the biotic and abiotic components of these systems?" (Humphries, 2007:107). Discussing the Brewarrina fish traps, Humphries states that such constructions would have "altered water currents locally, changing the hydraulic environment for riverine biota, enhancing conditions for some, while making conditions less conducive for others". He also suggests fish traps and harvesting of aquatic plants both may have altered the morphology of rivers, affecting habitat for plants and animals (Humphries, 2007:109). This paper draws attention to potential for the *absence* of traditional Indigenous impacts and management practices (such as functioning fish traps and weirs) to deplete the aquatic resources, in addition to non-sustainable settler fishing practices (Humphries, 2007:110).

The heritage listed Brewarrina Fish Traps (*Ngunnhu*) (AHIMS 08-6-0001) are located in the country of the Ngemba people on the Barwon River upstream from the study area, but are considered here for comparison and because they have excellent historical, photographic and survey data dating from the 1850s that confirm the original structures and use. The many references include Randell (1861), Mathews (1903), North (1916), Gilmore (1933) and are summarised and analysed in Dargin (1976), Hope and Vines (1994), and Rando (2007), as well as the documentation for the National and NSW State Heritage Register listings. The Brewarrina fish traps consist of a series of inter-connected tear drop shaped dry stone-walled enclosures with wings and internal partitions, arranged over the 400-metre-long rock bar with shallow rapids in the river channel and extending across the river for 100–200 m (Figure 2, Hope & Vines, 1994). Additional details are provided in later sections.

Fish species and behaviour

A discussion of fish traps on the Baaka must rely on an understanding of fish movements, spawning behaviour, and how they are affected by changes in river flows (Kelly, 2014:46). The four medium to large sized fish found in the Baaka are*: Maccullochhella peeli* or Murray cod*, Macquaria ambigua* or golden perch/yellowbelly*, Bidyanus bidyanus* or silver perch/black bream, and *Tandanus tandanus* or eel-tailed catfish. *Nematalosa erebi* or bony

bream/bony herring, is a small to medium-sized fish which can occur in great abundance and is also utilised by Barkandji people. Two small to medium-sized fish that may have occurred in the Baaka in lesser numbers are *Leiopotherapon unicolour* or spangled perch, and *Neosilurus hyrtlii* or Hyrtl's tandan/catfish. There were also a number of very small fish species that were not the focus of fish traps, however, they were an essential part of the ecology. While many second hand accounts of fish traps emphasise the catching of cod, actual eye-witness accounts indicate that the five species Murray cod, silver perch, golden perch, bony bream and catfish were caught in the traps (Krefft, 1866:368; Mathews, 1903:153; North, 1916:125; Scott, 2005). Mathews (1903:153) adds that the "principal fish… were Murray cod, black bream, and yellow bellies. The black bream was the favourite fish among the aborigines".

Pelagic spawning riverine fish (pelagophils) spawn in free-flowing river habitats with downstream drift of eggs and larvae (Stuart & Sharpe, 2020:675); they travel upstream before spawning so eggs and their larvae can drift downstream. Golden perch and silver perch are the most notable pelagophils, travelling in large numbers vast distances up the Baaka to spawn during spring and summer floods and freshes. Fish traps were opened up on the downstream side at such times and were the focus of large gatherings of people. There is evidence that these pelagophils migrated more frequently in the Baaka than in the Murray River and its tributaries, as the low gradient resulting in slow flows, warmer water temperatures, seasonally widespread low to medium freshes, and the numerous floodplain nursery areas such as ephemeral lakes and billabongs all favour golden perch and silver perch (Stuart & Sharpe, 2020:683).

Fish studies note that both juvenile and mature golden perch and silver perch also travel down-stream to start the migration process again, during other times of the year (Baumgartner et al., 2014:29; Reynolds, 1983:869). Fish also occasionally travel in mass downstream in front of an advancing turbid flood (Mathews, 1903:153) and are trapped in the stone fish traps with openings facing upstream.

The Baaka also has non-pelagophil species such as Murray cod that travel to a lesser extent: "The cod fish…ramble down as well as up-stream, and were caught in the pens at any time" (Mathews, 1903:153). Catfish are largely sedentary unless seeking a drought refuge (Reynolds, 1983:857).

Balme's large scale archaeological survey of the mid-Baaka and associated lakes and anabranches show that the four larger fish species Murray cod, golden perch/yellow belly, silver perch, and eel-tailed catfish, as well as bony bream, were caught throughout the Pleistocene from about 30,000 BP and throughout the Holocene. Some of Balme's sites have a preponderance of golden perch; for example, one site on the Pleistocene Lake Tandou near Menindee had an otolith count of 564 yellow belly to three Murray cod to one silver perch, suggesting exploitation of migrating golden perch. She suggests the use of nets to explain the focus on a particular species (Balme, 1995:4-10; Balme & Hope, 1990), although fish traps may also have been a contributing factor. Balme's work highlights the necessity of undertaking more archaeological analysis of midden sites along the Baaka to determine what fish species and what ratios were caught using the range of fishing methods throughout the river's long history.

RESULTS

Stone fish traps on the Baaka

Stone fish traps analysed

Historic accounts, recorded fish traps and oral history indicate that many if not most of the rock outcrops along the Baaka were used for fish traps, "on the long, slow waters of the inland rivers stone traps were made where a suitable place was available" (Gilmore, 1933:14). Hence a rarely recorded archaeological feature was probably once common, and a detailed survey is likely to find many more remnants of fish traps. Information on a total of twelve stone fish traps located along the Baaka (Figure 3) is analysed in this paper (Table 1). This includes two traps that are still in use, the Wilcannia town weir and Weir 32 at Menindee. Another four stone traps were visited and are partially preserved (Toorale Hells Gates, Newfoundland 1, Tilpa weir, and The Strip). Two are known only from historical records (Warrego Darling Junction, Newfoundland 2). The Island (Wilcannia), Rocky Crossing (Wilcannia), Christmas Rocks, and Menindee old weir are known only from Barkandji oral history.

The Fisheries

The language used in historical sources indicates that the stone fish traps on the Baaka had similarities to the Brewarrina fish traps, *Ngunnhu*, also called "The Fisheries". Historical maps detail "native fisheries" near Newfoundland Station in an area where low rocky hills come close to the river (Figure 4). Newland owned the adjacent downstream station of Marra, living there from 1864 until 1876 and extensively documenting Barkandji culture and people. He described these fish traps as "The Fisheries" (Newland, 1890:23-24), and they are still known by local station owners as "The Fisheries". An Australian Museum curator commented after a 1903 visit that these fish traps were similar to Brewarrina but a smaller structure (North, 1916:127-128). A. W. Mullen describes the Louth fish traps in his 1906 field notes as "fisheries on the rocks" (reproduced in Hope & Vines, 1994 Appendix 2:107). The word "fishery" is used to describe a place where fish are caught, and/or breed, and has the connotation of a commercial enterprise rather than recreational fishing. The use of the word "fisheries" suggests the early recorders recognised that the fish traps were significant large-scale enterprises.

