Archaeology of Aboriginal Fish traps
in the Murray-Darling Basin, Australia

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1 General Introduction

1.1 Introduction

Fishing and hunting are two of the most pervasive industries of indigenous peoples throughout the world since at least the Mesolithic. In parts of Europe hunting of big game, such as Elk and Reindeer, predominated from the Mesolithic (Gramasch 1973:71), but the proportion of fish in the diet increased over time (Zaliznyak 1998:3). This all changed in Europe with the Neolithic and the beginnings of agriculture when there was a sharp change in diet away from fish protein to land-sourced protein as evidenced by bone isotope studies (Richards 2006:444). All the world's peoples have at some stage utilised the technology of fishing with spears, poisons, hooks, nets and traps (Bannerman and Jones 1999:70; Connaway 2007:13). Remains of traps have been found across the world in places as diverse as the Orkney Islands north of Scotland, in Wales in the UK, across mainland Europe from Holland to Russia, in both North and South America, as well as Pacific islands, such as Hawaii, along with many areas in Australia (Zaliznyak 1998:45-6; Bannerman and Jones 1999:71; Connaway 2007:26; Clemente 2012:1). Sites of traps are diverse, ranging from inland rivers and streams, to estuaries and coastlines (Connaway 2007:26). Patterns of dates, trap locations in the landscape and technologies used in Australia mirror those found globally (Ross 2009:16; Rowland and Ulm 2011:2; McNiven et al. 2012:268).

The range of dates so far identified places traps in a relatively recent stage of human development. At present the oldest known traps are located at Zamostje 2 in Russia and date to 7500BP (Clemente 2012:3). Other old sites ranging from Europe to the USA and Australia all fall into the range 7500-5000BP. Materials and techniques used are also common, reflecting a pragmatic approach where locally available materials are used.

1.2 Fish traps around the world

Fishing apparently became significant in Europe only after the early Holocene in Boreal areas (Gramsch 1973:71). Prior to this, resource utilization studies of the early Mesolithic have shown that fish remains in middens occurred 10-100 times less than Elk and Reindeer (Gramsch 1973:70). However, by the second half of the Mesolithic, there was clear evidence of a decline in herbivore populations, and at the same time there appears to be an intensification in the amount of fishing with an increasing proportion of fish remains in middens as well as human bone isotope studies (Richards et.al. 2003:444) compared to mammals (Zaliznyak 1998:50). Evidence of traps is widespread in different parts of Europe, including both riverine and coastal sites. In comparison, there is clear evidence via collections of fish otoliths from sites along the Darling River in New South Wales that fishing occurred as far back as 24,000 years BP (Balme 1995:1) and bone isotope studies from along the lower Murray confirming significant contributions of fish to diet (Pate 2000:67).

Fishing technologies included spears, stream fences, rock walls, earth weirs, nets and hooks (Connaway 2007:7). There is evidence for the use of timber structures (fences, weirs and dams) to make passages (sometimes maze-like) that could be blocked off with nets or plaited material (Bannerman & Jones 1999:70). Often referred to as ‘stream fences’, they were usually made in Autumn in Europe as water tended to be shallower then. These also sometimes used plaited materials. Inlets for fish could be changed to either direction relative to the stream flow, depending on prevailing direction of fish movements (Zaliznyak 1998:45). Many traps have been located in coastal or estuarine areas. As timbers used in these traps have been submerged at all times, archaeological evidence has remained, which has allowed for carbon dating. The earliest dates recorded for wooden traps in Europe so far stretch back to the Mesolithic through to the Neolithic: from 7500BP to 3000BP (Pederson 1995). Timber remains of a trap at Begschenhoek, Holland (see Figure 1.1) have been dated to 5000BP in the Neolithic (O'Sullivan 2001). At Wootton Quarr (Isle of Wight) another trap was of a similar age (English Heritage 1996).

Table 1.1 - Overview of fish traps around the world

Location	Trap type	Date (cal BP)	Reference
Europe			
Bergschenhoek, Holland	Stakes, woven material	5000BP	O'Sullivan 2004
Blackwater Estuary in Essex, UK	Stakes		Dix & Bull 2000
Llanon, Cardigan Bay, UK	Stone		Lewes 1924
Lough Begg, Ireland	Stake	1000BP	Mitchell 1965
Shannon coast, Ireland	Stone	1000BP	O'Sullivan 2004
Wootton Quarr, Isle of Wight, UK	Stone		English Heritage 1996
Zamostje 2 near Moscow, Russia	Stakes, woven material	7500BP	Clemente 2012
East of Rødbyhavn, Denmark	Woven stakes	5000BP	Lolland-Falster Museum
USA			
Boylston Street fish weir, Boston	Stakes, woven material	5200BP	Banks 1990
Hawaii	Stone		McClenachan & Kittinger 2012
Sebasticook Lake fish weir in Newport, Maine	Stakes, woven material	5820BP	Miller 2006
South America			
Baures region, Bolivia	Earthworks, maze like zig-zag structure	335BP	Erickson 2000
South Africa			
Southwest Cape coast	Stone	2000BP	Gribble 1975
Middle East			
Bahrain	Stone, timber		Serjeant 1968
Qatar	Stone		Lockerbie 2013
Australia			
Brewarrina, NSW	Stone in maze-like shapes		Dargin 1976
Lake Condah, Victoria	Rocks, woven material	6000BP	McNiven 2012

The scale of some traps is quite substantial - the Wooton Quarr trap is one of the largest recorded, with stakes stretching 1.25 km at the low water mark. A similarly large site was identified in the Blackwater Estuary in Essex, UK with over 20,000 stakes identified across a river junction (Dix and Bull 2000). Records of other large traps include a stone shore trap at Llanon, Cardigan Bay (Lewes 1924:75) which is constructed in a V-shape (see Figure 1.2).

Figure 1.1 Fish traps - Begschenhoek, Holland, showing woven materials used in trap construction (O'Sullivan 2000)

Figure 1.2 Cardigan Bay, UK - large scale stone structures - note V-shape (English Heritage 1996)

In Ireland traps have been dated to 1000BP on the Shannon coast (O'Sullivan 2001) and at Lough Begg timber remains were also dated to 1000BP (Mitchell 1965:1). Later sites have been dated to the Medieval period in Ireland (500-600AD). In the UK, remains of fish traps of various types are one of the more common types of archaeological remains of past times (Bannerman & Jones 1999:1). A well preserved trap has recently been uncovered east of Rødbyhavn in Denmark. Again due to anaerobic conditions this trap is well preserved and is similar in construction to other timber stake traps - see Figure 1.3 (Lolland-Falster Museum 2013). Other coastal stone traps have been identified in areas as diverse as the Southwest Cape coast of South Africa (Gribble 1975:31), in the Bahrain area (Serjeant 1968) and in Qatar (Lockerbie 2013).

Section of wattle fence from fishtrap, Rødbyhavn in Denmark

Figure 1.3 Section of wattle fence from fishtrap, Rødbyhavn, Denmark (Lolland-Falster Museum 2013)

Designs of traps were influenced by the need to utilize natural features such as a spit or promontory or narrow and sometimes shallow sections of creeks or estuaries and were constructed from a range of available local materials such as wood, woven plant material, saplings or stone. The movement patterns of fish (especially salmon and herring) were also a major factor in trap placement (O'Sullivan 2004:454). Other examples of European fishing technologies include evidence from northern Neolithic sites in Holland that indicate the selective use of specific timbers such as Red Dogwood (*Cornus sanguinea*) in the construction of traps. In southern areas Willow (*Salix* sp.) and Hazel (*Corylus avellana*) were more common (Out 2008:1), again emphasizing the utilization of whatever material was at hand locally.

Studies from Russia, specifically the area known as Zamostje 2 near

Moscow, have identified and dated two large fish traps to around 7500 BP. These were constructed from woven pine rods and associated ropes. In addition, this site provided evidence of hooks, harpoons and moose-rib knives used to scale fish. Fishing in this area appeared to occur mainly in spring and early summer (Clemente 2012:1-3). Preservation of these otherwise ephemeral construction materials was facilitated as the items were buried in peat.

Figure 1.4 Zamostje 2 - Russia, showing structure of woven material (Clemente 2012)

In the USA at Boston, the Boylston Street fish weir enclosed over 2 acres (Banks 1990). At Newport, Maine, the Sebasticook Lake Fish Weir has been dated to around 5820BP (Miller 2006:5). Connaway (2007) has provided a detailed survey of fish traps along the Mississipi and elsewhere in the USA, clearly demonstrating the pervasiveness of traps over wide areas. Further afield, a trap site has been identified in Hawaii with evidence of long-term sustainable harvesting of fish resources via combination of social rules and behaviours and management strategies that assisted long-term sustainability of fishing (McClenachan and Kittinger 2012:239). In the Baures region of Bolivia zig-zag earthworks have been found, again indicating the use of maze-like structures. This site is an example of active management of the landscape via the construction of canals to redirect water flows and keep fish alive (Erickson 2000:193). Figure 1.5 illustrates the use of these Bolivian zig-zag structures to limit fish movements and this is similar to approaches used at Toolondo and Brewarrina where maze or zig-zag structures were also used. Perhaps the most interesting aspect of the wooden trap remains that have been unearthed in various areas of Europe and the USA is the similarity of design that appears to have continued over thousands of years and that the limited evidence of Australian timber traps are also similar to the European and American examples. It appears that once it was established this method of trap construction continued largely unchanged for long periods in many parts of the globe.

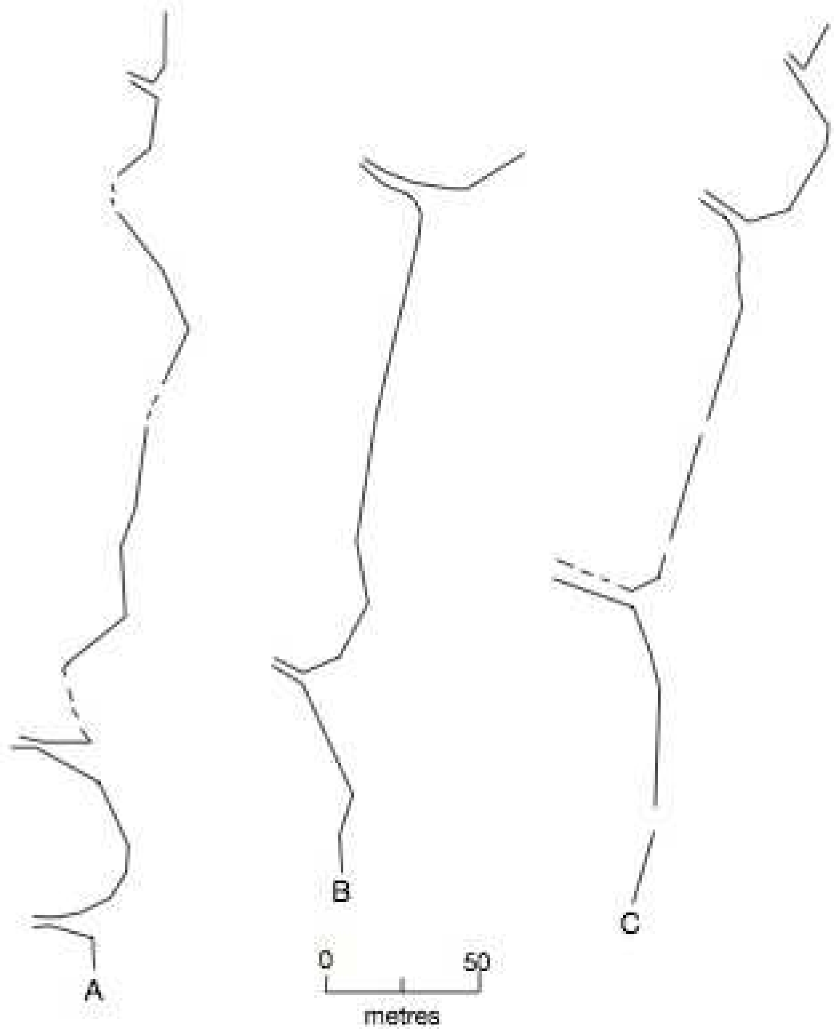

Figure 1.5 Baures, Bolivia - zig-zag structures to control fish movements (Erickson 2000)

1.3 Relationship between the fish trapped and fish traps

Inland fish traps are by their nature are passive devices. For a trap to work effectively it must be placed in areas where fish movements are reliable and predictable. Some species move long distance to spawn, for example movements of adult eels to the coast for spawning (Lintermans 2007:32), or the movements of Golden perch that can be stimulated by increases in stream flow (Lintermans 2007:72). For effective collection of fish, traps must be in operation at the correct times, either seasonally or as a response to stream flow changes. Movements of fish may also occur as tributaries dry out and it is not surprising that traps were set at lake and lagoon outlets, such as at Wagga Wagga (Gilmore 1933) and the outlet of Lake Bolac and Lake Buloke in western Victoria (Dawson 1881). Effective utilization of fish resources requires a good understanding of the seasons and what to do when streams rose or fell. To gain a better understanding of the role of fish traps in providing a food supply in the past it is important to identify the type of fish trapped at known sites as well as attempting to understand trap sites in relation to the time of year and seasonal patterns such as water levels that influence trap location and use. Closely linked to this are fish life history, movements and behaviour. For a fish species to be suitable as a target for traps it is more likely to have specific attributes including movement patterns (are they likely to move through trap areas), availability at different times of the year (are they subject to seasonal migrations such as salmon in Europe or eels in Australia), through to predictable behaviour such as returning to specific sites on a regular basis for feeding or spawning and hence more likely to pass through a trap site. At present little research has been published on fish ecology and behaviour in relation to Australian traps. Some work has been done in Europe where traps were known to be used for specific species such as salmon and herring (O'Sullivan 2004:455). In the Murray-Darling Basin likely fish species include Silver Perch, Golden Perch, Murray Cod and Catfish. Chapter 3 will examine fish species in detail.

1.4 The significance of fisheries for Aboriginal populations – food supply and social gatherings

Fishing has been a key resource over long periods of time and by providing a reliable food source, fish availability has had a significant impact on Aboriginal societies over long periods of time both in Australia and elsewhere. In Australia, there is ethnographic evidence that suggests a general correlation between language groups and key ecological zones, in particular such resource rich areas as coastlines, lakes and swamps (Dawson 1881:24; Louandos 1977:214). Overseas examples include the Baures earthworks in Bolivia where there is clear evidence that sufficient fish protein was reliably harvested over long periods to support dense populations in a savannah environment that otherwise could not have supported a large population (Erickson 2000:193). In the European region bone isotope studies of the Mesolithic diet indicate a move away from marine food resources only at the onset of agriculture in the Neolithic period in Denmark (Richards et.al. 2003:366).

It is a reasonable assumption that large-scale Aboriginal gatherings needed to be associated with a significant food supply. For example, gatherings of different sizes have been reported in various areas ranging from south-east Queensland where the Bunya nut provided a seasonal source of plentiful food allowing large gatherings of 600-700 in 1851 (Petrie 1904:19) through to reports of large gatherings (up to 5000) that have been recoded for the Brewarrina area (Mathews 1903) and also at Wagga Wagga (Gilmore 1986) and Lake Bolac (Dawson 1881).

1.5 Trap locations around Australia

Definitions

The term ‘aboriginal fish trap’ means different things in different areas (Gilmore 1986). The technology used varies widely. Iconic sites such as Brewarrina are often used as indicative of traps. However, the reality is that the technology of fishing varies substantially across different rivers, as well as in the varying aquatic environments of rivers, estuaries and marine areas (Roughley 1968; Rowland and Ulm 2011).

For the purposes of this thesis, fish traps are defined as structures designed to limit or redirect water flows to impede the movement of fish. Such structures may be constructed from one or more materials ranging from rocks, logs, saplings used as stakes, brushwood and earthworks. Some traps may be a combination of two or more materials, such as brushwood woven through stakes. In addition, a trap may be supplemented by the use of other techniques such as woven funnels or baskets, nets or in some cases poisons and fish may be driven towards a trap by groups of people moving through a stream in a line. Various words have been applied to traps in the literature (both historical and recent) and range from terms such as fish trap, fish weir, bough yard, yair, stream fence and fish station (Tindale 1931:74; Ross 2009:4).

Range of construction types

Traps came in many forms: stone weirs and walls, stakes, woven branches, deliberately fallen logs and earthworks (Gilmore 1986; Lourandos 1980:251; Welz 2002:49). It could be argued that the selection of such varying materials was largely opportunistic. The materials used of course influence greatly the likely remaining evidence of sites, if any (Colley 1987:2). Whatever was available was utilized. It is also important to note that various structures have been used not only to catch fish for immediate consumption, but also to keep them alive and fresh for harvest over long periods of time (Gilmore 1986). Structures such as pools, ponds, artificial weirs and baulks have been used in the past to redirect stream flows and hence fish populations, not only for immediate harvest, but also to keep them alive and fresh for later use. These structures may be constructed from rocks and soil, as well as brush or timber in various forms, ranging from stakes to logs. Examples of these include such sites as near Mount William in the Grampians and Toolondo and Lake Condah, both is southwest Victoria where earthworks have been used to redirect water flows, create artificial mazes and ponds to contain fish, and in the case of Lake Condah and Toolondo, eels (Lourandos 1980:250; McNiven et al. 2012:268-9).

1.6 Maze vs trap – sustainability of yields

When examining accurate plans of original traps, as well as the operation of the Brewarrina trap today, it is important to note that some traps were in fact mazes, not solid barriers - see Figure 2.12 for the original survey plan of Brewarrina (Matthews 1903) which clearly illustrates this, and this shape is still in existence and operational. Other examples are the structures at Lake Condah (McNiven et.al. 2012:272) and the structure of channels at Toolondo (Lourandos 1980:254). Similar maze structures have been recorded in Baures region of Bolivia (Erickson 2000). The progress of fish swimming through was limited by winding maze-like structures or dead-end channels allowing for ease of capture. But in many cases fish were not actually ‘caught’ by the structure and if no one was collecting them, fish would make their way out eventually (personal observations, Brewarrina). Similar constructs that allowed for effective trapping, but did not kill fish when the trap was not monitored also include the rock walls and earthworks combined with a funnel or other woven collector fitted to the outlet of the trap. When the woven material is removed fish can easily continue moving along the stream (Dawson 1881:94). This is an important factor to consider - Aboriginal people sometimes caught only what they needed - it was not a 100% catch, as was the case for later European fishing processes on the rivers that inevitably led to a crash in fish stocks (Royal Commission on Fisheries 1894-96:29).