Table 1. Summary of stone fish traps analysed in this section (DSW = dry stone wall).

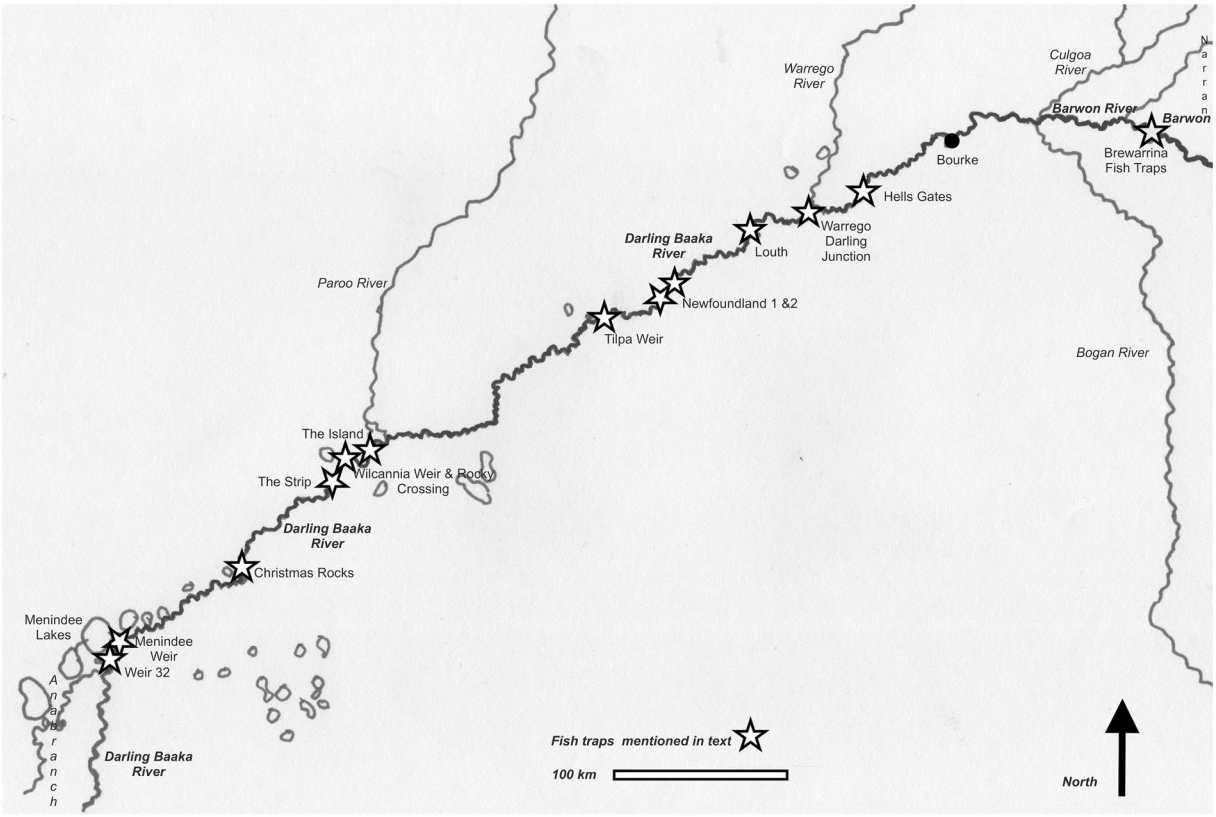
Fish trap location	**Type of documentation**	**Material**	DSW **enclosures**	DSW **wing**	**Rock outcrop natural enclosure with** DSW **section**	**Enclosure opening**	**Rapids or race**	**Water height and season**	**Fish species & method of catching**
Warrego Darling (Baaka) Junction, Baaka main channel	Historical material	Quartzite "bars and loose stones"	"walls in the bed of the river", "series of yards", "8 or 10 (yards)"	DSW "wing on both sides from largest yard, extending to bank on either side"	n/a	Opening upstream side	n/a	Ordinary water level, summer	Drive the fish into the yards
Hells Gates, Toorale, Baaka main channel	Field visit, oral history	Quartzite, outcrop and loose stones	Five small walled enclosures beside race	Traps and outcrops formerly spread right across river, ie. no need for wing	One large & two small	Facing race, or some trap openings facing upstream or downstream	Slope 1 m over 25 m, DSW form a man-made race	When the water was down low	Catfish, golden perch, caught with hands
Louth, Baaka main channel	Historical material	Quartzite, outcrop and loose stones	"fisheries on the rocks"	n/a	n/a	n/a	n/a	n/a	Fisheries
Newfoundland 1, Baaka main channel	Historical material, field visit, oral history	Sandstone outcrop, bars and loose stones	"permanent stone pens", "elaborate systems of pens opening one into the other"	DSW walls coming off natural rock bars reach across river	DSW walls coming off natural rock bars, 'stone pens formed on reefs'	Downstream	n/a	When the stream continued low	Caught or speared
Newfoundland 2, Baaka main channel	Historical material, oral history	Sandstone outcrop and loose stones	"permanent stone pens", "elaborate systems of pens opening one into the other"	n/a	DSW walls coming off natural rock bars, 'stone pens formed on reefs'	n/a	n/a	When the stream continued low	Caught or speared
Tilpa Weir, Baaka main channel	Field visit, oral history	Sandstone outcrop and loose stones	Series of DSW across low section of main channel, remnant walls on low rock outcrop	no	n/a	n/a	yes	n/a	n/a

(*Continued*)

Table 1. (Continued).

The Island Wilcannia, Baaka main channel	Field visit, now silted over, oral history	Sandstone outcrop and loose stones	DSW fish trap	n/a	n/a	n/a	n/a	n/a	Net in opening of DSW
Wilcannia Town Weir, Baaka main channel	Field visit, oral history	Sandstone loose stones	Over 30 DSW oval enclosures down rock apron of water supply weir	Weir forms wing	No	Down stream	Descending 3.8 m over 50m	Water just flowing over weir, -mainly spring and summer	Golden perch, cod, black bream, boney bream, yabbies, caught with hands
Wilcannia Rocky Crossing, Baaka main channel	Field visit, oral history, archival maps	Sandstone outcrop and loose stones	Yes, "make little fish traps out of loose stones"	Outcrop forms wing	Yes, small natural pools	Down stream	No	Mainly spring and summer	"they'd catch them with their hands"
The Strip, Baaka main channel	Field visit, oral history	Sandstone outcrop and loose stones	No	large DSW wing 8 m long and 50 cm high	Five large round natural enclosures and many small ones completed with DSW sections	Facing into mid-stream, influenced by natural outcrop	Water forced into narrow "race" between higher rocks, making water flow faster	Low water	"catch fish and throw them in the rock pools", "look in rock pools an get fish", catch with hands
Christmas Rocks, Baaka main channel	Oral history	Sandstone outcrop and loose stones	"there were fish traps at Christmas Rocks"	n/a	n/a	n/a	n/a	n/a	n/a
Menindee town weir, Baaka main channel	Field visit, oral history	Sandstone loose stones		Weir forms wing		Down stream	n/a demolished in 2019	Low water	Catch with hands, cod, golden perch, black bream
Menindee Weir 32, Baaka main channel	Field visit, oral history	Sandstone substrate and loose metamorphic stone from Broken Hill	DSW built on rock apron of weir	Weir forms wing		Downstream	Descending 3.9 m over 45 m	Low water	Catch with hands, cod, golden perch, black bream
Brewarrina (*Ngunnhu*), Barwon River main channel	historical material, research by Hope and Vines (1994); Rando (2007)	Desert sandstone and schist outcrop and loose stones	"collected large quantities of these stones and erected walls", at least 37 large enclosures with internal partitions	Wings stretched from bank to bank	Yes	"traps had their open ends towards the direction from which the fish approached" (Mathews, 1903)	Descending 3.35 m over a set of four low rapids covering 400m	"during times of low water" (Randell, 1861), "During the early spring months of the year, or at any time there was a fresh in the river, (Mathews, 1903)"	Cod, golden perch, black bream, used nets in openings (later replaced with wire mesh) spears, clubs, hands, driving fish

FIGURE 3. Map of Darling (Baaka) River and lower Barwon River showing stone fish traps discussed in the text.



Dry stone walls

All recorded stone fish traps are wholly within the main channel of the Baaka, where rock is intermittently exposed by fast flowing water downcutting through the sediments of the floodplain. Rock outcrops in the Baaka channel, usually sandstone or less commonly quartzite, provide large and small stones for walls, as well as natural rock bars and partial or complete natural rock pools. All the known traps have walls built of stones placed without the use of mortar, commonly termed dry stone walls. The Warrego-Darling Junction trap was recorded in 1859 as "walls in the bed of the river" forming a "series of 8 or 10 yards" with a large yard opening into smaller yards (Norton, 1907:101-102), and the Newfoundland traps were described as "permanent stone pens" and "elaborate systems of pens opening one into the other" (Newland, 1890:23-24). The eastern side of the Hells Gates traps consist of a series of dry stone walled enclosures opening out into a narrow race (Figure 5), and dry stone walled wings and enclosures can be seen coming off rocky reefs at Newfoundland 1 (Figure 6). Dry stone wall remnants can be seen below the Tilpa Weir, despite the disturbance resulting from the town weir overflow (Figure 7). The Wilcannia Weir fish traps consists of a series of dry stone wall oval shaped enclosures following down the rock apron of 1940s town water supply weir, "we used to go to the stone part and make fish traps" (Bates & Martin, 2010:18, Figure 8), and at Wilcannia Rocky Crossing fringe camp inhabitants made "little fish traps out of loose stones" (Figure 9) (Martin, 2020). Mathews (1903:148) gives extra detail on how the dry stone walls at Brewarrina were built, "The river- floor … consists of immense numbers of loose stones, ranging from twenty pounds to a hundred weight, with others of greater dimensions. The aboriginal builders collected large quantities of these stones and erected walls … in a substantial manner, being wider at the base, where also the largest stones were used, and tapering upward to the top".

Natural rock bars, rock pools and rapids

At Newfoundland 1 a series of nine natural rock bars form barriers part way across the channel, which were utilised for fish trap walls in conjunction with areas of dry stone walling (Figure 6). Rock outcrops may also provide partial and complete natural rock pools, usually roundish and varying in size from bathtub size to the size of a large room. Partial natural rock pools were completed with infill of dry stone walls where needed, as can be seen at Hells Gates and The Strip fish traps (Figures 10 and 11).

Minor rapids similar to Brewarrina are found along the Baaka at Hells Gates, Wilcannia Weir and Menindee Weir 32, and these were an important component of at least some stone fish traps. The rock apron at Wilcannia Weir descends 3.8 m over 50 m, and the Brewarrina fish traps descend 3.35 m over a set of four low rapids stretching 400 m along the channel (Hope & Vines, 1994; Rando, 2007). The Hells Gates fish traps on the eastern side descend about 1 m over

FIGURE 4. "Native Fisheries" marked on the 1914 Pastoral Map of Newfoundland Run, County Landsborough. Reproduced with the permission of the Office of the Registrar General, a unit of the NSW Department of Customer Service.

FIGURE 5. Hells Gates Fish traps eastern side of the Baaka channel. Water flows from right to left. Photo: Sarah Martin 2007.

25 m creating a minor rapid where low flows are channelled through a man-made race, with the enclosures opening to the side (Figure 5). The range of height of rock outcrop or river substrate in any one area was also utilised to enable fish to be caught at a range of water levels, with stone-walled traps built at varying heights. At Wilcannia Weir fish traps for example "when the water level changed, we'd move the fish trap" (Bates & Martin, 2010:18). At other fish traps, for example, The Strip fish trap below Wilcannia, the natural outcrop forces the water through a narrow gap, thus creating fast flowing water similar to a rapid but without a drop in height.

Numbers and shape of enclosures

Numbers of enclosures vary considerably, with Brewarrina by far the largest complex with at least 37 large

FIGURE 6. Newfoundland 1 stone wall with opening and remains of an enclosure, all coming off a natural rock bar. Photo: Sarah Martin 2007.

FIGURE 7. Small stone wall below the Tilpa Weir. Photo: Sarah Martin 2010.

enclosures with internal partitions mapped in 1906 (Rando, 2007:50, Figure 2). The Wilcannia Weir has over 30 small enclosures (water was covering some at time of counting) stretching across and down the front of the weir rock apron. At Hells Gates the lower eastern side consists of an area of large boulders and smaller rocks, some of which have been made into dry stone walls forming a series of at least five small enclosures averaging one by 2 m in size and walls about 30 cm in height (Figure 5). The western side has a large round natural rock pool with a section of dry stone wall to complete the enclosure, as well as several smaller partly natural enclosures. The Strip has five very large natural rock pools and numerous smaller ones, all with sections of dry stone wall to complete the enclosure. Enclosure shape varies, at Wilcannia Weir they are mostly oval but also round or irregular (Figure 8), at Brewarrina enclosures were often elongated tear drop shaped (Rando, 2007) although there were various shapes, "some of the pens were long and narrow, others nearly circular, whilst others were irregular in shape" (Mathews, 1903:148-153, Figure 2).