1.7 Knowledge gaps

Some archaeological research has been undertaken in Australia in relation to coastal fish traps (Welz 2002; Ross 2009). A survey of Queensland trap sites, both inland and coastal has also been completed (Rowland & Ulm 2011). There have been studies of campsites and associated middens in various areas (Hiscock & Mowat 1993, Clune & Harrison 1999) as well as some work on fishing and midden evidence in the Murray-Darling Basin (Balme 1983).

Middens are frequently associated with coastal, estuarine and riverine sites and often contain a variety of materials such as fish otoliths, fish bones and molluscs (O'Connor 1993:779). Such material can be useful in attempting to establish not only fish species being harvested at a site, but also studies of age and size distributions can provide indicators to the types of harvesting methods being used. In a study of otoliths of Golden Perch and Murray Cod at four sites on the Darling river, measurements were used to estimate fish length. The resultant distributions at two sites indicate fish populations characteristic of the use of a gill net, whilst another site had distributions that favoured the likelihood of a trap being used. Generally a collection of small fish tends to indicate a net, whilst larger fish are more likely from a trap (Balme 1995:15). Given that the construction of nets and traps takes significant effort, these tends to favour an interpretation that fishing was a significant part of the food supply of the local population at the time. Apart from Balme, such detailed research on fish remains has been limited across the Murray-Darling basin. Various other archaeological midden studies have been done, but there has often been an inconsistent use of sieving which can have a significant impact on what is recorded (Jenkins 2006:52). A more recent study of otoliths at Lake Mungo (Long et.al. 2014) has not shed any more light on trapping methods except that some fish (Murray Cod) showed signs of oxygen stress indicating that they were harvested at the lake dried up. At the present time little information has been recorded of the range of fish likely to be harvested.

The type of research done so far on ancient fish traps has been largely archaeological in nature. Information is available on distribution, dating and technologies used, but only for a few sites across the Murray-Darling and elsewhere. More work has been done in Europe than elsewhere and dating data is limited at most sites. In Australia the best documented site is Lake Condah (McNiven 2012). To date nothing has been done to relate fish distributions, ecology and movements to trap sites, and little to determine the species likely to be caught in traps. Very little work has been done on the Murray-Darling Basin area in relation to traps, compared to Queensland (Rowland and Ulm 2011) or Victoria (McNiven et al 2012).

1.8 The Murray-Darling Basin

The Murray-Darling Basin covers approximately 14% of the Australian continent and its three largest rivers (Murray, Darling and Murrumbidgee) in total stretch over 6900km. In addition there are 21 other rivers draining the basin (Lintermans 2007:10). Although the rivers start in the highlands, most of the fish species are recorded in the lowlands of the basin where the landscape is flat and the rivers are slow-moving and meandering (Lintermans 2007:13). Generally, slow moving rivers are preferred for traps and weirs as fast moving streams tend to damage structures too easily. This pattern favouring less volatile tidal movement zones is also evident for coastal traps along the Queensland coast (Rowland and Ulm 2011).

1.9 Aims and structure of thesis

The purpose of this thesis is provide background information on fish traps across the world and then apply this knowledge to develop a better understanding of Aboriginal fish traps in the Murray-Darling Basin. Commencing with a summary of distribution data, this will be extended to associations with riverscape features and fish ecology. In addition, the relationship between Aboriginal meeting places and fish trap sites will be explored.

Chapter 2 describes the distribution of fish traps in the Murray-Darling Basin, along with riverscape features associated with traps, and the technologies used in their construction. Given that a large number of the fish traps were constructed from wooden stakes, brushwood, woven nets and similar organic matter, their features are unlikely to have survived in readily recognizable form, unlike the stone traps. A methodology will be developed to overcome this issue. In essence, a broad range of data sources will be accessed, including, but not limited to: historical records (for example traveller's reports, diaries, nineteenth century newspaper sources); published, as well as grey literature encompassing various archaeological survey reports and archaeological site descriptions and State and Federal Heritage Registers; ethnographic/anthropological studies, linguistic studies, i.e. language maps and analyses of Indigenous place names; and historical maps. These data will allow the construction of a map of fish traps and fish trap types across the Murray-Darling Basin.

Chapter 3 establishes what is known about the species of fish collected in traps in the Murray-Darling Basin, how they were collected and relationships with the ecology of the species. At present little is understood about fish traps in the riverscape – where they are situated, when they were used and the types of resources utilized - what can fish traps tell us anthropologically, archaeologically ecologically? For example: What species, sizes and life stages were targetted? Were they likely to target sedentary or mobile species? Were traps used all year round or only seasonally, or perhaps related to flow patterns? What riverscape features were important to builders of fish traps?

Chapter 4 determines the importance of fish in the food supply, its impact Aboriginal population structure and whether there are any relationships between the locations of fish traps and gathering places, such as Bora or Corroboree grounds and establish the significance of fish traps for these events. Given that any gathering of large groups of people requires sufficient food resources to be able to stay for any length of time, it is possible that fish traps were used to supply food for such groups. Utilization of old maps will also be used to determine possible trap locations. Using the data sets collected for aims 1 and 2, it will be possible to develop detailed map overlays of relevant data. Mapping software will be used to determine possible associations between river structure and fish species distribution along with gathering sites and language groups.

Chapter 5 provides and overview of results and suggests areas for further research based on the findings.

2 Location, structure and technology of fish traps in the Murray-Darling Basin

2.1 Introduction

Fish have been a key food source in Australia for long periods of time (Balme 1995:5) and a variety of techniques have been used to catch fish on inland rivers and along coastlines (Welz 2002:36; Ross 2009:1). While hooks, spears and other active fishing gear have been used, it is generally thought that the use of traps provides a more efficient method of maintaining a food supply (Balme 1983:30). Although passive devices, traps can enable the restriction of large numbers of fish with minimal effort once a trap is built. Traps can also work in conjunction with other methods such as poisons or nets, improving the efficiency of these tools (Colley 1990:222; Welz 2002:16). Other indirect benefits of traps include reducing the effort required to obtain food, thus freeing people up to pursue other activities such as searching for a broader range of foods or having time for cultural activities (Bowen 1998:40). Other indirect evidence points to changes in population structure for those groups relying on fisheries (Curr 1883:240), which tends to confirm the importance of fishing to Aboriginal groups over time.

In Australia, coastal and estuarine areas generally have a higher proportion of recorded traps than inland areas. For example, in Queensland only about 11% of recorded sites are on inland rivers (Rowland and Ulm 2011:50). Similar patterns have been recorded in South Australia, for example on the Eyre Peninsula alone, 61 coastal traps have been recorded a very high density, even compared to northern Queensland (Welz 2002:36). This pattern of higher numbers of coastal traps is in evidence in a variety of other regions across the world (Connaway 2007:20) and this pattern of trap distribution is reflected in the Murray-Darling Basin where a variety of trap sites have been recorded on all the major river systems, but not in the densities recorded from coastal areas ranging from Queensland to South Australia and various areas in Europe. In Australia freshwater trapping sites have been less studied than coastal sites, where several detailed studies have been undertaken (Welz, 2002; Ross 2009; Rowland and Ulm 2011; Dortch 2012). This thesis aims to redress this imbalance by examining a range of freshwater sites across the Murray-Darling Basin.

A variety of riverscape features are associated with trap sites. These include anabranches and lagoons, such as at Wagga Wagga (Gilmore 1934) through to tributaries where fish can be easily confined by blocking off the exit points through to sections of open river, generally where it is shallower, such as at Brewarrina and Balranald (Dargin 1976) as well as in lakes such as Lake Tandou in NSW (Balme and Hope 1990:12) and Lake Bolac in Victoria (Dawson 1881:94). Certain types of riverscape were favoured for trap sites, with the most common being features that provided ‘choke points’ to restrict fish movements such as tributaries and anabranches or in relatively shallow sections of the main riverbed.

In addition to describing and mapping the distribution of traps, it is important to consider the technologies utilized as choice of technology is closely related to sites, and construction materials have a major impact on survivability of evidence as well as the likely species caught. It is also important to consider the use of multiple technologies such as enclosures coupled with funnels, baskets, nets, spears or in some cases poisons. Traps are basically passive structures that limit fish movements, but the actual catching process may also use additional tools such as poisons, nets or spears (Colley 1987:19). Trap construction is remarkably similar across the world and is generally opportunistic in nature, utilizing a variety of locally available materials and built in a variety of different shapes depending on the local riverscape features that could be incorporated into the structures (Connaway 2007:23). In the Murray-Darling Basin materials used are largely whatever is readily available in the area. Thus rocks, brush and logs were commonly used, and at times earthworks were also employed (Beveridge 1889). Apart for outliers, such as Toolondo and Lake Buloke in Victoria where substantial earthworks were developed, a majority of traps were built from plant materials or rocks (Lourandos 1980:251). To create effective traps without significant labour inputs riverscape zones with narrow sections such as entry/exit points of anabranches or tributaries where small stream fences or ‘bough yards’ were constructed to stop fish movement. Given the rough nature of most brush obstacles, such structures would only retain larger fish species.

Given the ephemeral nature of a lot of trap material, there has been very little dating of traps in the Murray-Darling or elsewhere in Australia. Some attempts have been made to date traps by using environmental contexts such as tide levels and the age of sandbars in coastal areas (Dortch 1997:28). However, such methods only manage to set a maximum point beyond which a trap could not function, not a reliable date of when a trap was actually constructed. Pollen studies have also been used as well as the collection of sediments from beneath rock structures at Lake Condah (McNiven 2012:281) and from fish remains at midden sites associated with traps such as Booral in Queensland (Frankland 1990; Bowen 1998). There are still many unanswered questions about dating, such as placing trapping technologies into a context - how long ago were traps first established and if the Australian experience has parallels overseas.

Aboriginal occupation of New South Wales has been traced back at least 50,000 years at places such as Lake Mungo (Bowler 2003:837) and at least 30,000 years along the Darling River at sites such as Lake Tandou (Balme 1995:4). Camp sites, gathering places, middens, burials and fish traps are widely spread throughout the area, both along the rivers as well as in the more drier parts of the landscape (Bowdler 1999:22). To date no synthesis has been undertaken of the role of fish traps across the basin and this research is aimed at exploring the role of traps and their impact on indigenous groups across the Murray-Darling Basin. In addition, parallels will be drawn with overseas areas to assist with understanding construction and operation of traps.

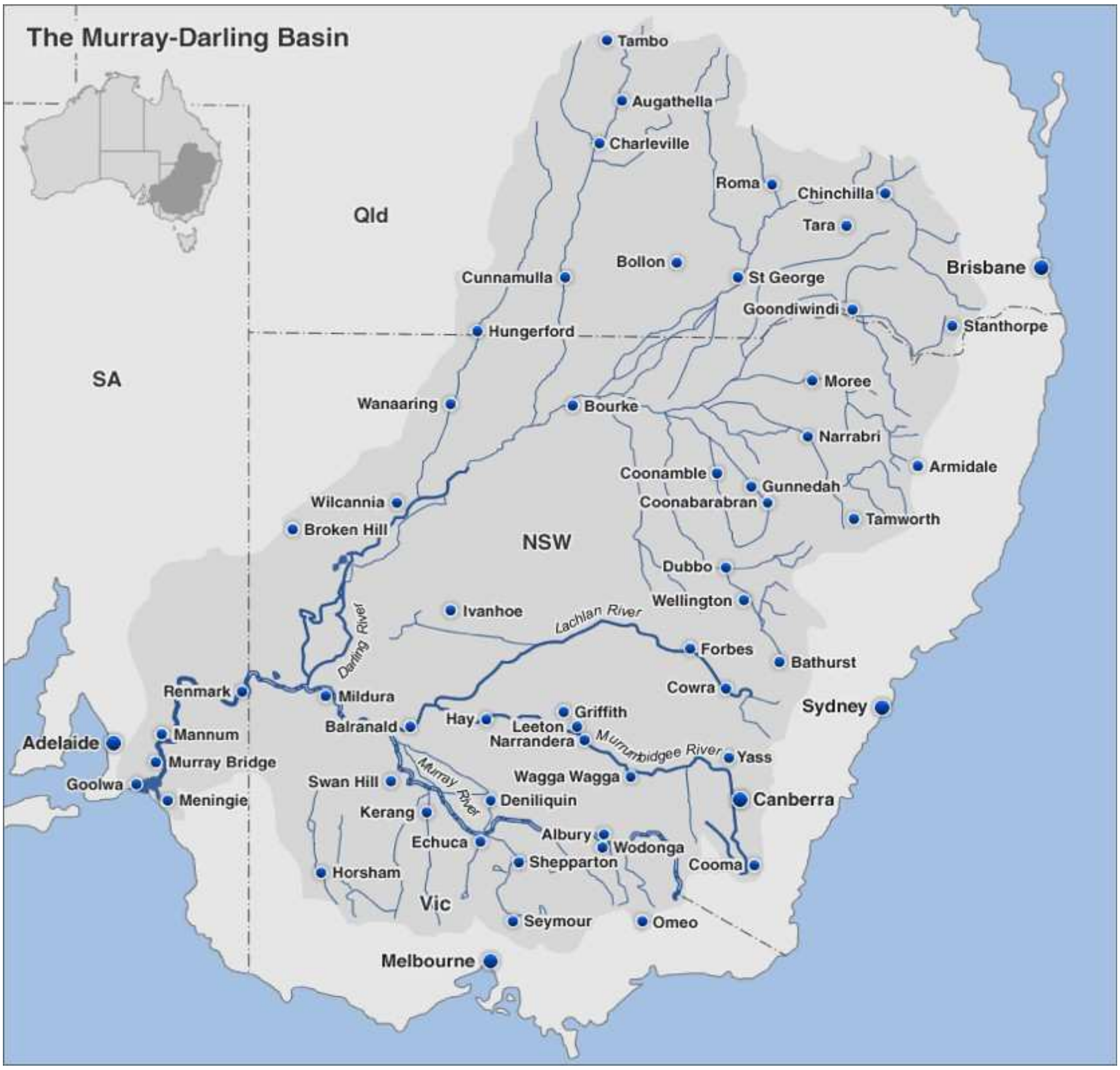

Figure 2.6 Map of the Murray-Darling Basin (MDBA 2009)

The basin encompasses over 1 million square kilometres or approximately one-seventh of the Australian landmass. Agricultural production is widespread and includes around 40% of all Australian farms (Murray-Darling Basin Authority 2012). Extensive development of farming has resulted in significant changes to the environment over time. Seventy five percent of Australia's irrigated crops and pastures are grown in the Basin. Sources of the water in the Murray-Darling river system originate from a very small percentage of the Basin area - mainly along the southern and eastern rim. Around 85% of the vast 'catchment' area contributes very little or no regular run-off to rivers. The rivers have very low gradients over most of their length, which cause them to flow slowly as they meander across the vast inland plains, and to spread widely at times of flood. Some of Australia’s longest rivers run through the Murray-Darling Basin - the Darling (2740 km), the Murray (2520 km) and the Murrumbidgee (1575 km). It encompasses a wide range of climatic conditions and diverse landscapes that range from sub-tropical areas in the north to cool alpine country in the east to the hot and dry semi-arid and arid western plains that comprise the main part of the basin. At least 35 different native fish species have been recorded from the area (Murray-Darling Basin Authority 2012).

The aims of this chapter are to: 1/ determine the distribution of fish traps in the Murray-Darling Basin; 2/ describe the riverscape features associated with fish traps; 3/ describe the structure of traps and how they operated; 4/ describe the technologies used in their construction and operation; 5/ survey dating of trap sites and 6/ review other techniques used to catch fish that may be linked to traps.

2.2 Methods

Sources of information

Reliable, verifiable, quantitative information about conditions in the Murray-Darling before approximately150 years ago are rare. By this time, Aboriginal populations had already declined and land use patterns had changed considerably from what they had been before European settlement. Prior to that, it is necessary to rely on opportunistic and anecdotal evidence (Table 2.2). Data of this type lacks the formality of scientific method, but it is often the only source of information to begin to reconstruct earlier times. A single observation of this type cannot be relied upon, but use of multiple lines of evidence allows a picture of Aboriginal life along the rivers to be developed. Information from analogous situations elsewhere in the world can also assist in identifying possible site remnants, as well as giving insight into how the technology of fish harvesting and management operates.

Search terms

Initial searching was performed based on the range of potential descriptive terms for fish traps (Table 2.1). Traps have been referred to by many names in the literature, from the descriptive and obvious (e.g. 'fish trap') to the vague (e.g. 'traditional fishing'), and search terms were refined as searches proceeded. Databases searched included state and national ones and involved searching newspapers, and a range of other sources from the time. These sources of evidence are summarised in Table 2.2.

Table 2.2 - Search terms for Aboriginal fish traps

Term	**Variations**	**Notes**
aboriginal fishing		
aboriginal gatherings	aboriginal corroboree	
bora	bora ring	
bough yards	boughyards	Potential location guides
corroboree	gatherings	
fish + earthwork		
fish + weir		
fish + balk	baulk	
fish maze(s)		
fish nets	netting	
fish trap(s)	fishtrap	
fish + funnel		Middle East term
indigenous fishing		
native fishing	indigenous fishing	
native fish mazes	indigenous mazes	

stone arrangements	
stream fence(s)	
traditional fish trap(s)	
traditional fishing	
yairs	Scottish term (‘yard’)

Given that a large number of the fish traps in the Murray-Darling Basin were constructed from wooden stakes, brushwood, woven nets and similar organic matter (Mitchell 1848; Gilmore 1986; Curr 2001), their features are unlikely to have survived in readily recognisable form, unlike the stone traps and earthwork channels. To allow for this, a methodology has been developed, whereby a range of data sources has been accessed. These sources of evidence include: 1. Primary historical documents (for example explorer’s journals, traveller’s reports, diaries, nineteenth century newspaper sources; 2. Archaeological reports including published as well as grey literature encompassing various surveys and archaeological site descriptions both of the basin and elsewhere along with State and Federal Heritage Registers and ethnographic/anthropological studies, linguistic studies and 3. A range of map resources ranging from early pastoral and parish maps through to more recent maps of fish distributions, riverscape features and river navigation maps as well as Aboriginal language maps and analyses of Indigenous place names. This range of data sources allows for the cross-checking of sources as well as allowing for the building of more detailed trap distribution maps and their associated riverscape features. These data allow the development of maps of fish traps and fish trap types across the Murray-Darling Basin. Given the ephemeral nature of a lot of traps, existing physical evidence is limited or non-existent. However, records from a variety of sources have been used to build up an overview of identifiable sites across the basin (Table 2.2). Where possible identified sites have been verified from two or more sources to confirm accuracy.

Table 2.3 - Sources of evidence

Source	Notes
Original accounts (primary sources)	
Explorers journals (published and unpublished)	
Royal Commission and government reports	
Other reports (e.g. Robinson, Matthews, surveyors)	
Art work (e.g. Blandowski)	
Newspapers reports	
Earlier settlers documents (e.g Gilmore, Curr)	Wide ranging evidence of location and materials used
Old maps and survey documents (e.g. Matthews)	Detailed surveys of Brewarrina, Lake Condah
Photographic records (TROVE, NLA, Photographic indexes)	
Archaeological reports	
Early Australian ethnological studies	Relevant for technologies, locations
Reports of bodies such as catchment management authorities and indigenous organizations	Useful for fish distribution
Peer-reviewed papers via library databases	
Surveys of known trap sites	
Dating studies	Overview studies
English Heritage	Comparative overseas data
Scottish Heritage	Comparative overseas data
Map data sources	

NSW historical Pastoral and Parish Maps	Trap sites
Riverboat navigation maps River Murray charts Local historical societies National Library of Australia State Library of Victoria	Potential trap sites
Heritage databases	NSW- AHIMS, Vic- VAHR, Qld- ICHD
Google Earth	Current river data
Murray-Darling Basin Authority	Fish distribution
Geosciences Australia	Current river data

Trap distribution cannot be viewed alone, as the choice of technologies utilized is closely related to trap sites, and different tools can be complementary. For example, a weir may confine fish to a billabong or river section, but then baskets, funnels, poisons, spears or nets are used to actually collect them. Simply knowing that a trap existed at a specific location is only part of the picture - how the trap operated is also significant as it has a bearing on identification of evidence as well as understanding likely target species. Contents of middens can also be related to the technologies. For example, recent midden studies at Barmah have shown a large preponderance of small fish, which raises the question of the use of nets at such a site (Humphries personal communication). Particular fishing technologies are suited to some locations more than others, probably because of landforms and available construction materials as well as the effectiveness of different technologies and/or the distribution of fish species. For example, poisoning is restricted to areas of water such as lagoons (Ghaleb 1990:165), because flowing rivers or creeks would quickly disperse any poisons in the water. To date, much archaeological evidence from middens is limited and inconclusive. However, it may be used as an indicator of certain fishing techniques (such as nets or poisons) when viewed in conjunction with the broader riverscape - for example if the midden is associated with a site that lends itself to fencing off fish, such as a lagoon, where nets or poisons may have been utilized 9Jenkins 2006:53).

Distribution of traps

Mapping data collected from sources such as the Murray-Darling Basin Authority, Geosciences Australia, heritage databases in each state and NSW government historical pastoral and parish maps has been organised using the ARCGis software , incorporating layers of location, river system, climate, geology, vegetation type, fish species distribution and language groups. Utilizing mapping overlays, it is possible to establish which fish species were present at known trap sites as well as identifying some of the common features of known trap sites.

Dating of traps

Various methods of dating have been reviewed to gain an overview of what is currently known about trap chronology both in Australia and elsewhere. This has included radiocarbon dating of pollen sequences from sediments to determine date ranges when trapping would have been possible (Dortch 2002:13), dating from associated geological features such as sand bars (Dortch 1997:20) and dates from other associated items such as midden contents (Balme and Hope 1990:88) and charcoal extracted from sediments beneath trap features (Lourandos 1980:253). Overseas data has also been used as a basis of comparison to determine if Australian dates at variance with overseas findings (Connaway 2007:18).

Associated fishing methods

Evidence from midden studies is examined to try and get an idea of both fish size and species distributions. For example, some sites contain large quantities of fish remains of similar size. A possible interpretation of this is that this is evidence of a single catch event, probably by nets which may have been related to fish already restricted in a river section by a trap. If such a collection was the result of harvesting from pools, such as during a drought as the river dried up, then a range of fish sizes would be expected, not a relatively homogeneous grouping. When other sites in the same area of the Darling were examined, such even distributions were not found, further favouring a trapping/netting collection event (Balme 1995:15). As traps are often physical barriers to movement rather than actual catching mechanisms, it is important also to review a range of methods used to actually catch fish as these approaches are likely to have been used in conjunction with the physical barriers of traps. Thus a variety of these associated techniques are reviewed in relation to their ability to assist with trap function.

Survivability of evidence

Given the types of technologies used, many of which are ephemeral in nature such as organic materials, it is worthwhile to review the potential for items to survive in the archaeological record and this is summarised in Table 2.5, as this will have an impact on the possible archaeological record at sites. Organic trap remains have been recorded in both European and the USA in relation to organic material based traps, mainly due to anaerobic conditions in water-logged soils (Out 2011:212). Although not directly related to the Murray-Darling Basin, this data does provide an indication of how such traps were constructed and this can be compared with Australian data to provide a clearer idea of design. At present little has survived in the Australian archaeological record of traps built from plant materials apart from some drawings and photographs. However, evidence from European and American sites tends to confirm that designs were very similar. Thus a review of overseas data can provide insights into what trap looked like, and the type of materials that have survived over time.

Table 2.4 - Potential archaeological record (after Roughley 1968, Colley 1987)

Fishing Method	Material used	Likely survival
Basket/Cage	Woven material	Only in anaerobic conditions (Evidence from Europe, USA)
Stream fence	Stakes	Only in anaerobic conditions (Evidence from Europe, USA)
Boughyard	Branches, stakes	Only in anaerobic conditions (Europe, USA)
Maze	Stone, stakes	Earthworks
Weir	Rock, earth, log	Stone, earthworks
Hook/line	Bone, plaited matter	Bone hooks
Spears	Wood, stone	Stone points

A review of studies has been done on archaeological fish assemblages in Europe and Australia. Studies of Mesolithic deposits in Denmark concluded that the deposits and been strongly influenced by differential preservation (Noe-Nygard 1983:125). Similar studies in Tasmania at Rocky Cape have also shown varying deposit patterns (Colley 1987:24). Thus any archaeological data on fish assemblages associated with trap sites must be viewed with caution as the remaining archaeological evidence is likely to contain only the more resilient materials, not necessarily providing a complete record of species utilized.

The significance of these findings is that it provides a guide as to what is likely to be available and how accurate such data is likely to be.

2.3 Results

Distribution of trap sites

Traps sites are distributed widely across the Murray-Darling Basin, along main rivers and on numerous tributaries and anabranches. Results are summarized in Table 2.1 and Figure 2.2. In total, 21 trap sites were identified in the basin (Table 2.1, Figure 2.2). Of these only one (Brewarrina) is still extant in a functioning state. A few, such as Balranald and Toolondo have limited identifiable remains, mainly earthwork remnants. As the bulk of traps were constructed from saplings and branches (see Figure 2.5) this is to be expected. In relation to location in the riverscape, about half the traps were located on main rivers, whilst the balance are distributed along tributaries and anabranches. Traps off the main rivers are more likely to be variable in their use as such places are more dependent on flooding for flows and subsequent fish movement.

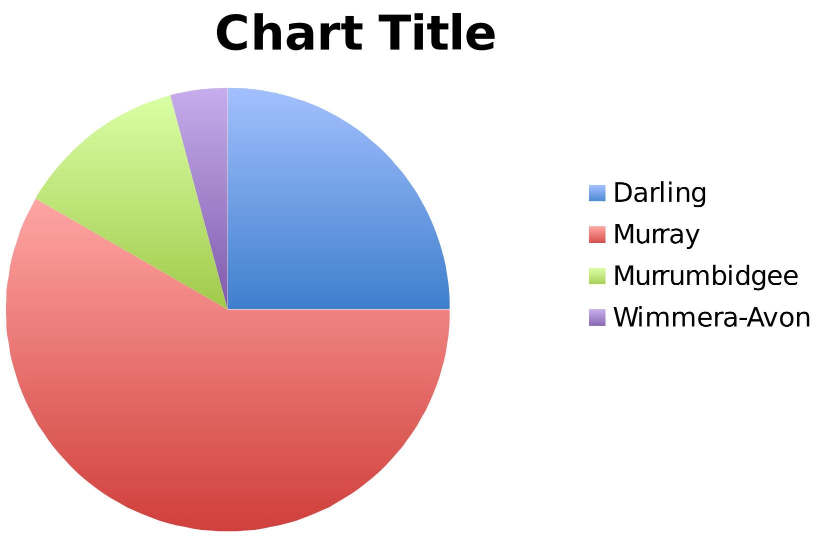

Figure 2.7 - Traps by river system

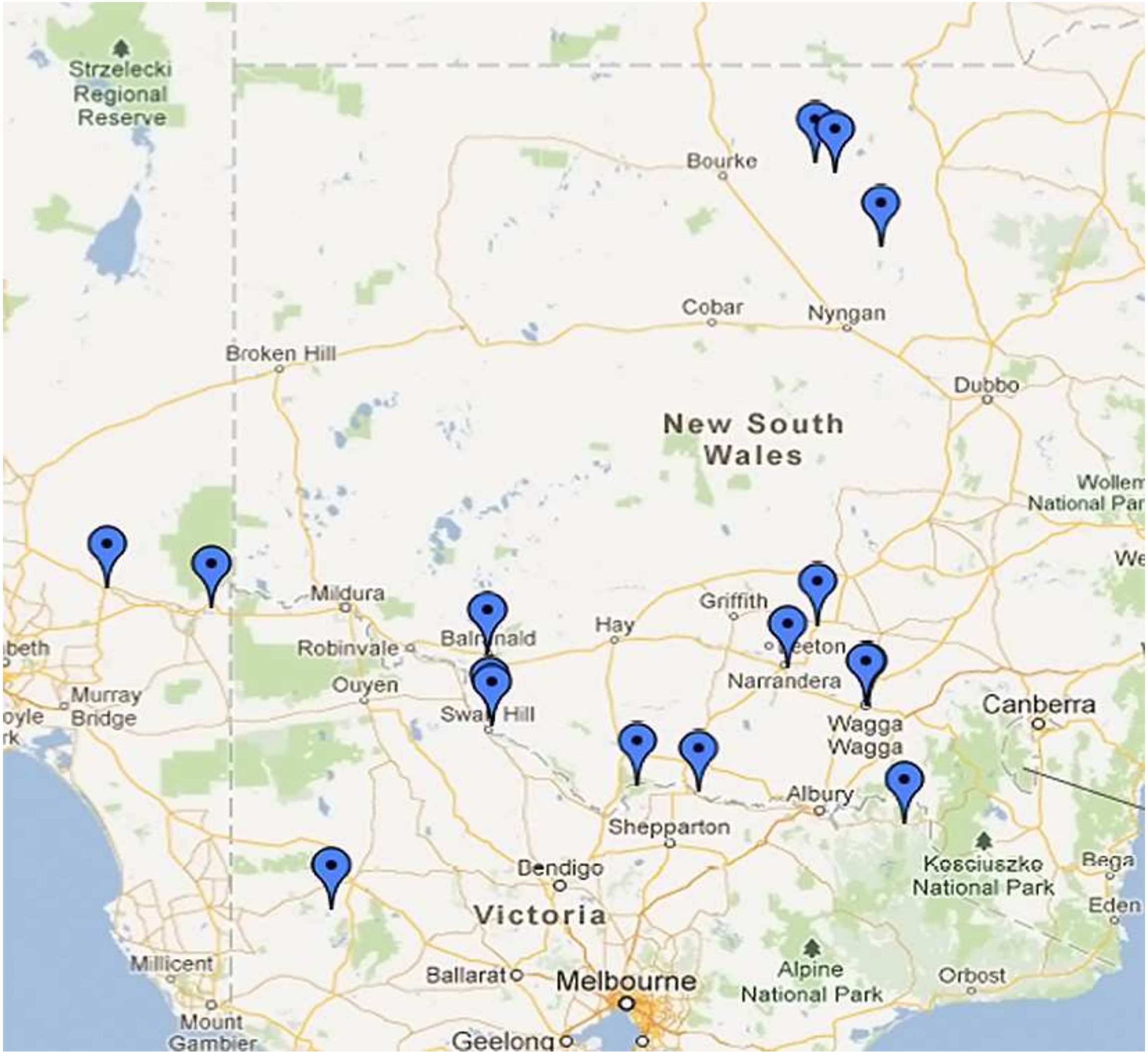

Figure 2.8 - Overview of trap distribution in the Murray-Darling Basin

Riverscape features of fish traps

The map in Figure 2.2 clearly illustrates that traps are widely dispersed across the landscape. A majority of the traps (9) are in the Murray system and its tributaries, reflecting that it is the largest and most reliable of the main rivers. The Darling system has six trap sites and the Murrumbidgee three. The Wimmera-Avon system has one identified site. Locations of traps in the riverscape (see Figure 2.4) are fairly evenly divided between main river sites and tributary streams (9 each) with four being located in anabranches/lagoons.

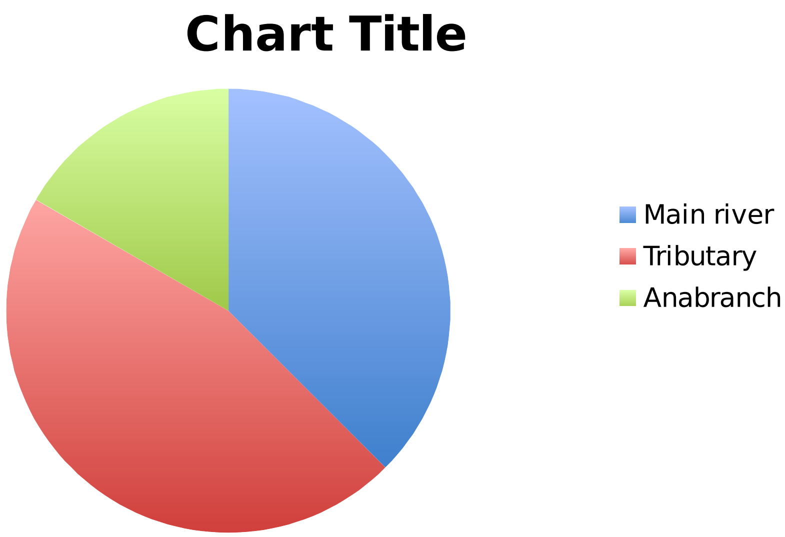

Figure 2.9 - Proportion of traps by riverscape type

Table 2.5 - Summary of identified trap sites in the Murray-Darling Basin

Site	River detail	Material	River System	Notes	References
Albury	Murray river at bends	Rock structure across stream	Murray		Parish map Albury Council Archaeology report
Ardelthan	Mirool and Yanjerry Creeks	Mix of logs, brush, stakes on tributaries	Mirool - tributary to Murrumbidgee	Last seen in 1880. Numerous on various tributaries	Trueman:2011 Gilmore:1934
Balranald	Murrumbidgee downstream of Balranald	Rock and earth	Murrumbidgee		Parish maps AIHMS record

Barmah	Boughyards	Similar to boughyards downstream at Swan Hill Use of earthworks	Murray	On Country presentation - Yorta Yorta	Mitchell:1838 Curr:1883
Brewarrina	Barwon upstream of Darling	Rock	Barwon (Darling)	Aboriginal names: 'Nonah', 'Ngunnhu' Last recorded use 1899	Hope and Vines:1994 Dargin:1976 Matthews:1903 Sturt:1833
Cudgewa Creek	Near Kalangee and Lucydale	Brush and saplings	Murray - tributary	Higher altitudes	Trueman:2011 Carmody:1981 VAHR - DPI map
Cunnamulla 1	Belonne River	Rock	Darling tributary	Destroyed 1949 to build weir	Richardson:1983
Cunnamulla 2	Nebine River	Rock	Darling tributary	Destroyed 1980	Richardson:1983
Deniliquin	Billabong - Edwards Lagoon	Logs, branches 6-8" saplings	Edwards - lagoon, anabranch of the Murray	Utilized billabong Logs with woven branches	Gilmore:1933
Gwydir and Barwon	Gwydir and tributaries		Barwon (Darling)	Elaborate wooden structures, Trellis type of woven brush	Mitchell:1832 Trueman:2011
Macquarie Marshes	Creeks and anabranches of main river	Stakes, branches Vertical stakes woven with horizontal sticks and branches	Macquarie-Bogan - anabranch (Darling)		Trueman:2011 Sturt:1833
Lake Bolac	Creek outflow from lake	Rocks, woven baskets	Murray	Primarily eels	Dawson 1881 Robinson 1841
Lake Buloke	Creek outflow from lake	Rocks, woven baskets	Murray	Primarily eels	Dawson 1881 Robinson 1841
Moira area (Cobram)	“Boughyards”	Saplings and brush across various tributaries	Murray	Woven brush - 'Boughyards" Owned by specific families and allowed semi-permanent occupation of area Similar to those described by Mitchell near	Curr:1883

				Swan Hill	
Narran River	Angeldool, NW of Brewarrina	Stakes	Darling tributary	Stake fence across stream	Mitchell 1848
Morgan	Across creeks and billabongs	Earth, stakes	Murray - tributary	Two on Markaranko Station north of Morgan	Trueman:2011 Gilmore:1895
Narrandera	Bundidgerry Creek	Stakes Earthworks	Murrumbidgee - tributary	Narrandera Reserve Bundigerry Creek upstream of Narrandera	Gammage:2006 Gilmore:1933
Renmark	On anabranches and billabongs		Murray	Earth, stakes, branches	Trueman:2011 Gilmore:1895
Robinvale-Mildura	Anabranch of the Murray	Stakes, branches	Murray - anabranch		Argus: March 30 1850 Beveridge:1889
Swan Hill	"Boughyards"	Saplings and branches	Murray	Described as fences or boughs ('bough yards'). Used extensively by Yorta Yorta	Mitchell:1838
Toolondo	Swamp management	Earth	Wimmera-Avon	Eels Specialized swamp management - known only from limited areas. Also at base of Mt William (not Murray-Darling basin) Complex artificial drains of 3km draining swampy ground between two swamps. Two swamps straddle north-south drainage systems	Lourandos:1976, 1980 Massola:1962 Robinson:1841 VAHR - DPI map
Tyntynder	Tributaries of Murray	Saplings	Murray	Closely driven stakes across drains and tributaries	Beveridge:1899
Wagga Wagga 1	Parkan Pregan Lagoon	Logs, branches 6-8" saplings	Murrumbidgee - lagoon	Large trees used as barriers across	Gilmore:1933

				entrances of lagoons. Interlaced with small branches	
Wagga Wagga 2	Wollundry Lagoon	Logs, branches	Murrumbidgee - lagoon		Gilmore:1933

Trap structure and operation

In many cases fishing involved a combination of technologies and methodologies. For example weirs (of earth or wood) were used to confine fish to limited areas (Curr 1883). Then spears and/or nets were used to actually catch the fish. Similar behaviour continues to this day at Brewarrina, where the maze-like structures slow down fish allowing the use of nets to actually catch them (Personal observation, 2012). Thus a detailed consideration of associated fishing technologies is an important part of any discussion of fish traps.