Barkandji oral history indicates the Newfoundland fish traps were well known as large complexes of traps to older people, and the name of one of the adjacent stations Curranyalpa [*karnayalpa*] fittingly translates as "many rocks":

> [Granny would] point in there to where them fish traps. So there's lots of fish traps and at New Finland [Newfoundland] there's more along there, and I think there must be more down towards Curranyalpa there, in that area, but you can't sort of get in there now (Badger Bates in Bates & Martin, 2010:53).

FIGURE 8. Wilcannia weir fish traps in use by young Barkandji people, water flows from left to right. Photo: Sarah Martin 2014.

FIGURE 9. Wilcannia rocky crossing and fish trap (river chart indicating rock outcrop as circles and loose stones as crosses). Water flows from right to left. National Library of Australia image file 443/tarkine/nla.obj-229876645. Reproduced with permission from Echuca Historical Society.

> Compadore Station, there's big ones there too [fish traps], and just below at Curranyalpa, on Compadore Station, was the **big** shell midden right around there… No, we wasn't allowed to go near them sort of things [without an elder] to use them things because the spirit was still there of the old people (Billy Elwood in The Elders and Martin 2011:86)

Wings

Fish traps on the Baaka display dry stone wall wings built to the bank to deflect fish into the traps, for example at the Warrego Darling Junction fish traps there was a "wing on both sides from largest yard, extending to bank on either side" (Norton, 1907:101-102), similar to Brewarrina where

FIGURE 10. The Strip fish trap showing the main wing to right, four partly natural rock pool enclosures, and clear water of the spring in the far-right rock pool. Water flows from left to right. Photo: Sarah Martin 2008.

"fish were intercepted by ‘wings’ of this maze, which stretched from bank to bank" (Mathews, 1903:148-153). The Strip fish trap displays a wall about 8 m long and 50 cm high which acts as a wing pushing fish into the enclosures (Figure 11a).

Direction of trap openings

Enclosures had an opening that allowed fish in, these were then closed with stones or net to trap the fish inside. The direction of the openings could be changed depending on the direction fish were travelling: "traps had their open ends towards the direction from which the fish approached" (Mathews, 1903:145-146). When pelagophil fish were travelling in mass upstream to spawn the openings faced downstream, otherwise they opened on the upstream side.

Fish in the Barwon-Darling Rivers also occasionally travel in mass downstream in front of an advancing turbid flood and "When such a fish-laden current reached the *Ngunnhu* at Brewarrina, the aborigines had the ‘up-stream’ ends of their traps ready for action" (Mathews, 1903:153).

Driving fish

Fish could be driven by people from upstream into the traps, at this time the opening would also be facing upstream, for example at the Warrego Darling Junction in 1859:

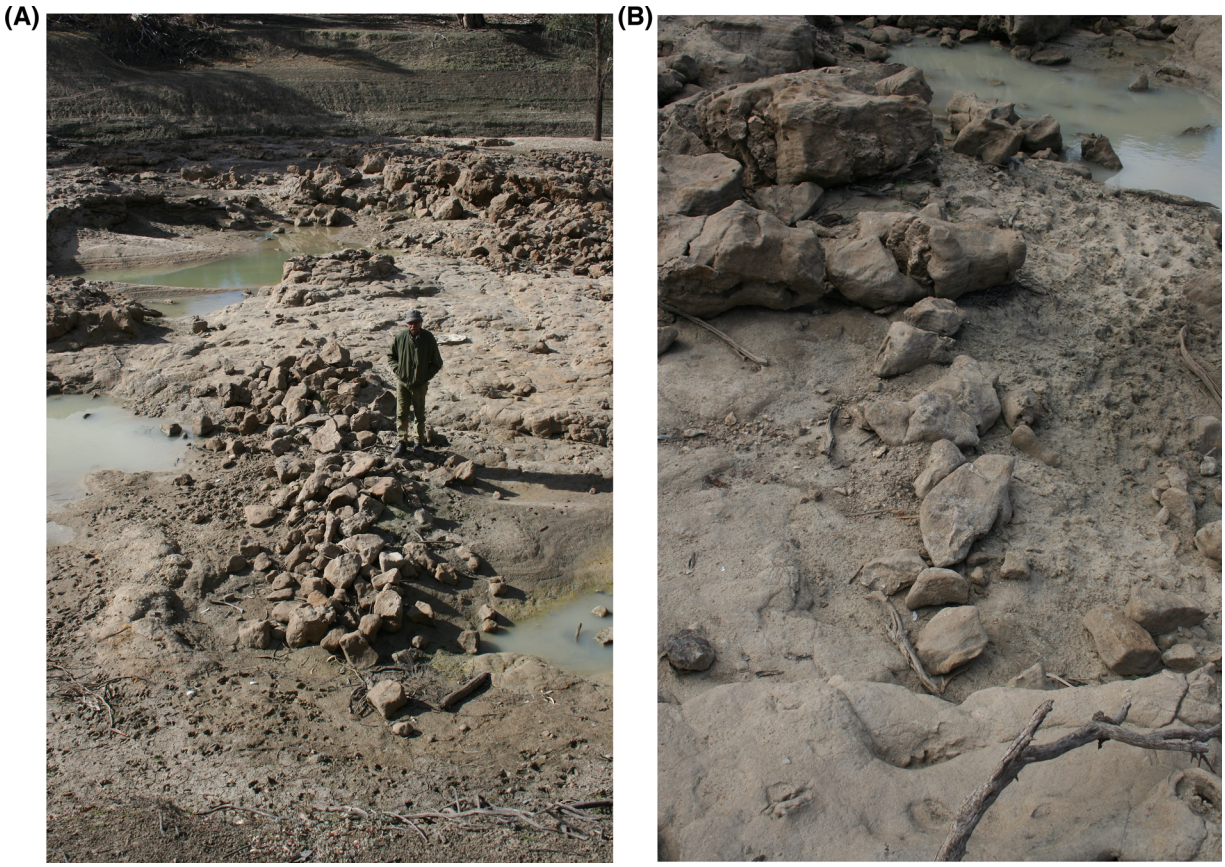
> walls were built, so as to form a series of yards, each having an opening on the upstream side … Near these yards the blacks camped, and when they were ready for the fun … men, women and children forming a line across, swam towards the yards, shouting and diving as they advanced, to disturb the fish and drive them into the receiving yards, the opening into which was then closed (Norton, 1907:101-102)

Randell gives a similar early account of chasing fish into traps at Brewarrina: "ascending the river for a considerable distance, they come down in it, making a peculiar noise, and driving multitudes of fish before them into the cells" (Randell, 1861:145-146). Both accounts describe people chasing fish from above the traps and we know that at the time of Randell’s account the water was low over the rocks as his paddlesteamer could not travel over the fish traps. This suggests that driving fish occurred at a time when there was little or no water flow, thus people power was used to frighten the fish into the traps.