Trap construction

As can be observed from Figure 2.5, a variety of materials have been used in the construction of traps ranging from rocks through to earth and various plant materials. Saplings and brush are by far the most common material, but these are also the least likely to survive.

Observations of the various areas where traps occur leads to the conclusion that construction is opportunistic, depending on local availability of materials. Overseas studies indicate that traps and weirs are widespread in many parts of the world - there are examples from examples: Sweden, Scotland, USA, Russia (Bannerman and Jones 1991:1). Construction materials are opportunistic and designs are similar across the world (Connaway 2007).

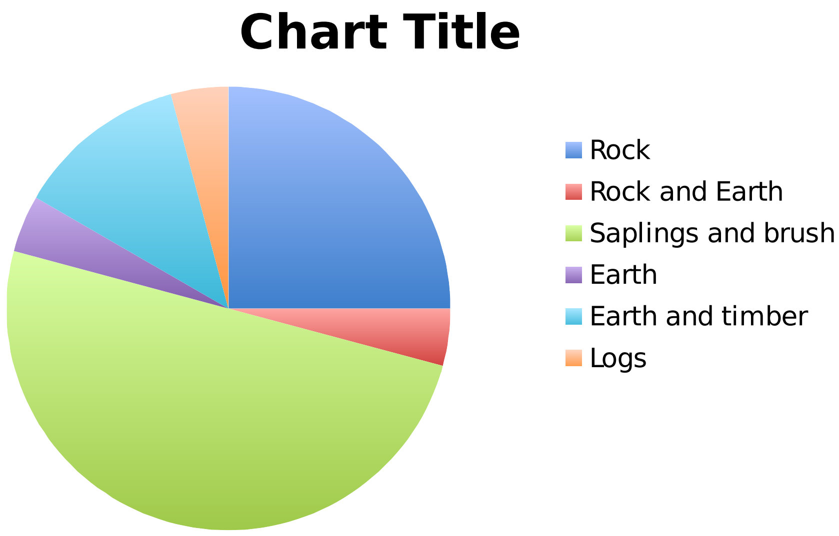

Figure 2.10 - Traps by type of construction

The most common type of trap is constructed from saplings and brushwood. Generally, saplings were driven into the stream bed to create a fence. Often this was reinforced by weaving horizontal cross-pieces through the vertical stakes (see Figure 2.6). This trap is a relatively late example of a trap fence from Lake Condah as older timber structures would have rotted long ago. Figure 2.7 shows a 1900 image of a larger sapling trap still extant in the Murray River in Western Australia. This image does give a good idea of how larger traps would have looked on the main rivers (Western Australian Museum collection).

Figure 2.11- Lake Condah woven stakes (McNiven 2012)

Several overseas trap sites have been recorded with surviving organic material - for example in the USA, Denmark, Holland and Russia. In each case, the shape and materials have significant similarities with known Australian traps. It is likely the design and operation is very similar across the globe.

Figure 2.12 Murray River (WA) trap in 1900 (Western Australian Museum collection)

Sometimes this row of saplings ran straight across the stream or may have been in a V-shaped structure. Figure 2.8 provides a schematic view of the stream fence. Nets were used in conjunction with the fence to collect fish. Traps of this type are likely to be high maintenance as floods would tend to damage them, as well as timbers rotting over time.

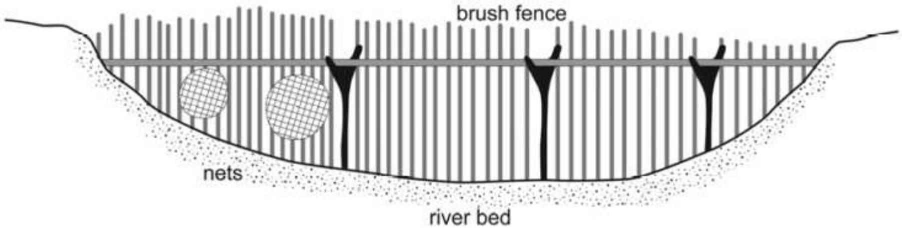

Figure 2.13- Cross section of trap fence similar to the trap shown in Figure 2.7

(Western Australian Museum collection)

Traps are known to have used a variety of different shapes ranging from straight lines of stakes through to V-shaped structures along with earth banks, channels and mazes.

Extant traps

Observations of functioning traps would be extremely useful in improving understanding of how traps operate. However, the only fish trap in the study area that is still operational is the Brewarrina trap. Photographic evidence from 1900 (Dargin 1976) clearly shows Aboriginal children holding Golden Perch caught at that site. Personal observations in September 2012 indicate that children are still catching Golden Perch at this site - a remarkable indicator of continuity. During my observations the only other fish species observed was the introduced European carp. It also moved through the trap site, but the children actively catching fish ignored these fish, preferring to target only the perch. Lack of any other functioning traps in the study area does limit understanding via direct observations. However, by incorporating knowledge of fish behaviour and movements it is possible to gain a clearer understanding of fish species likely to be utilized. This is covered in detail in chapter 3.

Trap operation

Riverine traps are by nature a passive device, creating barriers to the movement of fish, either by slowing down movement via mazes, for example at Brewarrina (Dargin 1976) and Toolondo (Lourandos 1980), or by blocking movement altogether via the placing of a barrier across a lagoon, such as at Wagga Wagga (Gilmore 1933) or via fences across tributaries to prevent fish already upstream from returning to the main channel, such in the Moira area (Curr 1883). Unlike coastal and estuarine traps, which rely on daily tidal movements, inland traps must rely on fish movements. Such movement may be the result of spawning behaviour, homing patterns or related to changes in river flows such as floods. To try and fully understand the operation of fish traps requires knowledge of fish ecology and behaviour. A trap is not a random way to collect food. To use it effectively you need to understand fish behaviour - movements, times of the year, impact of floods and seasonal changes in river levels. Also, the amount of energy that you put into the development and use of the technology needs to be commensurate with the returns. For example, Curr (1883:240) records how the Wongatapan people of the Moira area found fish catching by lines of people in the water very physically demanding in cold weather. For long-term survival the energy expended cannot exceed the energy gained in food calories. This is covered in detail in chapter 3.

There are two useful first-hand accounts of Aboriginal fishing in western Victoria by Robinson (1841) and Dawson (1881) that are worth examining as they give a clear idea of how groups of people co-operated in forcing fish towards traps and how a funnel is used as part of the stone trap. Lake Buloke is very similar to Lake Bolac in the Murray-Darling and trapping is known to have occurred along the outlets of both lakes. Lake Colangulac and the Kilgower traps are also outside the basin.

"The small fish, 'tarropatt,' and others of a similar description, are caught in a rivulet which runs into Lake Colangulac, near Camperdown, by damming it up with stones, and placing a basket in a gap in the dam. The women and children go up the stream and drive the fish down… Eels are prized by the Aborigines as an article of food above all other fish. They are captured in great numbers by building stone barriers across rapid streams, and diverting the current through an opening into a funnel-mouthed basket pipe, three or four feet long, two inches in diameter, and closed at the lower end. When the streams extend over marshes in time of flood, clay embankments, two to three feet high, and sometimes three to four hundred yards in length, are built across them, and the current is confined to narrow openings in which the pipe baskets were placed...Lake Boloke is the most celebrated place in the Western District for the fine quality and abundance of its eels; and, when the autumn rains induce these fish to leave the lake and to go down the river to the sea, the aborigines gather there from great distances. Each tribe has allotted to it a portion of the stream, now known as Salt Creek; and the usual stone barrier is built by each family...For a month or two the banks of the Salt Creek presented the appearance of a village all the way from Tuureen Tuureen, the outlet of the lake, to its junction with the Hopkins" (Dawson 1881:94)

Another similar historical record, although outside the Murray-Darling, is that of Lake Colangulac near Camperdown Victoria, where the outlet streams were blocked by stone structures with a basket in a gap in the stones to catch the fish. People (generally women and children) then moved downstream forcing the fish towards the stone dam (Dawson 1881:94). Dawson also adds that in marshy areas or times of flood, earthen walls often stretching 300-400m were built to redirect flows via a single outlet where fish were trapped.

What can be learned from the above commentary is significant: 1./ the use of traps plus woven funnels to catch fish; 2./ the use of co-operative groups to shepherd fish towards a trap and 3./ the significant effort put into earthworks as part of water management. This co-operation extends to sections of the creek being divided up between different family groups. Also of note are the seasonal importance of the eels and the scale of the exploitation process.

The second description is provided by Robinson and describes a riverine trap on the Port Fairy River (now known as the Moyne) in 1841. This description is useful in that it provides good detail on the construction of the trap – in this case a hybrid of rocks, stakes and woven pot. It also shows how the trap actually functioned. Although again this is outside the basin, it does give a clear insight into trap design and function. They also match description by Curr and others (see below).

"The country at Kilgower is but slightly elevated above the sea. Kilgower is on the [blank] or Port Fairy River...He...took me to a very fine and large weir and went through, with several other of the natives, the process of taking eels and the particular spot where he himself stood and took them. I measured this weir with a tape, 200 feet; five feet high. It was turned back at each end. The eel pots are placed over the holes and the fisher stands behind the yere.roc or weir and lays hold of the small end of the arrabine or eel pot. And when the eel makes its appearance he bites it on the head and puts it on the lingeer or small stick with a knob at the end, thus or, if near the bank, he throws them out. The fishing is carried on in the rainy season. Arrabine or eel pot made of bark or plaited rushes with around mouth and having a small end to prevent the eel from rapidly getting away.

These yere.roc or wiers are built with some attention to the principles of mechanics. Those erected on a rocky bottom have the stocks inserted in a grove made by removing the small stones so as to form a grove. The wier is kept in a straight line. The small stones are laid against the bottom of the stick. The upright sticks are supported by transverse sticks, resting on forked sticks as shown above. These sticks are three, four or five inches in diameter. Some of the smaller wiers are in the form of a segment or circle. The convex side against the current" (Robinson 1841).

Maze structures served to slow down fish allowing easy capture, a good example being that of Brewarrina. Equally, the narrow channels of Toolondo also served to restrict eel flows. However, there is no point in having a maze if there are no suitable fish that will readily enter such narrow confines. And it was also important to know the times of the year (or trigger events such as flood) that it is best to catch fish. For example, if fish are not moving along a river, then a trap will not be of much use. An interesting aspect to consider is that many traps were not 100% in their kill impact. In fact, very high kill rates, or elimination of young or breeding stock would result in a rapid reduction in food supplies over time. Hence, a maze that did not kill if no one was around to collect the fish would in the long term tend to guarantee a reliable supply of food. Too much killing is counterproductive in the long run. The same can be said for the trap structures for eels described by Dawson – without the funnel the eels are free to move on and again there is no 100% kill of stocks.

This is not to say that this was always the case. Curr (1883:260) describes events where nets were used and too many fish were caught so that a lot went to waste. But that is the nature of nets or poisons in a confined area such as a lagoon. Midden evidence from Balme (1991) along the Darling also tend to confirm large catch events of significant numbers of fish of a similar size. So, clearly not all fishing was more sustainable like the maze type approach.

Of course, mazes are really only one way to do things. There are many records of stream fences/bough yards with openings that were covered when needed. They have been recorded by Mitchell (1837), Curr (1883), Beveridge (1889) and Gilmore (1933) amongst others. The widespread record of these types of trap descriptions are a clear indicator that they were a widespread technology. The lack of archaeological evidence makes further study difficult, but the consistency of historical accounts from many sources is a good indicator that such traps were widely used. The advantage of such traps is that they could be placed anywhere as streams flooded or changed direction and used whatever plant material was at hand. Rock traps and earthworks are rather more limited to areas with suitable material and the weight would have precluded movement of rocks over any great distance. Hence such structures, although effective and long-lasting, were not the dominant technology. Stakes, branches and such like were more readily available and clearly were more widely used. Their disadvantages were that floods would have easily pushed them aside and timber tends to rot fairly quickly. Gilmore (1933) also describes how the early settlers burned or used the timber material for other purposes. In places trap sites were often associated with shallow sections suitable for river crossings, or choke points suitable for the construction of dams and weirs. Even Brewarrina has suffered from its use as a crossing point and still has a weir just upstream (see Figure 2.14).

Figure 2.14 - Brewarrina weir 2012, upstream of the traps

Apart from stakes and rocks, overflow points from lagoons, tributaries and anabranches were utilized as a suitable point to intercept fish movements. There are descriptions of indigenous people felling trees at the Wagga Wagga lagoon, not by chopping down, but by excavating under a tree at the edge of the water and letting rising flood waters erode further, causing the tree to fall. This trapped fish as floods receded, leaving them alive and fresh, ready to harvest by spear or net as required (Gilmore 1933).

As more data is collected about trap types and locations and associated riverscape features it should be possible to begin to make predictions of possible trap sites for further investigation. As part of a field survey in September 2012 as part of this research an area north of Swan Hill was chosen for further investigation based on the existence of riverscape features (rivers and creeks with branches and junctions) and because it was not far north of the Moira area where traps have already been recorded in detail by Curr and Gilmore. At the junction of two creeks where it was narrow enough to easily put in a fence across the inflowing stream it was interesting to not the existence of significant middens and hearth stones on the high side of the water (an area less likely to be flooded). Although not conclusive, it is not inconsistent with known patterns of trap positioning and such surveys of riverscapes are worth further investigation.

Figure 2.15 - Google Maps view of Edwards/Wakool area

Clearly showing meandering watercourses suitable for weirs (Google Earth)

It is important to note the design of traps in relation to maze-like structures. Traps often did not result in a 100% catch and more importantly, did not catch fish when no people were around. Observation of the Brewarrina traps gives a very clear idea of how this works. The rock structures at Brewarrina are not set out in a straight line, nor do they cover the whole width of the river. However, they do create a barrier to easy movement for fish across the main section of the river. As has been recorded over 100 years ago (Dargin 1976), aboriginal children today still catch fish by wading through the maze and easily catching fish that are moving slowly through the maze structure. In the past they would have used woven bags or nets, but these days the ever-resourceful children use cylindrical tree-guards made either from plastic or metal mesh, often pilfered from surrounding tree-plantings (personal observations 2012). The catching technique is simple: with a slow moving fish - Golden Perch (*Macquaria ambigua*) in my observations in September 2012, and also visible in Figure 2.2. Any form of 100% catch would rapidly deplete food resources in an area and become unsustainable, as occurred with European fishing on the Murray from the 1880's which did cause crashes in fish populations (Royal Commission on Fisheries 1894-96:29).

Figure 2.16 - Brewarrina - maze-like structure (Dargin 1976)

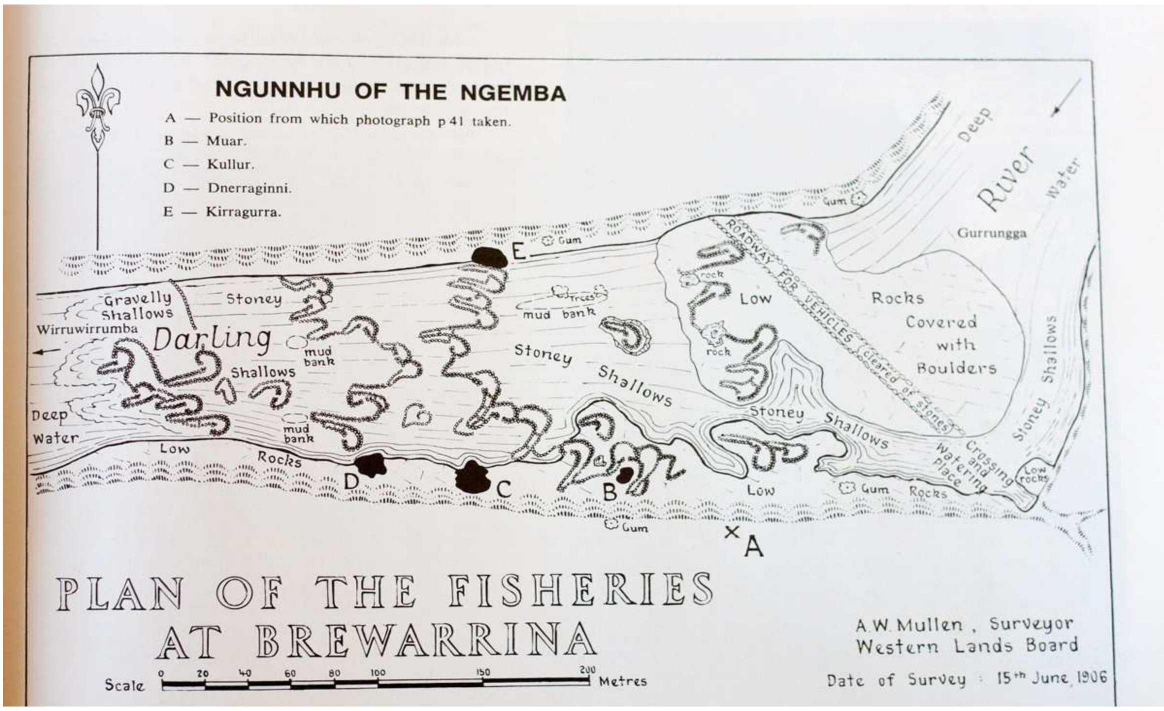

Figure 2.17 - Survey plan of Brewarrina (Mathews 1903)

The above photograph (Figure 2.10) and the plan view (Figure 2.11) give a clear view of the maze-like structure with various loops and dead-ends that slow down fish as they move through the area. Both the photograph and the diagram clearly illustrate the maze-like structure of the traps. Observations of the Brewarrina trap in use in September 2012 (see Figure 2.12) have assisted in understanding how this type of trap operates. In the photo you can see a child with a white plastic tree guard (pinched from the nearby park). Cylindrical in shape and pen at bot ends, the user simply placed it over a slow moving fish and then caught it by hand. Whilst observing them over a period of 30 minutes the three children caught four good-sized Golden Perch (~30cm long). As long as fish are moving through the area they are easy to catch. More importantly, during observations the next morning when no people were about, Golden perch were easily observed as they moved through the area and came out the other side (Personal observation, 2012). This is significant from the point of view of sustainability as fish do not get trapped and die if no one is there to collect them.