Catching fish

Once the fish were in the traps a number of methods were used to actually catch them. At Brewarrina the "larger fish were speared, or killed by a club, but the smaller ones were caught by hand" (Mathews, 1903:148-153). A "memory" painting by a Wilcannia artist based on traditional knowledge passed down to him (Figure 12) shows The Island fish trap as having a net placed in an opening in the dry stone wall (Bates & Martin, 2010:32-33). At Newfoundland 1 and 2 fish were "caught or speared" (Newland, 1890:23-24), "caught" possibly referring to catching with hands. In the past and currently at Wilcannia Weir, The Strip, Rocky Crossing, and Menindee Weir 32 "they’d catch them with their hands" (Bates & Martin, 2010; Martin, 2020). Small rock pools were used over the last 60 years to hold caught fish for later use at The Strip fish traps (Bates & Martin, 2010:4), in contrast to

FIGURE 11. (a and b) The Strip fish trap main wing (left) and smaller internal wall (right). Photos: Sarah Martin 2008.



some evidence that suggests at Brewarrina all fish in the traps had to be dispatched (Mathews, 1903:153).

Water levels

Records consistently describe fish trap use during periods of low water rather than high water levels associated with a large flood, as the traps only worked when the water was below or just over the top of the trap walls. Descriptions include "ordinary water levels" (Norton, 1907:101-102), "when the water was down low" (The Elders and Martin 2011:147), "when the water continued low" (Newland, 1890:23-24), and "during times of low water" (Randell, 1861:145-146).

Size of groups of people and gender considerations

There are a number of references to large gatherings of people at the various fish traps, for example at Newfoundland 1 and 2, Newland (1890:23-24) states "great camps of blacks collected at these places for the purpose of obtaining fish". At the Island Wilcannia in "1866 there was a rather large gathering" (Bonney, 1884:131) and Barkandji oral history records that "the old people said there were fish traps at Christmas Rocks and it was where they had large gatherings of people" (Figures 13 and 14, Badger Bates pers comm. 2020), and a gathering of 300 people was recorded near the fish traps at the Warrego Darling Junction in 1880–1882 (Caldwell, 1937:9). Brewarrina is known for its very large gatherings, "people mustered here in considerable numbers in the fishing season" and "the fishing season was sometimes made the occasion of inviting neighbouring tribes to join in their great corobboree [sic], initiation ceremonies, or meetings for trade and barter" (Mathews, 1903:148-153).

However, the fish traps were also used by small groups of people when there were no migrating fish, for example, individual Barkandji families fished at Hells Gates in the 1950's:

> I know about them [the fish traps], when the water was down low me and old Uncle Rupert [Crowe] went up and he showed me how they caught em … [they] put all the stones in to make the traps, … he'd sit down and tell me all about it, and I said "Uncle look there's one there look" and we went and herded? a big catfish, and you'd catch yellow bellies there, but that was when the water was low. Yes, of course I done all that there with old Uncle Rupert (The Elders and Martin 2011:147).

The Wilcannia town weir, the old town weir in Menindee (demolished in 2019), and Weir 32 about thirty kilometres downstream of Menindee (Martin, 2001:25), were built in the 1940s-1950s and transformed and used as fish traps by locally based Barkandji families when there is a medium to small sized flow of water in the river (Figure 8).

FIGURE 12. Steamer Point Island fish trap, showing dry stone walls and net, painted at Wilcannia, 1996. Permission given by the artist Phillip Bates.

> Well this the Wilcannia weir, and down in the weir we … make fish traps and catch fish. The stone for the weir come from the 10 Mile Hill out on the Sydney road. They made it out of stone, and they drove wood in, see it there, and we used to just go to the stone part and make fish traps, and you'd lift the stone up too and a lot of yabbies live under there, we used to get big buckets of yabbies (Bates & Martin, 2010:18).

There is little information on the gender of people who used fish traps. However, it is clear the driving of fish was carried out by "men, women and children" at the Warrego-Darling Junction fish traps (Norton, 1907:101-102, and women and men are described at Brewarrina as "Aboriginal fishers" (Mathews, 1903:150). At the Wilcannia and Menindee weir fish traps there is no distinction between the genders catching fish (Badger Bates pers. comm).

Wooden fish traps and weirs on the Baaka

Wooden stake, brush and woven traps were probably far more common than stone fish traps, although seldom noticed and recorded by early settlers. Details about Barkandji stake and basket weirs are provided by Krefft who camped at the junction of the Baaka with the Murray River (present day Wentworth, Figure 1) for several months in 1858:

> … the women are very expert … with a sort of flat net fixed to a bent stick about 6 or 8 feet in length, similar to a dredge; this of course, is only fit for shallow lagoons, the outlets of which, when the flood waters begin to fall, are enclosed with sticks or basket-work to prevent the fish escaping, thus creating a considerable reserve for the following months. … The principal fishes used as food by the natives are the Murray Cod … Silver Perch … Cat Fish … and Manor [bony bream] … and another species of so-called Perch [golden perch] (Krefft, 1866:368).

Sturt uses similar language to describe the large shallow Menindee Lakes that formed "temporary reservoirs" when filled from the Baaka holding "immense numbers of fish … which may thus be considered a providential provision for the natives, whose food changes with the season" (Sturt, 1849 [2001]:135). Sturt also describes a wooden weir intercepting a fresh flow of water coming up the Darling Anabranch creek, "At the head of the water they had made a weir, through the boughs of which the current was running like a sluice" (Sturt, 1849 [2001]:67), it was "a Weir which the Natives have set to take fish" (Sturt 1844–1846 [2002]:37).

Newland does not specify wooden fish traps or weirs on the middle Baaka, but it is likely that nets were held in place by wooden structures when there was a strong current:

> For catching fish a smaller net than that used for birds was stretched across a small creek emptying a lake or

FIGURE 13. P.S. Colonel and barges at Christmas Rocks in 1926 (PRG 1258/2/2260 Godson Collection, State Library South Australia). No known copyright.

FIGURE 14. Christmas Rocks circa 1888 pilot chart (National Library of Australia image file 443/tarkine/nla.obj-229876315), showing two islands, outcropping rocks (circles), boulders (crosses) and widened river channel. Water flows from left to route. Reproduced with permission from Echuca Historical Society.

> billabong. As the river falls a considerable current is created, down which the fish are forced into the net. In this way great numbers were caught (Newland, 1890:23).

Badger Bates recalls that in the 1950's:

> Granny used to tell us what to do at the creek of the billabong, she'd say put bushes across and sticks and when the fish go in and when it fill up you leave it then, and when [the water] its going back, that's when you catch the fish, or you can catch them going in too, if you had a spear you know.

Given the limited amount of evidence along the Baaka of wooden weirs and traps, we searched for other possible clues to understand how these were distributed and what role they played. Historical sources and oral history indicate that wooden, basket and branch structures where often replaced with wire netting on stick frames. Importantly it

seems that this new material was used in the same places and times as previous organic structures, for example at Brewarrina fish traps in 1916, "the egress was blocked with a small wire covered iron wheel, and the lengthened deep purse-like net, wherein to put the fish, and if necessary, keep them alive, was [now] made of the ordinary galvanised meshed fencing wire" (North, 1916:124).

Barkandji people remember using wire netting on a stick frame to catch fish, yabbies and shrimp in billabongs as water was flowing back into the river. Badger Bates recalls:

> When I was 18 or 19, Granny used to tell us, and we went down to the billabong … and I think we only got bony bream and one little perch because the other ones was all gone. We used wire netting instead of a fish net … near Wilcannia, we made the wire netting and go along, put the sticks there, and go along and catch the fish … [we used] ordinary chicken wire.

Earthen weirs and pens on the Baaka

Earthen weirs and "pens" probably disappeared after settler arrival into Barkandji country even earlier than the wooden ones. In 1844 the explorer Sturt described an earthen bank or weir across the channel of the Darling Anabranch: "At the head of the water … the further progress of the floods was stopped by a bank that had been gradually thrown up athwart the channel" (Sturt, 1849 [2001]:67). Newland gives us an important description the use of earthen traps or "pens" in billabongs, swamps and low areas of floodplain back from the middle Baaka around the 1870's: "When the water back from the river became low, large quantities [of fish] were obtained by driving them into shallow pens made of mud" (Newland, 1890:23). Frederic Bonney, based near Wilcannia from 1865 to 1881, describes implements suitable for making earth banks: "a sharp pointed stick called a *pirrah* to loosen the ground, and shovelling out the loose earth with the wooden bowl called *yokudjah"* (Bonney, 1884:134), and "*Purpurra*, a wooden trowel with a long handle made and used chiefly by the natives of the river" (Bonney MS c.1881).

We examined both the archaeology and morphology of floodplain features as proxy evidence for earthen banks or weirs. Major archaeological surveys of the Menindee Lakes demonstrate a higher density and diversity of archaeological material including ovens, ashy deposit, mounds, middens and burials near lake inlet and outlet creeks (Martin et al., 1994:44; Pardoe & Martin, 2002:55; Witter 2009) indicating a focal point for occupation (Pardoe, 2003:45). It was further suggested that as the water flowed in or out, the inlet creeks "would have been prime places for fishing" or "a place where fish traps may have been built" (Pardoe & Martin, 2002:10-11).

The morphology of lake and billabong inlet/outlet creeks also provide a clue to the use of earthen banks or weirs. An early proposal to dam the Baaka and fill the ephemeral Menindee Lakes states "Cawndilla … will retain water for years after being filled, because the creek connecting it with Lake Menindee is not deep enough to drain it dry" (Anonymous 1911). This creek is actually very deep except for one area that prevents water flowing back out into the river. The inlet creek to Woytchugga Lake near Wilcannia shows a similar morphology, as the creek travels towards the lake entrance there is a slightly higher narrow sill that floodwaters have to climb over before emptying into the lake. We suggest these narrow higher features are the remains of earthen weirs built to keep water in the lake longer to store, grow and catch fish.

This idea is supported by a similar feature at many billabongs along the Baaka, where one or both of the entrance creeks from the river have a slightly higher section near the river than the rest of the billabong, resulting in much of the billabong water being kept in the billabong instead of flowing back out into the river. These blocked ends may be remnants of earthen banks "thrown athwart" to hold water back in the billabongs, forming a reservoir of fish, yabbies, turtles, mussels and aquatic plants. Accurate survey and excavation of these slightly higher features in the entrance creeks may indicate their origin and is a priority for further research.

DISCUSSION OF THE BAAKA FISH TRAPS AND WEIRS

Stone fish traps-comparison with other fish traps on the Barwon-Darling Rivers

There are many similarities between the Baaka stone fish traps and Brewarrina *Ngunnhu* fish traps, although it is acknowledged that *Ngunnhu* is the largest and most complex stone fish trap in the MDB. All display at least some of the *Ngunnhu* features, such as dry stone wall wings, enclosures and partitions, openings that changed with direction of fish movement, a range of heights to address different water levels, rapids, caught the same range of fish, sometimes people chased fish into the traps, trapping of pelagophil fish migrating up the river to feed large gatherings of people, and use of traps by smaller groups at other times. Little is known about the Collywarry fish traps except that they incorporated rapids similar to others described here.

The Narran River and south-western Queensland stone fish traps operate differently to the Barwon-Darling fish traps, as in such shallow and ephemeral streams the fish usually only travel downstream into the traps with the seasonal floodwaters, and the pelagophil fish are unable to migrate upstream to meet the floodwaters. The Narran River is a closed system ending in Narran Lake, so it is not connected to the Barwon River pelagophil fish migrations.

The stone fish traps in the Baaka were not built to a standard template, but utilised and adapted to the natural rock outcrop features and loose stone offered at each location. They frequently utilised natural rock pools and natural rock bars, which were usually completed or enhanced with sections of dry stone wall. Incorporation of natural rock pools and rock bars reduced the time spent building, the amount of flood damage, and necessary maintenance of fish trap enclosures. Fish traps were

constantly maintained and manipulated depending on the water flow and the fish migrations, for example the enclosure openings were changed to face up or downstream depending on the movement of fish and flow of water.

Seasonality of the Baaka compared to the Murray River

Scientific evidence indicates that pelagophils travel upstream to meet freshes and floods to spawn in spring and summer, and this is when large numbers of fish could be caught. Mathews states "During the early spring months of the year, or at any time there was a fresh in the river, the fish travelled up stream in immense numbers" (Mathews, 1903:148-153).