Figure 2.18 - Brewarrina 2012 - children using mesh (tree guards) to trap fish

It is useful to note that trap designs were quite adaptable and varied depending on the type of resource being targetted. Traps used to catch eels were different to those for other fish, particularly in areas such as Toolondo and Lake Condah. The distribution of eels in the Murray-Darling is largely confined to southern areas as this species moves down to the sea for part of its life-cycle (see MDBA maps). Traps used for Short-finned eels (*Anguilla australis)* have been recorded at Toolondo (on the edge of the MDB), Lake Bolac and Lake Buloke, also outside the Murray Darling near Mount William (Grampians, southern Victoria) and Lake Condah area in southern Victoria (McNiven 2012). These traps tend more to channel structures that are blocked with rocks, utilizing a woven basket at the outlet to catch the eels, capitalizing on the spawning movements of eels down to the sea each year. In the case of Toolondo quite significant amounts of digging were undertaken to build channels, effectively to extend the range of the eels to an additional lake (Lourandos 1980:253).

Around areas around Lakes Bolac and Buloke, in north-western Victoria, where there are marshy areas that were often flooded, earthen walls often stretching 300-400m were built to redirect flows via a single outlet where eels were trapped (Dawson 1881:94). These channel structures have only been recorded in areas where eels are available and are not recorded in more northern areas where fish such as Golden Perch were harvested. Such channel structures also have maze-like dead-end sections to assist in easy capture as well as utilizing woven baskets (sometimes called pipe baskets or funnel traps) at the actual catch point.

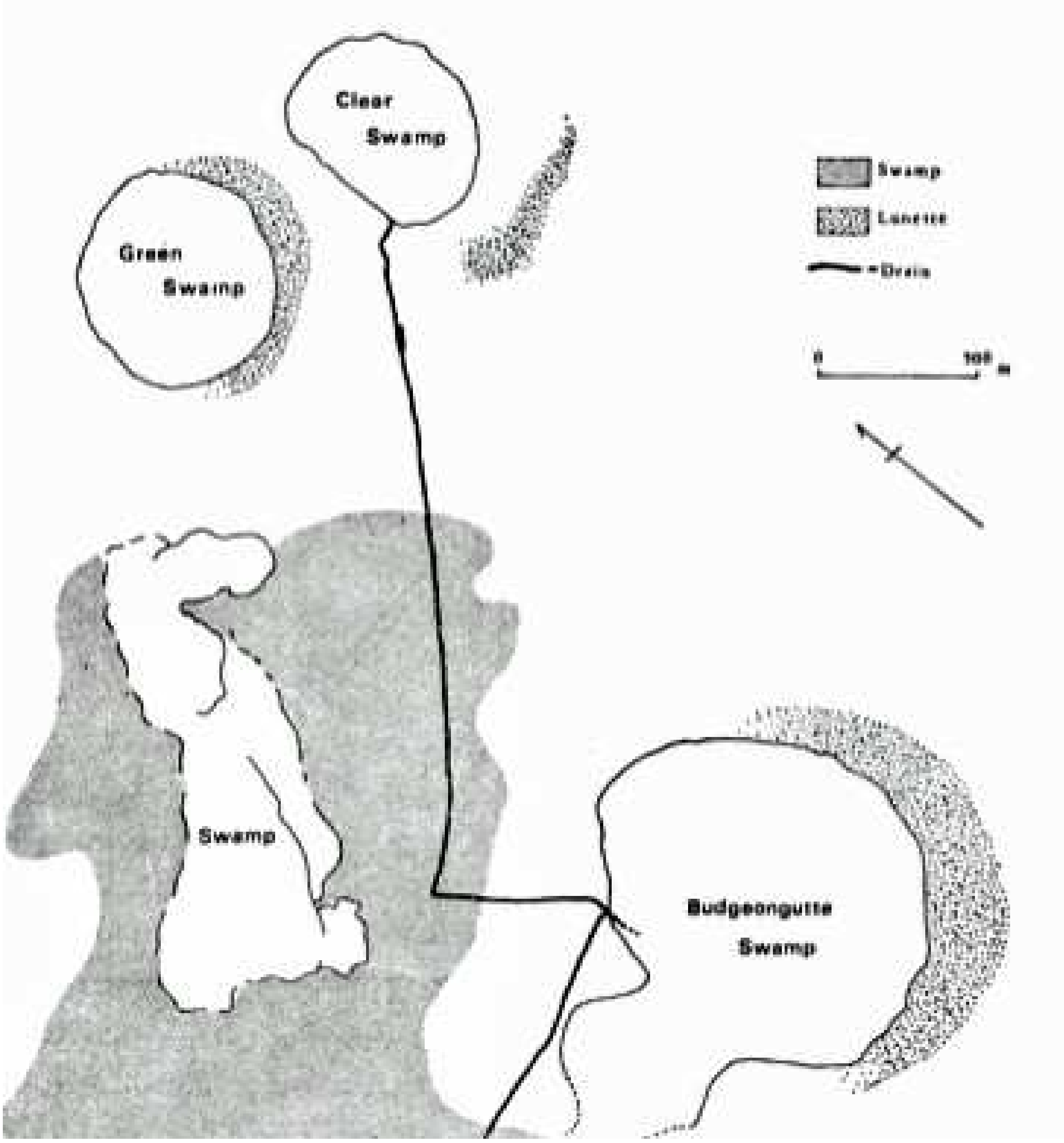

Figure 2.19 - Map of Toolondo channels (Lourandos 1980)

Northwest of the Toolondo site in the Mount William area of the Grampians, long artificial drains were constructed running from a creek to a maze of artificial channels (Robinson 1841 - original in the Mitchell Library). It has been estimated that this maze covered an area of approximately 3.5 hectares (Lourandos 1980:252).

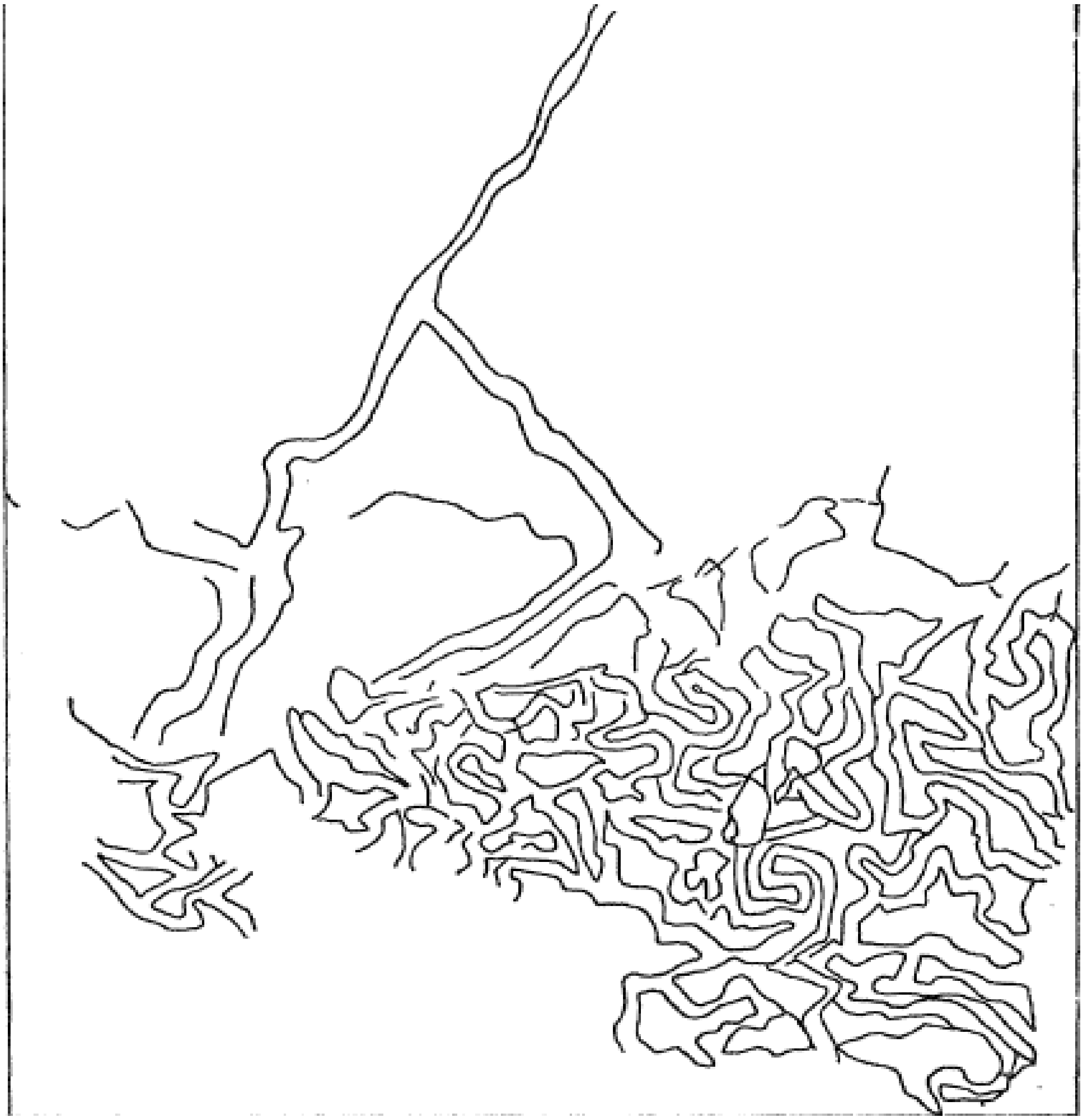

Figure 2.20 - Mount William trap maze (Lourandos 1980)

There are many records of a variety of weirs and other structures used to limit and/or re-direct stream flows to facilitate the catching of fish. Depending on the local environment, construction materials varied widely, encompassing rocks at Brewarrina (Mathews 1903) and Cunnamulla (Richarson 1983), earth such as at Balranald (Hope 1994) and Toolondo (Lourandos 1980), timber stakes and branches at Moira and Swan Hill Stakes and brush fences (also referred to as boughyards) and woven timber structures are also sometimes also associated with nets (Curr 1883).

Figure 2.21 - Balranald weir (Hope 1994)

Overview of trap dates in Australia

Methodological issues have caused considerable difficulties in attempting to date traps both in Australia as well as in various parts of the world. Stone traps have a variety of attributes that make dating difficult. Such traps often changed and re-built as rocks move over time and water levels vary which makes the determination of stratigraphy problematical, organic matter needed for carbon dating is often removed by water flow and rock dating methods via Accelerator mass spectrometry or Thermoluminescence dating are hard to apply to material exposed to light over time. In comparison, traps built using organic materials have been dated in various parts of the world as material such as stakes have survived by being buried in silt or otherwise covered in moist environments, mostly along coasts, but also along some rivers.

In general terms, the oldest overseas dates have been Mesolithic - around 7500BP being the current limit. This is consistent with the limited Australian dates, with Lake Condah at 6600BP the oldest recoded site. Other dates from Australia (but outside the Murray-Darling Basin) include Booral in Queensland with a date of 3000BP for associated midden deposits (Bowen 1998:39). In archaeology, there has been a long-running debate about “intensification” - basically that things changed in regards to resource utilization and a variety of new resources were being used (Lourandos 1980). Fish traps appear to have arisen around this time, not only in Australia, but also overseas. The key driving factor for this change is still uncertain, but clearly something changed. Whether it was climate, population pressure of other factors is still to be determined. However, there is little doubt that a new wave of people settled in Australia around this time. Evidence includes the arrival of the dingo, changes in tool manufacture and even DNA evidence (Pugach 2013). On the current state of dating evidence, both in Australia as well as overseas, it is not unreasonable to conclude the fish trap technology was also part of the change at this time, and the range of dates identified so far are all within this range in the Australian context.

Dating of extant rock traps in Australia is very difficult. Attempts have been made at Lake Condah that have returned 2 dates: c6600 cal BP for sediments containing charcoal and stone artefacts. A second date of 600-800 cal BP was recorded for multi-tiered walls (McNiven 2011:268). This is one of the key problems with dating - traps are continually modified and rebuilt due to a variety of factors, ranging from flood, changing river heights and availability of materials. Any given trap will have a range of dates and at times new additions will destroy old evidence.

However, by taking a broad view of dates across the world (see table 2.7 below) it is possible to determine patterns of dates. Dates range from around 7500BP onwards. A range of coastal and inland traps are listed, indicating similar patterns of dates. Interestingly, Lake Condah is one of the earlier dates on a world scale. Undoubtedly trap technologies were being used in Australia from quite early times.

Outside the Murray-Darling Basin Dortch (2012) has attempted to date estuarine traps by using geomorphological data to determine when land and water features were formed that facilitated coastal weirs. Again, a maximum data of 7000BP is the likely earliest time when the water flows were suitable for weir traps. Oyster Harbour has ethno-historic accounts of trap use but clear evidence of other trap sites is minimal. At Booral in coastal Queensland midden deposits of fish bones have been dated to a maximum of 3000BP (Bowen 1998). However, these middens are only provide an association with traps, not hard evidence of a trap date.

Table 2.6 - Range of fish trap dates across the world

Location	Site	Date	Source	Notes
Zamostje 2 (near Moscow, Russia)	River	7500BP	Clemente 2012	Also associated with hooks.
Lake Condah (Victoria)	River	6600BP	McNiven et al., 2012	Sediment beneath rocks
Northern Europe (Finland)	River	6500BP	Zaliznyak 1998	Stakes
Sebasticook Lake Fish Weir (Newport, USA)	River	5800BP	Miller 2006	Enclosed 2 acres
Begschenhoek (Holland)	River	3000BP	O'Sullivan 2001	Stakes
Wootton Quarr (Isle of Wight, UK)	Coast	3000BP	English Heritage 1996	1.25km of stakes
Booral (Queensland)	Coast	3000BP	Frankland 1990; Bowen 1998	Dated from associated midden
Blackwater Estuary (Essex, UK)	Coast	3000BP	Dix and Bull 2000	20,000 stakes
Boylston Street fish weir (Boston, USA)	River	2500BP	Banks 1990	2500 stakes
Shannon coast (Ireland)	Coast	3000-1000BP	O'Sullivan 2001	Rock sediments
Toolondo (Victoria)	Lake	210BP	Lourandos 1980	Infill of channel

At this stage in research and dating worldwide it appears that the use of fish traps and weirs really only commenced sometime around 7500BP and continued on until recent times, with traps being regularly maintained until Medieval times in some areas. Dating data from across the world is remarkably consistent (Connaway 2007:23) With a range of dates encompassing coastal, estuarine and inland sites it seems reasonable to conclude on current evidence that this is the timescale for fish traps. As yet none have been reliably dated earlier than around 7500BP, with a significant proportion in the range 3000-1000BP. The Australian record, although limited in scope, tends to match overseas patterns. A key question, of course, is that of origins of the Australian technology. Did it come in with the wave of new people around 5000-7000BP, or was it developed independently? In some respects this question can add to the intensification debate that has occurred in Australian archaeology over time (Lourandos 1980). Recent DNA evidence has only added to the case that the dingo is a relatively recent arrival. (Ardalan et. al. 2012), which tends to favour the likelihood that trapping in Australia was a later introduction and not utilized by the earliest inhabitants.

Fishing techniques associated with traps

In some situations, a trap is used in conjunction with other techniques and tools to enable the capture of fish. Traps cannot be viewed in isolation, but rather should be evaluated in conjunction with other fishing techniques as they are at times closely linked and complementary to one another. For example, although a trap or weir may confine fish stocks, to actually catch them may require other tools such as spears, nets or poisons. Hence it is worthwhile to provide an overview of fishing methods often associated with traps to assist in fully understanding how these technologies operated.

Spears

Spearing is best done when fish are limited in movement, such as in billabongs and quiet sections of rivers and creeks. The use of stream fences or boughyards was one method of limiting flow, for example out of a billabong, making spearing easier. The are many records of the use of spears. One factor to consider is that in early times rivers were far less turbid most of the time and this allowed for easy use of spears as fish were clearly visible to quite a depth. Mitchell (1837) comments on the clarity of water and how fish swam as if they appeared to be floating in air. In unmanaged sections of rivers today, such as the Naree area of NSW, the Paroo and Warrego river waters are still noted for their clarity, confirming what Mitchell reported (McNally 2013:1). However, many stretches of water in the Murray-Darling today are quite murky and spear-fishing is not practical. Although entering the water to use spears can be effective, Curr (1883:230) notes that in cold weather the men always came out of the water suffering from cold, and preferred other methods where possible.

Nets

Nets were used in conjunction with fish traps, weirs and mazes to block off sections or to collect fish at the outflow point of v-shaped traps, for at example Lake Condah (Allen 2010; McNiven 2012). Pictorial records by Blandowski exist of the use of nets (see Figure 2.7).