The Baaka receives water from both the northern predominantly summer rains from the Queensland catchment and both summer and winter rains from north-central NSW. The seasonality of floods and freshes is therefore different to the Murray River and its tributaries, which often have one massive spring flood linked to snow melt in the highlands. Prior to recent over-allocation of water, the Baaka had infrequent big floods (when fish traps cannot be used until they subside), but many medium to low freshes throughout the year of the right height for stone fish traps in the river to function (Mallen-Cooper & Zampatti, 2020). While the Baaka is more unpredictable; the warm climate, long spring and summer seasons, and many medium to low freshes, potentially provided extended pelagophil migrations spread out over the seasons resulting in a much wider window of opportunity for the use of fish traps.

Management of floodplain ecosystems using wooden and earthen structures

The extreme flatness of the landscape that the Baaka flows through results in relatively slow-moving floods and freshes, and an extremely tortuous course with many cut-off meanders or billabongs, as well as large floodplain lakes and anabranches (*talyawalka*). The juvenile fish find nursery areas in shallow lakes such as the Menindee Lakes, before migrating further downstream and into the Murray River (Stuart & Sharpe, 2020:685). The inlet/outlet creeks of these features provide the perfect location for wooden stake weirs or woven branch weirs, as well as earthen weirs, trapping fish behind them as the water level dropped and flowed back to the river. Historic sources indicate some of the wooden and earthen traps or weirs held water and aquatic life behind them, creating a lentic hydraulic environment and forming "a considerable reserve for the following months" (Krefft, 1866:368) and floodplain nursery areas that favour golden perch, silver perch and bony bream (Stuart & Sharpe, 2020:683).

Archaeology and morphology of lake inlet/outlet creeks and billabongs suggest Barkandji were using the wooden and earthen weirs to create reservoirs of fish and enhance the nursery habitats to increase the number of juveniles safely and quickly grown to the right size to travel on. Barkandji people are well aware of the role of billabongs and lakes in reserving and replenishing aquatic plants and animals:

> Billabongs keep plants and animals safe in a dry time and then they let these go into the river when it floods, to seed the river with life again. We know that the floodplain must flood for small things to breed, which together with nutrients wash back into the river to feed the fish and other animals. Nothing is wasted, everything has its role (Bates & Martin, 2020:33).

Complex management of nursery areas and fish re-stocking is also hinted at by Gilmore (quoted in Dargin, 1976:21) describing the deliberate transportation of juvenile fish in water-filled coolamons (large bark or wood dishes) to replenish floodplain water bodies depleted of juvenile fish.

Fish traps, weirs, aquifers and spirititual connections

Stone outcrops in the Baaka often exhibit freshwater springs and soaks. This is of spiritual significance because the shallow freshwater aquifers that create the soaks and springs in the river are the home of the Ngatji or Rainbow Serpent. Barkandji "know", "feel", and "see" the shallow underground aquifers through their ancestors' history and utilise this for practical purposes as well as the spiritual (Jones, 1989; Martin, 2020). Such information provides insight into interactions between the people, riverine landscape and aquifers and raises new possibilities about the management of fish and water by Barkandji people. The role the shallow aquifers play in fish ecology is well known to Barkandji people, for example, the spring at The Strip fish traps (Figure 10) is known to attract fish into that section of the trap and provide a fresh water refuge for them in dry times (Bates & Martin, 2010:5). Use of wooden and or earthen weirs at billabong and lake inlet creeks to form temporary reservoirs also replenished the shallow aquifers, providing longer lasting water resources linked to the springs noted at stone fish traps.

Rock outcrops with stone fish traps on the Baaka are also known to be connected to other ancestral stories, including the story of the creation of the Baaka, however permission needs to be obtained from different families to tell these stories.

Climate, palaeo-flows and fish traps

At the time of colonial settlement, and for around 600 years beforehand, the stone fish traps would have been used under generally higher flows due to a wetter phase of the ENSO (Vance et al., 2015). Two simultaneous changes would have impacted the use of the traps from the mid-19th century onwards: rainfall over the catchment reduced at the same time as colonial settlement expanded (Tibby et al., 2018). The effect of changing river flows on the traps has yet to be investigated, but the effect of colonial settlement was negative, as described above. Nevertheless, the dated large gatherings recorded at Brewarrina and along the Baaka in association with the fish traps show that even after settlement the fish traps could still support large gatherings.

In 1880–1882 a drover reported about 300 people camped at the Warrego Darling Junction on Christmas Day

(Caldwell, 1937: 9), which likely refers to a large gathering enabled by the fish traps described by Norton (1907:101-102). Although Warrego river height and flood records are lacking before 1890, (http://www.bom.gov.au/qld/flood/brochures/warrego/warrego.shtml#PreviousFlooding, Tannock, 1990), climate reconstructions suggest that warm season rainfall in the Warrego catchment in late 1880 to late 1882 was fairly average for that period (Freund et al., 2017). The 1880 La Niña event (which brought wetter conditions to eastern Australia) had ended by December (http://www.bom.gov.au/climate/current/soihtm1.shtml), giving way in 1881 either to a (drier) El Niño event, or a neutral state (Barrett, Jones, & Bigg, 2018; J. L. Gergis & Fowler, 2009). The El Niño Southern Oscillation was neutral in 1882, and the year was generally dry, although moderate flooding was reported just west of the Warrego catchment early in the year (Hunt, 1914; Phelps et al., 2007). Cyclone activity (primarily responsible for the flow in the Warrego) was average from late 1880 to 1882 according to speleothem records (Haig et al., 2014), while Antarctic ice cores show an increasingly positive Interdecadal Pacific Oscillation (IPO), suggesting decreased rainfall specifically over the catchment above the Warrego/Darling junction (Vance et al., 2015), an assessment confirmed by eastern NSW documentary sources, rainfall measurements and palaeorainfall proxies (J. Gergis & Ashcroft, 2013). If the early 1880s gathering was related to successful fishing, this event provides confirmation that fish traps could be productive during the summer season in average conditions.

Hydraulic engineering and fish traps

Stone fish traps were major hydraulic structures normally placed within the main river channels rather than the floodplain, as they depended on the flowing water to function. They were installed in variable and fluctuating rivers, attributes of the Baaka, rather than rivers that had a relatively constant high flow. The structures had to be stable across a very broad range of discharges, ranging from low flows to very large floods, lasting sometimes a few months. They operated on low to moderate flows only, when the water depths were less than 1.2 to 1.5 m. This was a basic requirement to enable the fishermen/women to work safely in the waters, in line with modern understanding of human stability in waters (Chanson & Brown, 2018; Takahashi et al. 1992). Historic descriptions of the people using the fish traps and the documented height of fish trap walls at a maximum of 90 centimetres (Hope & Vines, 1994) as well as historic accounts of paddle-steamer movements over the fish traps confirm that the traps were used on low to medium flows, not high flows. During large floods, the stone fish traps acted as large roughness elements, enhancing turbulent mixing in the water column above. The enhanced mixing may have helped prevent sediment filling the traps, as well as creating strong secondary circulations and transverse currents in the whole river cross-section, thus improving the water quality of the river water.