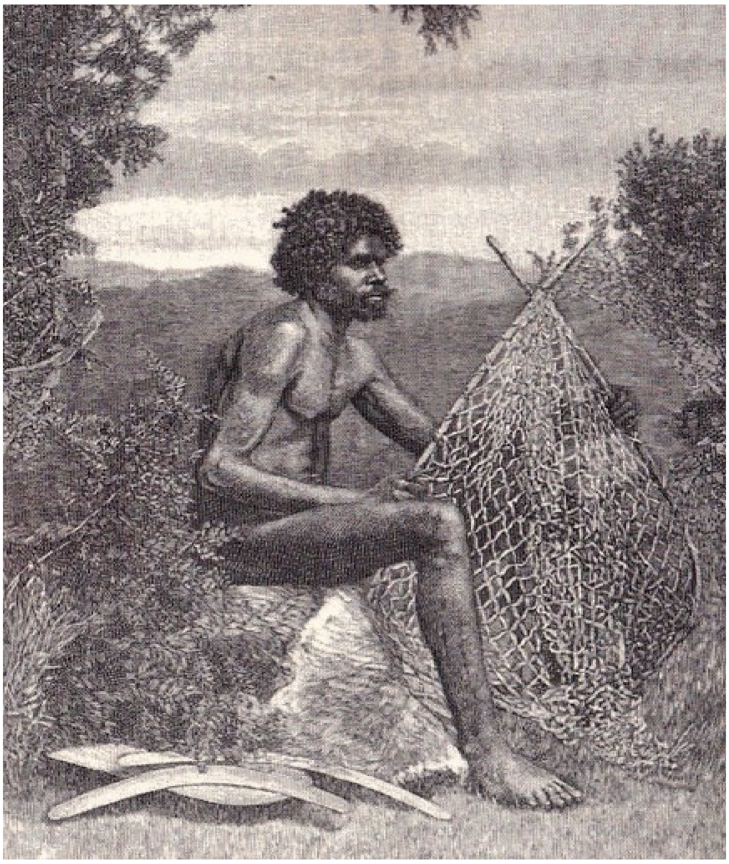

Figure 2.22 - Example of net (Beveridge 1883, from a photo by J.W. Lint)

Early records provide a lot of evidence for the use of nets, not only for fishing, but also for catching wallabies and birds. Although such material as nets rarely survives in the archaeological record, there are historical records of a range of traps and methods of tying knots (Satterthwait 1987:615). Accounts of explorers such as Mitchell (1839:153) and Eyre (1845:286) describe duck nets as large as 18.3m by 12.3m with meshes of 5cm square. Based on these known sizes and using observations of contemporary net construction, estimations have been made of the time taken to make large nets such as the 18.3 x 12.2 metre waterfowl net recorded by Eyre (1845:286). Such a net would have over 90,000 individual knots (assuming a 5cm grid) and it is likely that it would take more than 90 days to make (Satterthwait 1987:616). The time taken to collect the raw materials and make the cords for the nets would have meant that the making of such nets represented a major investment of time by a group of people (Satterthwaite 1987:615). Other estimates from ethnographic research in the Central Congo of net traps ranging in size from 28-65 metres indicate that it would have taken around 5 days to make, but collecting the raw material could take 3-4 months (Lupo and Schmitt 2002:153). It should also be noted that a 5cm grid is too large the catch fish, and thus fish nets would have had smaller grids and an accompanying increase of raw materials required and a lengthening of the construction time.

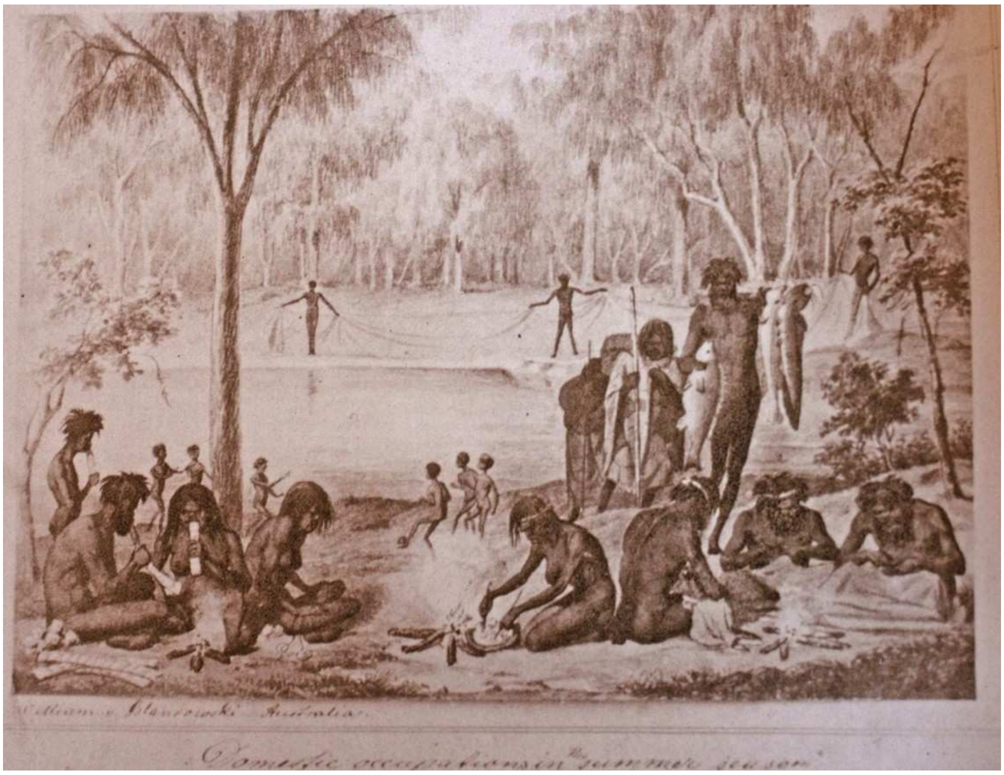

Figure 2.23 - Use of nets (Blandowski 1847)

There is ample evidence that the use of nets was a widespread technology across the world as documented several researchers (Balme 2013:68). In the Australian context, nets were used to catch not only fish, but also wallabies and birds such as Emu and waterfowl as well as for wallaby and duck trapping as well - they were a widespread technology and nets were closely associated with traps at times. There is evidence that nets were regarded as a valuable resource and well cared for by the group (Duncan-Kemp 1933:122), which is not surprising given the time invested in their construction.

Hooks and lines

Although not directly related to fish traps, it is worth noting that hooks and lines were used in some areas, although Curr (1883) notes that such equipment was absent form the Moira area as the locals relied on weirs and nets along with spears, although a later description of an indigenous fishing expedition on the lower Murray indicated that the women had fish hooks in their bags (Curr 1889:86). There is some evidence for the use of hooks along coastal areas (Gerritsen 2001:19; Walters 1987:99). It has been argued that fish hooks represent an indicator of the intensification of resource utilization (Lourandos 1985:401). However, evidence for the large-scale use of hooks is limited. Very few items have survived, but there is some evidence of the use of bone hooks (Mathews 1895:188; Berndt 1933:14).

Poisoning

Closely related to weirs and other enclosures is the technique of poisoning or reducing the oxygen content of water to disable or kill fish. This has been observed in confined areas of water such as lagoons. One method consisted of throwing a lot of fresh eucalypt branches into the water. After a few hours fish began to die and rise to the surface. Presumably this approach increased some chemical in the water and/or reduced oxygen levels resulting in fish incapacitation or death (Curr 1889:241).

Various other records of the use of poisons have observed. For example in Queensland on the Normanby River Aboriginals poisoned the water with branches and leaves (Jack 1921:434), but the actual type of poison is not recorded. It has been suggested that the introduction of tannins from plants introduced into the water in weirs or other confined areas would bring fish to the surface (Lawerence 1991:250). On Mabuiag Island (Torres Strait) there are records of *Indigofera australis* (Australian Indigo) being used as a poison (Ghaleb 1990:165). Further evidence from the Macleay District (NSW) indicates similar practices using plant material, with two species of Acacia: *Acacia impleza* and *Acacia longifolia* being mentioned by observers at the time (Roberts 2010:24).

2.4 Discussion

Distribution and riverscape associations

This chapter has provided an overview of trap locations, materials used and riverscape associations. Traps are widely distributed across the Murray-Darling Basin, but their density is much lower than some coastal areas. However, to more fully understand the importance of traps they need to be related to fish behaviour and ecology, and this is addressed in chapter 3. Materials used vary considerably as construction materials are opportunistic - in rocky areas stone structures are used, but in many other places stakes and other plant materials are used. This mirrors the findings of research overseas (Connaway 2007:20) where fish trap sites use a variety of locally available materials.

In terms of riverscape features, tributaries rather than the main river bed were found to have a higher proportion of traps. Possible reasons for this could be that tributaries are easier to block off, and in the Murray-Darling context the flood/drought cycle means that fish would more often move in and out of tributaries with the rise and fall of the water. The significance of fish movements is dealt with in detail in chapter 3. In addition, wider, fast flowing rivers are harder to control, except at shallow points like Brewarrina that made tributaries a more workable option.

Anabranches were also exploited, probably for the same reasons as were tributaries.

Persistence of the technologies

Perhaps of greater significance is the observation that there are the considerable similarities in design and construction both geographically and over considerable time periods. Once established, fishing using weirs and timber structures maintained consistent designs and materials. For example, the design and layout of the Zamostje 2 site (7500BP) is very similar to more recent trap remains such as Begschenhoek (3000BP) that are similar to descriptions of Australian traps both in the Murray-Darling and elsewhere such at Western Australia (see Figure 2.7). On the basis of current evidence it is not unreasonable to suggest that in Australia and across the world fish trap design remained essentially unchanged over many thousands of years (Connaway 2007:12). Presumably, once an effective method of collecting fish was established it remained the preferred option and was not refined to any great extent.

The significance of these findings for further research must also be taken into consideration - a majority of sites used organic materials which have largely decayed over time, unlike some of the consistently moister European and American sites where anaerobic conditions were conducive to the preservation of plant materials for long periods of time (Out 2008:1). Thus research into Murray-Darling traps necessarily is skewed towards historical records rather than detailed archaeological work. The same could be said for coastal regions.

Fishing methodologies and potential yields

As already discussed, traps are passive devices and generally only restrict movement. Other approaches are also needed to actually retrieve the fish. The significance of more traps in tributaries emphasizes this aspect, as such locations make fish easier to manage and catch than is often the case in wider, deeper sections of rivers. Different fishing methods will inevitably result in quite different combinations of species and sizes of individuals caught. Some methods, such as poison, are indiscriminate and result in high mortality of all species in the area. Others will result in far more selective catches, for example nets with a fixed grid size where smaller fish will normally avoid capture. Hooks also target only certain species that are attracted to a lure. Equally, care must be taken with assumptions about the composition of fish populations. As a general rule, fish of differing age (and hence size) will use different parts of a river at different times. Thus any discussion of size composition of a population needs to reference times/season/place to be meaningful (Colley 1987:17). Any analysis of the archaeological record to attempt to reconstruct fish populations must take this into consideration. This is dealt with in more detail in chapter 3.

3 Fish traps and river ecology

3.1 Introduction

At present much of the research into fish traps, both in Australia and elsewhere, has been of a general descriptive nature: mainly recording location, construction materials and the structure of individual sites. In Australia, few studies have attempted to try and link trap sites to the associated environment (Welz 2002; Bowen and Rowland 1999), nor to address fish ecology and the species most likely to be exploited by traps. To gain a better understanding of the role of fish traps in providing a food supply in the past it is important to identify the species of fish likely to be trapped at known sites as well as attempting to understand trap sites in relation to the time of year along with seasonal patterns such as water levels that influence trap location and use. Closely linked to this are fish life history, mobility and behaviour. For a fish species to be suitable as a target for traps it is more likely to have specific attributes including movement patterns - whether they likely to move through trap areas, availability at different times of the year - whether they are subject to seasonal migrations or predictable behaviour, such as returning to specific home sites on a regular basis for feeding or spawning and hence are more likely to pass through a trap site. Movements up tributaries and into lagoons are also significant as there is a variety of evidence that fish were often locked into these areas via brush traps and log weirs (Gilmore 1934). Such movements are likely to be associated with changes in river levels.

The climate and river flow patterns associated with the Murray-Darling Basin are not homogeneous, but rather are composed of zones that differ markedly, ranging from high summer-flow areas through to high winter-flow areas, erratic and variable flow patterns along with flood events in springtime in some years (Humphries et.al. 1999:3). This variation and unpredictability in both flow and water temperatures has resulted in fish species breeding in varying times and locations. Unlike trap sites in such places as Europe and the USA, the Murray-Darling rivers do not have peak migrations such as salmon runs. In contrast, fish in dryland rivers have adapted to unpredictable and extreme changes in temperature and river flows (Balcombe and Arthington 2006). Limited evidence so far from hearths and middens indicates that two key species were Murray cod and golden perch (Bowler et. al. 1970; Balme 1990). However, Blandowski documented the catching and consuming of more than a dozen species at the junction of the Murray and Darling Rivers (Blandowski, 1857), although many of these were unlikely to have been collected in fish traps. Trap sites identified in this research (see Figure 2.2) are largely confined to the slower-flowing river systems of the Murray-Darling Basin and discussion of fish species will be confined primarily to this area.

Fish stocks are known to have declined significantly over the last 50 years in the study area (see Figure 3.1), and thus it is difficult to estimate population size and diversity in the past. However, it is possible to establish fish distribution patterns and relate these to aspects of species that lend themselves to being trapped (Table 3.3).

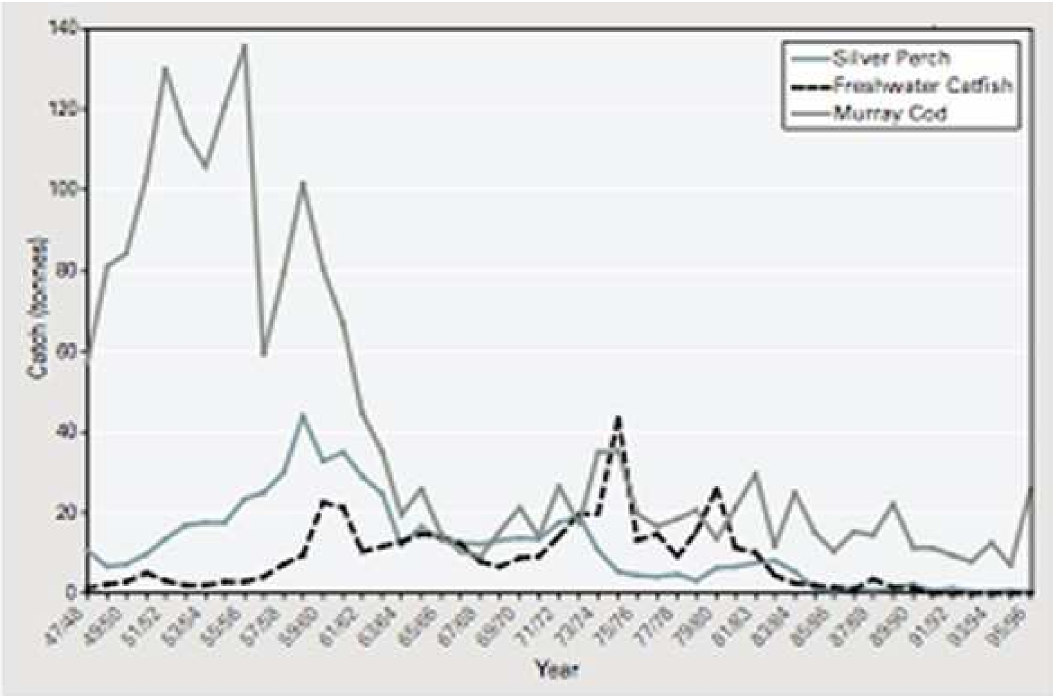

Figure 3.24 - Decline in commercial catches of Murray cod, Freshwater catfish and Silver perch in NSW between 1947 and 1996 (Source: Reid et al. 1997)

The overall aims of this chapter are to establish what is known about the species of fish likely to be collected in traps in the Murray-Darling Basin, how they were collected and relationships with the ecology of the species. Specifically, the following questions are posed: 1/ What species, sizes and life stages were targetted? 2/ Were they likely to target sedentary or mobile species? 3/ Were traps used all year round, seasonally, or perhaps in relation to flow patterns?

3.2 Methods

General methods

Significance of different types of evidence

Studies have been done on archaeological fish assemblages in Australia as well as in Europe. In the Murray-Darling context, Balme (1995:1-3) discusses the difficulties of interpreting faunal remains from open sites bordering the lakes and rivers of western New South Wales and notes that if a midden exposed by wind and/or rain then it will decay quickly. Personal observations of midden sites at Lake Mungo over 30 days in the winter of 2009 confirm this observation. This area is subject to sudden rain squalls and strong winds that rapidly erode sand dunes and middens. Thus it is not unreasonable to assume that a midden site containing relatively fragile and intact faunal remains can be assumed to have been recently exposed and unlikely to be contaminated by mixing. The reverse is the case for poorly defined or badly eroded sites. This makes dating and the evaluation of material problematical. In addition, when surveying the literature on midden studies in the basin it has been found that archaeological techniques are quite inconsistent, particularly in relation to the sieving of material, in particular the size of grid selected for the sieve. Recent midden studies at Barmah have shown a large preponderance of small fish, which raises the question of the use of nets at such a site (Humphries personal communication).

Studies of Mesolithic deposits in Denmark have concluded that the deposits and been strongly influenced by differential preservation (Noe-Nygard 1983:125). Similar studies in Tasmania at Rocky Cape have also shown varying deposit patterns (Colley 1987:24). Thus any archaeological data on fish assemblages associated with trap sites must be viewed with caution as the remaining archaeological evidence is likely to contain only the more resilient materials, not necessarily providing a complete record of species utilized. However, when trap site locations are viewed in conjunction with key behavioural attributes and distribution data of fish species it is possible to compile lists of likely species that can be compared with known midden and hearth data.

Figure 3.25 - Golden Perch otolith

Otoliths are small structures related to hearing that are found in the head of fish. The shape of an otolith is characteristic to a specific species and growth increments are recorded in the otolith, which allows for accurate estimates of both the growth patterns as well as the age of an individual fish (Campana and Thorrold, 2001; Furlani et al., 2007). Recent research has focussed on isotopic and trace element data from otoliths that has been used to address a number of ecological and fisheries questions (Elsdon and Gillanders, 2005). This analysis permits the recoding of patterns of environmental conditions such as growth rates and sources of food (Elsdon et al., 2008). Such research holds promise in the future, but more needs to be done. To date otolith data is very limited in the Murray-Darling context, however archaeological research in the Devon Downs rock shelter on the lower Murray has some evidence that fish stocks were under pressure. Murray Cod otoliths dated to 5000BP were significantly larger than those dated from 3000BP (Rowland 2004:46). Other research also identified variations of Golden perch otoliths that reflect exploitation of local fish stocks on the Darling near Tandou, NSW (Balme 1983). Otolith evidence has also been used to provide insight into the breeding patterns of the Golden perch (Ebner et.al 2009:571).

The above discussion of different types of evidence casts doubt on drawing too many conclusions from current data on middens and other archaeological contexts. Given the issues described, midden data is unlikely to be fully representative of what fish species were consumed and at present otolith data is sparse. Consequently this research has been focussed on fish distribution and behaviour in relation to identified trap sites as this is more likely to provide a clearer insight into fish utilization before European settlement, although it is still worthwhile to compare results from both sources to improve understanding of the issues. Although it is difficult to be able to quantify fish stocks and their degree of utilization in the Murray-Darling Basin before the arrival of Europeans, there are indirect indicators that Aboriginal peoples utilized a wide range of aquatic resources including fish. Indirect evidence relating to the significance of aquatic food in Aboriginal diet has been obtained from sources as diverse as early settler accounts through to palaeodiet studies. There is evidence of different population structures in the Moira area, where Aboriginals relied heavily on fish and differed from groups further inland in that they were sedentary, had more young children and more older people (Curr 1883:241-2). Bone isotope studies from the lower Murray indicate that protein in the diet from freshwater fish and shellfish was in the range 30-40% (Pate 2000). Other data drawn from these bone studies also indicate that populations along the lower Murray were significantly more sedentary than populations further inland, indicating the likely impact of reliable aquatic resources (Pate 1995:81). Trap sites have been recorded on the lower Murray (Table 2.3). A detailed study of over 200 midden sites on the Darling recorded Golden Perch and Catfish (Balme 1995). Other indirect data includes evidence of widespread commercial fishing in the basin after European settlement (Royal Commission on Fisheries 1894–96:29), which also tends to confirm the extent of fish stocks in the river systems.

Whilst the various studies and sources of indirect evidence do not prove the existence of traps, they do confirm that fish stocks in the basin were much higher than at present and that a significant proportion of diet was sourced from aquatic resources and this resulted in identifiable evidence in human bone composition as well as variations in population structures. Clearly there was a range of aquatic resources available.

Consequently, for each of the stated aims, analysis of data is based on distribution maps of all species present in the Murray-Darling Basin. Associated with distribution, fish ecology and behavior is also summarized providing an overview of species that are likely to pass through trap sites. The limited scope and problems with other data sources such as midden studies dictates that any attempt to establish what fish were caught in the past must rely on distribution, ecology and behavioral data rather than the archaeological record.

Determination of species, size and life stage of fish caught in traps

Specific attributes of species for trapping

For a fish to be suitable as a target for traps it is likely to have specific attributes ranging from evidence of movements, availability at different times of the year, predictable behaviour such as returning to specific sites and of a size suitable for harvesting. However, there are certain attributes that are worth examining as they relate closely to a species being more likely to be trapped (Table 3.1).

Table 3.7 - Fish attributes related to susceptibility to trapping

Movement	Is species likely to move through trap areas?	Essential for trap function
Consistency of supply	Is spawning only at one time of more frequent or limited by temperatures of floods?	Relevant to reliability of food supply
Predictability of occurrence	Can they be relied on to appear regularly?	Relevant to reliability and for gatherings
Habitat	What parts of the riverscape are preferred?	Species entry to trap zone

Fish data for all identified trap site areas has been collated and summarized. To improve the relevance of this data it has been refined by tabulating it in conjunction with some key attributes of fish: 1./ movements 2./ preferred habitat of species 3./ links to the riverscape features of each trap site. For example, if a species is known to move up or down stream it is more likely to be caught in a trap. In addition, some species tend to have preferred habitat and this can be related to specific trap sites. And finally, as movements are seasonal, a significant number of fish are likely to be moving through a site in a particular season and thus providing a greater supply of fish. Tables 3.2 and 3.4 present fish data in a different form – that of fish species by the type of preferred habitat and also movement and spawning data. This can potentially provide a more precise indicator of which species were at a specific site, and what times of the year they would be more prevalent. This becomes even more important when considering the role of traps in relation to Aboriginal gatherings – this is covered in more detail in chapter 4.

Selection of fish species listed for detailed analysis is based on distribution maps, specifically known distributions before 1980, along with presence in at least one river system with identified trap sites. Species are ranked by average length as this is one likely indicator of relevance to diet and ease of capture. Species have been divided into 2 groups - species with a minimum length greater than 100mm and those less than this. This has been done to try and delineate species likely to be caught by traps, and those more likely to only be caught via traps and/or poisons. Obviously larger species could also be caught in nets or poisoned, but smaller species are less likely to be trapped in structures such as Brewarrina or the stream fence structures as illustrated in Figure 2.7. It is useful to consider both categories as this division may help in the interpretation of middens and other fish remains at sites where the existence of traps is undetermined as yet

Eels and Lampreys are included, although as these species have a limited distribution in the Murray-Darling Basin and spend part of their life-cycle in the sea and estuaries far from the main areas of the basin. However, eels in particular have been well documented as a significant source of food at least three sites in the Murray-Darling as well as being associated with gathering places and so are included in the analysis. By relating species attributes and distribution of species in relation to identified trap sites, this enables a clearer understanding of possible species that could have been utilized in the different trap areas as well as the diversity of fish species potentially available at each trap site as well as likely seasonal availability.

Based on the above data about each species, for each trap site each fish species are ranked under three categories: D – definitely recorded at the site; L – based on known data likely to have been present or moving through that area and U – unlikely to be at that site, but some individuals may be present, for example during floods. This data is summarised in Tables 3.3 and 3.5.

Movement patterns of fish caught in traps

Identification of movement patterns of fish are based on various studies of the ecology of different species (Lintermans 2007). Tagging data has provided useful insights into movement patterns of some species. Linking this information to known distribution patterns and trap site data it is possible to identify which species are likely to move through known trap sites. Tables 3.2 and 3.4 summarize current knowledge of fish movements of target species.

Seasonal use of fish traps

In order to build up an overview of fishing in the Murray-Darling Basin, a mixture of approaches has been developed. Trap sites and types of construction along with riverscape features have already been established in Chapter 2. Using this data it is now possible to relate fish distribution patterns to trap distributions to gain an idea of possible species that might have been caught in these known traps. The first stage of analysis is confined to the larger fish species, as most trap designs have quite coarse filtering abilities, whether they are rock or sapling based traps. Other factors such as breeding patterns, homing movements and the impact of floods on fish movements will also be examined by establishing key attributes of the identified fish species that relate to being susceptible to traps. Specific species are examined in detail to determine their behaviour in relation to trapping.

3.3 Results

Determination of species, size and life stage of fish caught in traps

There are a total of 46 species in the MDB, approximately 22 of which have been recorded in trap areas and would have been available for capture in Aboriginal fish traps (Tables 3.2 and 3.4). Larger species with average sizes ranging from 100mm to 900mm are listed in Table 3.2. Smaller species in the size range less than 100mm in length are recorded separately in Table 3.4. These smaller species are included even though they are not likely to be caught is some traps, such as Brewarrina, they are susceptible to being trapped via the funnel-type enclosures known to be used at some sites such as the Wagga Wagga lagoons, Lake Buloke and at Moira, as well as being caught by nets or poisons and should be considered in any review of archaeological material.

Data summarizing fish species are tabulated below in different ways to assist with the determination of species at each identified trap site. In Table 3.2 the 11 larger species (> 100mm length) are tabulated, ranked by size. In addition, favoured habitat, movement patterns and spawning patterns are also included where available. This provides a clear overview of each species in terms of behavior and ecology.

Across the 24 identified sites, the average number of larger species per site was 5.4, and an average of 4 smaller species per site, providing clear evidence that a range of fish were available at each site.

Table 3.8 - Summary of behaviour and ecology of Murray-Darling species > 100mm length

Common name	Length (mm)	Favoured River	Habitat Tributary	Lagoon	Swamp	Flow	Movement	Spawning
Short-finned eel *Anguilla australis*	700-1100	●	●	●	●	Varied	Downstream for spawning in sea	Autumn
Freshwater catfish *Andanus tandanus*	500-900	●	●	●		Slow	< 5km	Spring-Summer
Murray cod *Maccullochella peelii*	500-900	●	●	●	●	Varied, deep pools	Upstream to spawn - 120km. 80% return to home site	Spring-Summer
Trout cod *Maccullochella macquariensis*	500-850	●	●			Deep pools	High return to home snags	Oct-Nov
Golden perch *Macquaria ambigua*	400-760	●	●	●		Slow	> 1000km Oct-April Return to home sites	Flood related

Silver perch *Bidyanus bidyanus*	350-500	●	●	●	●	Slow	Up/down stream	Flood related
Macquarie perch *Macquaria australasica*	350-465	●	●	●	●		Move to tributaries to spawn	Oct-Dec
Short-headed lamprey *Mordacia mordax*	300-440	●	●			Varies	Upstream from sea, then sedentary	
Northern river blackfish *Gadopsis marmoratus*	200-250	●		●	●	Varied	Small home range	Oct-Jan
Spangled perch *Leiopotherapon unicolor*	150-300	●		●	●	Varied	Up and down stream, laterally in floods	Nov-Feb
Bony herring *Nematalosa erebi*	120-200	●		●	●	Varied	Up and down Up/down stream	Oct-Feb

Table 3.9 - Summary of trap sites and available species - minimum length > 100mm

Distribution data adapted from Lintermans (2007).

Trap Site	Short-finned eel	Freshwater catfish	Murray cod	Trout cod	Golden perch	Silver perch	Macquarie perch	Northern Blackfish	Spangled perch	Bony herring	Total species
Albury		L	L	L	L	L	U	U			7
Ardelthan		L	L		L	L					4
Balranald		U	L	U	L	L	L	U		L	8
Barmah		L	L	L	L	L					5
Brewarrina		L	L		D	L			U	U	6
Cudgewa Creek		L		U	L	L	U				5
Cunnamulla 1		L	L		L	L			L	L	6
Cunnamulla 2		L	L		L	L			L	L	6
Deniliquin		L			L	L				U	4
Gwydir and Barwon		L	L		L	L			U		5

Lake Bolac	D	U			U	U					4
Lake Buloke	D	U									4
Macquarie Marshes		L			L	L			U	L	5
Moira area (Cobram)		L	L		L	L	U			L	6
Narran River		L	L		L	L			L	L	6
Morgan		L	L		L	L		U		L	6
Narrandera		L	L	L	L	L		U		L	7
Renmark		L	L	L	L	L				L	6
Robinvale-Mildura		L	L		L	L				L	5
Swan Hill		L	L	L	L	L				L	6
Toolondo	D	U						U			3
Tyntynder		L	L		L	L	U				5
Wagga 1		L	L		L	L				L	5
Wagga 2		L	L		L	L				L	5

Table 3.10 - Summary of behaviour and ecology of Murray-Darling species - length < 100mm

Common name	Habitat					Movement	Spawning
	Favoured River	Tributary	Lagoon	Swamp	Flow		
Desert rainbowfish		●	●	●	Slow		Flood related
Murray-Darling rainbowfish		●	●	●	Slow	Up and down stream	Spring-Summer
Southern pygmy perch		●	●		Slow	Slow	Sept-Jan
Olive perchlet		●	●	●	Slow		Oct-Dec
Un-specked hardyhead	●	●	●	●	Slow	Upstream	
Darling River hardyhead	●	●			Slow		Sept-Feb
Carp gudgeons		●	●		Slow		Temp. related
Murray hardyhead	●	●	●	●	Slow		Sept-April

Australian smelt	●	●	●	Slow	Upstream	Spring-Summer

Table 3.11 - Summary of trap sites and available species - minimum length < 100mm

Distribution data adapted from Lintermans (2007).

Trap Site	**Desert Rainbow fish**	**Murray-Darling rainbowfish**	**Southern pygmy perch**	**Olive perchlet**	**Un-specked hardyhead**	**Darling river hardyhead**	**Carp gudgeon**	**Murray hardyhead**	**Australian smelt**	**Total species**
Albury			L		L		L			3
Ardelthan					L		L			2
Balranald					U		L	L	L	4
Barmah					L		L		L	5
Brewarrina		L		U	U		L		L	5
Cudgewa Creek		U					L		L	3
Cunnamulla 1	L			U	U		L		L	5
Cunnamulla 2	L			U	U		L		L	5
Deniliquin		L	L		U		L		L	5
Gwydir and Barwon		L		L	L	L	L		L	7
Macquarie Marshes							L		L	2
Lake Bolac					U		U		L	3
Lake Buloke							U		L	2

Moira area (Cobram)	L	L		L	L	L	L	6
Narran River	L				L		L	3
Morgan			L	L	L	L	L	5
Narrandera		U	L	U	L		L	5
Renmark			L	L	L	L	L	5
Robinvale-Mildura				L	L	L	L	4
Swan Hill				L	L	L	L	4
Toolondo				U			L	2
Tyntynder				L	L		L	3
Wagga 1				U	L	U	L	4
Wagga 2				U	L	U	L	4

Sedentary vs mobile species

As can be seen from Tables 3.2 and 3.4, most species have at least a period of movement either up or down stream. Generally this is related to spawning and is often, but not always spring-summer, except for the eels which migrate in Autumn back to the sea. Thus, for any given trap site it is possible to detail not only the species likely to be caught, but also the time of year most suited to trapping. However, given the erratic nature of flows in the rivers at times, some species such as Golden Perch will move in response to water level changes and thus may be trapped at other times. Presumably the Aboriginal inhabitants were aware of this behavior and utilized it whenever possible.

Trap use in relation to seasons and flow patterns

For a given trap site it is now possible to establish which species are likely to enter traps by examining the attributes of each species. Some data on fish in the Murray-Darling Basin is available from various sources related to such things as movements and the impact of flooding on movement and spawning is limited. As flood events are very unpredictable it is not surprising that no basin fish species have been shown to be dependent on floodplain habitats to breed. Fish in the Murray-Darling Basin have evolved in an unpredictable, fluctuating environment. A number of species breed under low flow conditions (Humphries et.al. 1999, 2002; King et.al. 2003). In addition, movement patterns of some species have been studied, and this provides a useful guide as to the behaviour of three common species. Murray Cod are known for an 80% return rate to home sites with distances travelled up to 240km, the Trout Cod have a high fidelity to home snags (Koehn & Nicol 1998) and the

Golden Perch also return to home sites (Crook 2004; O’Connor et al. 2004).

3.4 Discussion

General

The evidence presented clearly shows that all identified trap sites have a range of species present in the area. Most of these species have at least a period of their life-cycle when movements occur, which is important for effective trapping in what are passive devices.

Determination of species, size and life stage of fish caught in traps

Based on the data tabulated in Tables 3.2 and 3.4, this knowledge of behavior and ecology is then applied to each species to provide a ranking of species by likelihood of capture at each trap site. Species are ranked in three categories, based on distribution, habitat preferences and likelihood of movement: 1./ Definite (known records at site) 2./ Likely (definitely present, but limited evidence to date) and 3./ Possible but less likely based on ecology and behavior. This is summarized in Table 3. 3 for species > 100mm in length and Table 3.5 for smaller species.

Depending on the region, quite different groupings of species could have been trapped – see Tables 3.3 and 3.5. Species such as eels and lamprey have very limited distributions and are unlikely to be targets at most trap sites identified in the basin. The exception is that of eels at the Toolondo, Lake Bolac and Lake Buloke where they were the prime resource at certain times of the year. Eel sites are atypical compared to all other trap sites in the region and really is an outlier as far as the Murray-Darling Basin is concerned. However, it is worth including these sites because of their significance in that they demonstrate that Aboriginals were quite adaptable in the way they used different technologies to utilize aquatic resources, and were capable of building large structures. Outside the basin at Mount William and Lake Condah similar approaches were also used to harvest eels, and also represent the construction of large structures.

Some sites had more species available than others, with both Golden and Silver perch present at most sites along with Freshwater Catfish and Murray Cod also widely recorded. Other species vary somewhat across the different river systems. Having established potential species it is now relevant to examine the behaviour and ecology of these species to gain a better understanding of their significance at trap sites. With behavior and riverscape features included it is possible to have a more accurate species list for each site with a ranking of likelihood of capture of different species.

Movement patterns of fish caught in traps

Data relating to fish movements is tabulated in tables 3.2 and 3.4. Most species demonstrate a period of movement, generally related to spawning. Traps would be of more use with adults moving along rivers rather than the movements of small, immature. movements. Thus at each site there would be a range of species available, and in particular in the spring-summer period at most locations there would have been regular movements of fish through the areas.

Seasonal use of fish traps

Aboriginal seasonal use of some sites is well documents, such as Lake Bolac and Lake Buloke which are closely tied to seasonal movements. Other sites without eels would at times have experienced significant fish movements related to spawning, particularly for species such as Freshwater catfish, Murray Cod, Trout cod, Macquarie Perch and Bony herring. Golden Perch generally moves in response to flood flows and may have been more widely available in terms of seasons. Little information is available of river flow patterns before most rivers were controlled via locks and dams. Generally, though, spring flows would have been fairly consistent, and the use of barriers at tributary and anabranch entry/exit points would have been useful in times of flood, especially when fish began to return to the main rivers as water levels subsided.