The shape of most stone fish traps was convex arching upstream against the flow of water (Figure 2). This added strength against floods, the way a Roman arch dam resisted the force of water against it. It is also possible that the curved shape, opened at the downstream end, induced some flow and turbulence patterns well-suited for attracting the fish into the trap enclosure. The curved shape further reduced the risks of blockage of the fish traps by large debris, such as trees, logs, large branches during a range of river flood discharges. As fish moved up or down minor rapids, they were attracted into the fish traps through a combination of fast-moving flow into the traps during downstream migration, and wake effect and recirculation vortices behind the traps during upstream fish migration.

The fish trap dry stone walls were built without mortar or clay, resulting in porous-walled structures to sustain the current and prevent siltation during floods (Dargin, 1976: 49). The wall porosity may have contributed to the stability of the structure during large floods, indicating an understanding of the forces of the current including during large floods, and understanding of basic hydrodynamic processes around fish trap structures. During medium to low flows the porous walls also created a different wake region turbulence in which fish swimming upstream would be better attracted. The walls were also designed to have a more porous structure on the upstream side, letting water in, and less porous walls on the downstream side to steady the flow of water in the enclosure (Hope & Vines, 1994), which may also have been attractive to fish.

Fish traps and species management

The dry stone walls were "keyed" so that blocks of stone could be removed and replaced resulting in control over the size of fish that were trapped or let through and control over the flow of water into and out of the traps. The "keyed" fish traps were designed to let the juvenile fish through so they could complete their lifecycle and also let through the small fish species that are an important part of the food chain (Gilmore, 1933:14).

Stone-walled fish traps also provided ideal habitat for invertebrates in the fish food chain, such as yabbies, freshwater snails, and aquatic insects. The description of the practice of gathering yabbies from the Wilcannia Weir fish trap rocks; "you'd lift the stone up too and a lot of yabbies live under there, we used to get big buckets of yabbies" (Bates & Martin, 2010:18), indicates this was an extra layer of resource management facilitated by the stone-wall trap structures. Barkandji continue the cultural practice of yabbying and obtaining smaller molluscs and aquatic insects for fish bait by lifting rocks at the stone-walled fish traps. Such rocky locations with flowing water are also habitat for the once common but now almost extinct river snail (Mallen-Cooper and Zampetti 2020:6), which was previously used by Barkandji for both food and bait. Constructed fish trap stone walls effectively formed "multi-storey apartments" for the yabbies, snails and other invertebrates.

Further research

The next phase of this project aims to research in more detail how the varying flows both in the river channel and in associated creeks, billabongs and lakes, were utilised and managed, and how the fish trap structures and weirs may have enabled Barkandji to enhance, grow and store a wide range of aquatic resources by modifying the environment of the river and floodplains. This will include additional survey of rock outcrops in the river channel for remains of stone fish traps and more detailed recording of stone fish traps, as well as survey and excavation of lake/billabong entrances to look for evidence of wooden and earthen weirs. Research into adjacent middens will determine the range of fish species and ratio of fish species and other aquatic fauna present in the Baaka system over the Pleistocene and Holocene, to build on Balme's work (1990,1995). Dating of the fish traps will be difficult but possible avenues include dating of middens, dating of river, billabong and lake features, dating of any excavated wooden or other organic material, and dating of carbonate encrustation on stone fish trap walls.

Modelling of fish traps and weirs will help determine the complexity of hydraulic engineering used by Barkandji people and give insights into the effects of the fish trap structures on the physical footprint of the river channel and floodplain features and ecosystems. It is also important for Barkandji people to be able to document the effects of the impact of the sudden removal of the fish traps and weirs and associated Barkandji management systems on the ecology of the river and floodplains.

CONCLUSION

This paper describes ways in which the Barkandji used stone, wood and earthen structures to manipulate and enhance the river and floodplain ecosystems, indicating fish and other aquatic resources were managed, grown, and stored. It shows how ecology, agency and historical processes can be intertwined to provide an exploration of complex processes, including modification of landscapes by creating enduring assets such as fish traps and weirs. The continuity of Barkandji cultural knowledge is demonstrated by the transformation of the 1940s–1950's government-built town weirs at Wilcannia and Menindee into a series of stone-walled fish traps, still in use by Barkandji today. This is an example of how Barkandji are able to survive the "logic of elimination" of settler colonialism and use settler structures for their own logic of survival (Forsyth & Gavranovic, 2018:464). Use of wire netting in place of wooden traps is another example of continuity and transformation of cultural practice.

Fish traps and weirs on the Baaka and its floodplain have similarities to those recorded in other areas of the MDB. However, there are distinct characteristics relating to the different flow regimes and seasonality in the Baaka, as well as different geology and fish behaviour including frequent migrations of pelagic spawning fish spread more widely over the seasons.

Barkandji people living along the Baaka have a sophisticated understanding of the hydrodynamic processes relating to the in-stream stone-walled fish traps that provide food for large gatherings when focussing on mass migrations of pelagophils during spring and summer floods and freshes. Large stone fish traps had their own agency, enabling but also encouraging large intergroup gatherings and ceremonies. Conversely, large and small fish traps also provide food for small local groups during periods of low or no flow. The stone fish traps increase flow turbulence, reduce silting and increase water quality, and are "keyed" to let small fish through. They also increased rocky habitat for invertebrates such as yabbies and river snails. In addition, stone fish traps are often found in association with shallow aquifer springs, and at least one recorded fish trap is built around a spring, evidence that fish are carefully managed.

Barkandji people understand the necessity of flooding lakes and billabongs and previously enhanced these through the use of wooden and earthen weirs, providing fish reserves, fish nurseries, and temporary rich and diverse habitat for aquatic plants and animals. Such structures kept aquatic plants and animals safe to seed the river with life when floods came down after a dry period and held water to replenish the shallow aquifers that create springs and soaks in the river that act as drought refuges for fish and other aquatic life.

The potential for Barkandji cultural and archaeological information to facilitate sustainable management of environmental and cultural flows in the Baaka has been largely ignored by water managers. This paper demonstrates the capacity Barkandji cultural knowledge and sympathetic archaeological research have to understand the long history of Barkandji water management and inform improved management of the Baaka, its floodplains, and aquifers. The real challenge is convincing water governance bodies and industry to support ongoing research, and then delivering on recommendations that will emerge from a clearer understanding of Barkandji river management strategies.

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