4 The significance of fisheries for Aboriginal populations – food supply and social gatherings

4.1 Introduction

Fishing has been a key resource over long periods of time in the Murray-Darling Basin and elsewhere (Balme 1995:2). By providing a reliable food source, fish traps have had a significant impact on Aboriginal societies over long periods of time. Ethnographic evidence suggests that there is a general correlation between language groups and key ecological zones, in particular such resource rich areas as coastlines, lakes and swamps (Lourandos 1977:214). Evidence from diverse sources in Victoria such as (Howitt 1906:69; Robinson 1841) also confirm this pattern. Similar aggregations have been recorded in Queensland (Dixon 1976:209) along productive coastal areas in northern areas, where a large number of tidal fish traps have been recorded (Rowland and Ulm 2011:51). In addition there is evidence of large-scale food-gathering activities across a range of areas. These ranged from cooperative hunting and fishing drives (Dawson 1881:79) through to the large-scale channel systems at Toolondo (Robinson 1841) that required significant labour input both to build and to maintain. Some of the Victorian western district tribes were at least partially sedentary with well constructed, permanent huts associated with eel fishing (Robinson 1841). A similar group of huts has been recorded at Cape Otway, in Victoria (Lourandos 1976:188). Clearly Aboriginal groups were involved in cooperative endeavours, and many of these were closely associated with fish resources.

A variety of gathering sites for Aboriginal people have been recorded in many different areas in the Murray-Darling Basin. One type of gathering site was that of Bora grounds, which are earthen rings ranging in size from 1-12m to 35-30m that have been associated with a range of ceremonies. Bora usually occur in groups of two or three rings, linked by paths. Ceremonies may be public or restricted (Bowdler 1999:4). Generally Bora sites are restricted to NSW and Queensland, although there is some evidence of one near Sunbury, Victoria (Frankel 1982:83). Some Bora can be found on sloping ridges, but others are located on low-lying grounds near swamps, lagoons, creeks and rivers. In some areas, other types of structure are associated with gatherings, for example that of the stone structures at Lake Bolac, a known seasonal gathering site associated with eel traps (see Figure 4.1).

Figure 4.26 - Lake Bolac (Victoria) stone arrangement.

In Western Australia the Barragup weir on the Serpentine River has been recorded as having a significant role to provide food whilst annual gatherings took place (Gibbs 1987:91). Other evidence from Western Australia linking gatherings with fishing in the Swan River area have been recorded (Bunbury 1930:88) as well as at the coastal rock weirs at Oyster Harbour, Wilson Inlet and Broke Inlet (Mulvaney and Green 1992:252). Although outside the Murray-Darling Basin, it is still clear evidence of links between fishing resources and gatherings.

For a gathering of people to continue for more than a few days, a regular supply of food is necessary. The commonly held view that indigenous peoples subsisted on hunting kangaroos and emus along with plant resources would simply not work for large gatherings to be held - and very large gatherings have been recorded at Brewarrina (Mathews 1903), Moira (Curr 1883), Wagga Wagga (Gilmore 1933), Albury and Balranald (Bowdler 1999). For such large gatherings a more reliable source of food would be that of fish, either trapped or netted. It is significant that of the above trap sites, all are close to known gathering places. Key attributes of fish traps are the ability to provide food for large groups with minimal effort and the ability to hold live fish as fresh food which is useful if a gathering occurs over several days. Hence it is likely that gathering sites will often be associated with fish technology. Little research as been done to date on this area.

The aims of this chapter are 1./ Determine the importance of fish in the food supply 2./ Determine whether there are any relationships between the locations of fish traps and gathering places, such as Bora or Corroboree grounds and 2./ Establish the significance of fish traps for these events. Given that any gathering of large groups of people requires sufficient food resources to be able to stay for any length of time, it is possible that fish traps were used to supply food for such groups

4.2 Methods

Dietary significance

To determine the importance of fish in the Aboriginal diet in the basin two useful indicators are the degree to which a group is sedentary and the comparison of population structures of such groups with groups further away from riverine resources. Records of population structure and density have been collated as well as comparative data on population densities for different population groups relying on varying diets to try and gain an understanding for populations and their relationship with diet.

Bone isotope studies provide another source of data on ancient populations. Such data can provide an indicator of diet and also to some extent the movement of people. Both the organic and inorganic components of ancient teeth and bone provide a record of the long-term dietary structure of the person. Although only a broad measure, such studies can provide data on plant compared to meat diets and terrestrial compared to land-based food sources. Although little has been done in Australia, two studies are available – Roonka Flat on the lower Murray (an area with identified fish trap sites) and a coastal study at Broadbeach, near Surfers Paradise in Queensland (Pate 2000:67).

Gathering sites

The study of gathering sites has to rely on indirect evidence. Given the wide-ranging impact of European contact upon Aboriginal societies from very early times, only limited evidence has remained of the frequency, seasons and scale of many gatherings. To allow for this, a methodology has been developed, whereby a range of data sources has been accessed. These sources of evidence include: 1. Primary historical documents (for example explorer's journals, traveller's reports, diaries, nineteenth century newspaper sources; 2. Archaeological reports including published as well as grey literature encompassing various surveys of gathering sites such as Bora grounds and Corroborree sites and archaeological site descriptions both of the basin and elsewhere along with State and Federal Heritage Registers and ethnographic/anthropological studies, linguistic studies and 3. A range of map resources ranging from early pastoral and parish maps through to more recent maps of fish distributions, riverscape features and river navigation maps as well as Aboriginal language maps and of Indigenous place names.

4.3 Results

How important were fish in the food supply?

A lot of the archaeological record on fish traps is purely descriptive. However, to gain a better understanding of the significance of traps to indigenous peoples, and the possible links between trap sites and large gatherings of people it is important to also consider the likely yield of fishing technologies. Do traps provide an ongoing resource over long periods? Are yields high enough to support a large gathering? Are there differences in populations that rely on fish compared to other resources? What evidence might survive to assist in understanding this?

Population structure and density

To date little research has been done on the impact of fishing on food availability, although some evidence tends to indicate that areas with significant fish resources such as the Moira area in Victoria and on the lower Murray in South Australian, differing population attributes were evident such as greater sedentism along with different population structures compared to indigenous groups further inland (Curr 1883; Pate 1997, 2000).

Descriptions by Curr (1883:240) of the Wongatapan tribe provide an insight into the role of fish in their diet. The Wongatapan homelands were areas subject to inundation between the Golburn and Murray Rivers. The area consisted of many channels and fishing weirs were constructed widely along these flood channels. Sections of this area were allocated to individuals who looked after traps. In one case Curr (1883:243) describes how a boy was responsible for one stretch of channel and weir. More significant were his observations on the Wongatapan, especially in relation to the reliability of the food supply - fish were the main source of food, along with various roots. Fish were caught with nets, spears and controlled via weirs. He found no evidence of hooks for fishing. It is important to note that as a result of having a reliable source of food (Curr 1883:241-2) the tribe was sedentary, rarely leaving the riverbank area. And possibly related to that, infanticide was rare compared to other areas as they were not moving about which resulted in a higher proportion of children than in higher than in drier areas. As well, there was a higher proportion of older members of the tribe (up to 70 years old) than in drier areas. These factors all serve to support the view that a reliance on fish, either from trapping, nets or spearing could be a key factor in maintaining a quite different population structure than in surrounding areas. Comparisons were made with the Bangerang who lived at a distance from the rivers. This group had much higher rates of infanticide, the reason being that women could not carry more than one infant whilst moving about the landscape (Curr:1883:263).

Research from elsewhere such as in Hawaii (McClenachan and Kittinger 2012:3) tend to support the idea that indigenous populations were not just randomly catching fish, but rather were cognisant of long-term sustainability of the resource and managed accordingly.

Attempts have been made by various researchers to relate population densities in different areas with the types of food gathering that was taking place (Hiatt 1965:17; Tindale 1974:326; Modjeska 1977:37; Lourandos 1977). See Table 4.1 for a summary of these findings. These sites varied from New Guinea to Arnhem Land and Victoria. The table below is a summary (after Lourandos 1980:248). Not unexpectedly, there is an increase in population density as resource utilization methods expand. Fishing does allow higher population densities, and this matches the observations by Curr (1883:240), above.

Table 4.12- Population densities and food resources

Location	**Pop'n density persons / sq.km**	**Technology**
Oyster Bay - Tasmania	0.09-0.07	Hunter-gatherer
Northwest Tasmania	0.2-0.1	Hunter-gatherer
Southwest Victoria - inland	0.4-0.3	Hunter-gather/fishing
Southwest Victoria - coastal	0.7-0.4	Hunter-gather/fishing
Northeast Arnhem Land	0.77	Hunter-gather/fishing

Baktaman New Guinea	0.75	Shifting cultivation/hunter-gathering
Oksapmin New Guinea	8-10	Taro, sweet potato
Duna New Guinea	10-40	Intensive taro, sweet potato

Bone isotope studies

Bone isotope studies from the lower Murray indicate that protein in the diet from freshwater fish and shellfish was in the range 30-40% (Pate 2000). Other data drawn from these bone studies also indicate that populations along the lower Murray were significantly more sedentary than populations further inland, indicating the likely impact of reliable aquatic resources (Pate 1995:81). These finding tend to confirm the anecdotal evidence from Curr (1883) in relation to population structures and sedentism of Aboriginal groups that utilized aquatic resources.

Relationship with gathering places

Data on Aboriginal gatherings is limited in the historical record, but a summary of know fish trap sites that are associated with or are close to known gathering sites is summarized below. This covers various sites in Australia, but includes four sites from the Murray-Darling basin. Clearly fish traps were associated with some sites.

Table 4.13 – Overview - gathering places and trap sites

Location	References	Associations	Notes
Albury	NSW Atlas of Aboriginal Places NSW Parish maps	Trap site	
Balranald	NSW Atlas of Aboriginal Places NSW Parish maps	Murrumbidgee Trap site	Gatherings
Barragup Weir	Bunbury 1930	Serpentine River, WA with trap sites	Large annual gatherings
Brewarrina	NSW Atlas of Aboriginal Places Matthews	Trap site	Large gatherings up to 5000
Casino	Bowdler 1999	Water course to north of site	Largely destroyed 1976
Lake Bolac	Dawson 1881 Kenyon 1928	Lake with fish traps on outlet stream	800-1000 during ceremonies lasting 2 months
Nudgee Qld	Bowdler 1999 Register of National Estate	Swamp area	Last used 1860
Orara River - Braunstone	Bowdler 1999	Orara river	Bora Ground
Oyster	Mulvaney and	King George	Large annual

Harbour, WA	Green 1992	Sound trap site	gatherings
Samsonvale Qld	Bowdler 1999	Swamp now a dam	Best preserved
Toorbul Point Qld	Petrie 1904 Bowdler 1999	Fish trap	Bora Ground
Wagga Wagga	NSW Atlas of Aboriginal Places Gilmore 1933	Lagoon trap site	Corroboree site on lagoon
Wilson Inlet	Mulvaney and Green 1992	King George Sound trap site	Large annual Gatherings

There is evidence that seasonal abundance in different resource zones resulted in greater interaction between different Indigenous groups. There is evidence of large groups of people from different bands congregating when food supplies were in abundance. At Lake Bolac gatherings of 800-1000 people have been recorded during eel migration season (Kenyon 1928:146). Eels migrate back to the sea from this area and stream fences could have been easily deployed across streams at this time.

4.4 Discussion

Significance of fish traps for Aboriginal societies

Trap sites should not be viewed purely in terms of their food production. In reality they were a significant part of the Aboriginal cultural landscape. By providing a reliable and predictable food source, traps had significant impacts on population structures, the ability to become more sedentary (which changed population structures such as more children and older people being supported) as well as allowing for large gatherings of people at certain seasons. These gatherings had many purposes ranging from initiation ceremonies at places like Bora rings (Bowdler 1999), through to general social interaction which was important for trading materials such as stone tools through to marriage and the sharing of knowledge.

In relation to eels, both Lake Bolac and Lake Buloke are rich eel habitat. When autumn rains occur eels move from the lakes down towards the sea. Eel traps have been recorded on Lake Bolac and a large stone arrangement was also recoded here (see Figure 4.1) that was associated with gatherings. At this time large groups of Aborigines travelled considerable distances to gather there (Robinson 1841; Dawson 1881:93). Even today there is still a Lake Bolac Eel Festival inspired by it being a traditional gathering site.

Population structure and density

Evidence from different sources such as historical accounts and bone isotope studies are in general agreement that Aboriginal groups closely associated with aquatic environments did have different population structures and densities. This is clearly related to a more reliable food supply being available in such environments.

Gathering places

In the Murray-Darling Basin, only four out of 24 identified trap sites had associated gathering places. Data on gathering sites is limited in the historical record – apart from locations, which can be linked to identified trap sites, little information is available on numbers of people, duration of events or time of year. There is clear evidence in the historical record from Lake Bolac and Lake Buloke (Dawson 1881:94) as to the time of year, with gatherings being closely linked to eel migration. It is likely that known gatherings at other sites such as Balranald and Brewarrina did occur in spring time, as this is the season where fish migrations are at their highest (see Tables 3.2 and 3.4). However, little hard evidence exists for this supposition.

5 General discussion

The aim of this thesis was to improve our understanding of the Aboriginal fish traps of the Murray-Darling basin. Given the very limited hard evidence of fish and fisheries prior to the arrival of Europeans in the basin, a methodology that relied on a broad range of data sources was used, including, but not limited to: historical records (for example traveller's reports, diaries, nineteenth century newspaper sources); published, as well as grey literature encompassing various archaeological survey reports and archaeological site descriptions and State and Federal Heritage Registers; ethnographic/anthropological studies, linguistic studies, i.e. language maps and analyses of Indigenous place names; and historical maps. In addition, fish distribution records along with data on the behavior and ecology of fish was utilized. This approach enabled the development of a broad picture of fish traps across the basin including distribution, technologies used and some dating. Overseas data was also examined to provide insights into trap design and function and this provided useful insights.

The main results of this thesis can be summarized as: 1./ Detailed maps and summaries of trap distributions 2./ A better understanding of how traps were built and operated 3./ A linking of fish distribution and ecology to the historical record enabling a ranking of likely fish utilized at each trap site 4./ A better understanding of the significance of fish in the diet of Aboriginal peoples 5./ The links between traps and gathering sites and 6./ The continuity of fish trap design over time and place across the world.

Traps should not be seen just as a food resource, but rather part of the cultural landscape of Aboriginal Australia. Some trap sites provided reliable locations for social interaction as any extended gathering needs a food supply that can be accessed in a time efficient manner. The impact of fisheries on Aboriginal populations should not be underestimated.

On a broader scale it has become clear that there are significant similarities between the Australian trap sites and fish trap sites across the world. These similarities include date ranges when traps were known to be operating, through to the specific designs, particularly of timber and brush traps. The evidence from very early European sites clearly shows trap construction methods and materials that closely match photographs and drawings of known Australian traps. Undoubtedly, once a working methodology was established it was maintained over many thousands of years.

5.1 Directions for further research

This thesis has provided detailed information not only on identified trap sites, but also provides information on associated riverscape features and fish distribution patterns. This data could be used as a basis for prediction for the identification of other possible trap sites. In addition, the collation of fish data could provide a useful reference point in midden and other archaeological studies as a pointer to fish remains likely to be found in archaeological deposits.

6 Bibliography

Allen, H., 2010. *Australia: William Blandowski's Illustrated Encyclopaedia of Aboriginal Australia*, Canberra: Aboriginal Studies Press.

Ardalan, A. et al., 2012. Narrow genetic basis for the Australian dingo confirmed through analysis of paternal ancestry. *Genetica*, 140(1-3), pp.65–73.

Balcombe, S. R., A. H. Arthington, et al. (2006). Fish assemblages of an Australian dryland river: Abundance, assemblage structure and recruitment patterns in the Warrego River, Murray-Darling Basin. *Marine and Freshwater Research* 57(6): 619-633

Balme, J., 1983. Prehistoric fishing in the lower Darling, western New South Wales. In *Animals and archaeology; 2. Shell middens, fishes and birds*. pp. 19–32.

Balme, J., 1990. *A Pleistocene tradition : Aboriginal fishery on the lower Darling River, Western N.S.W.* Microfiche copy at Latrobe University Library, Bundoora.

Balme, J. and J.H. & Hope, J., 1990. Radiocarbon dates from midden sites in the lower New South Wales Darling River area of western. *Archaeology in Oceania*, 25(3), pp.85–101.

Balme, J., 1995. 30,000 years of fishery in western New South Wales. *Archaeology in Oceania*, 30(1), pp.1–21.

Balme, J. & Beck, W., 1996. Earth mounds in southeastern Australia. *Australian Archaeology*, 42, pp.39–51.

Balme, J., 2013. Of boats and string: The maritime colonisation of Australia. *Quaternary International*, 285, pp.68–75.

Balme, J. & Hope, J., 1990. Radiocarbon dates from midden sites in the lower New South Wales Darling River area of western. *Archaeology in Oceania*, 25(3), pp.85–101.

Bannerman, N. & Jones, C., 1999. Fish-trap types: a component of the maritime cultural landscape. *International Journal of Nautical Archaeology*, 28(1), pp.70–84.

Berndt, R.M. and C.H.B. with J.E.S., 1993. *A World That Was: The Yaraldi of the Murray River and the Lakes, South Australia*, Melbourne: Melbourne University Press.

Beveridge, P. 1889. *The Aborigines of Victoria and Riverina as seen by Peter Beveridge*, Melbourne: Hutchison.

Blandowski, W., 1857. Recent discoveries in natural history on the lower Murray. *Transactions of the Philosophical Institute of Victoria*, 2, pp.124–137.

Bowdler, S., 1981. Hunters in the Highlands: Aboriginal adaptions in the eastern Australian uplands. *Archaeology in Oceania*, 16, pp.99–111.

Bowdler, S., 1999. A study of indigenous ceremonial (Bora) sites in Eastern Australia. In *Heritage Landscapes: Understanding Place & Communities*. Lismore, NSW

Bowen, G., 1998. Towards a generic technique for dating stone fish traps and weirs. *Australian Archaeology*, (47), pp.39–43.

Bowen G.M, and Rowland, M.J, 1999, Indigenous Fish Traps and weirs of Queensland – An overview, Assessment and Recommendations. Report for the Australian Heritage Commission, Canberra and Environmental protection Agency, Brisbane: Queensland

Bowler, J.M. et al., 2003. New ages for human occupation and climatic change at Lake Mungo , Australia. *Nature*, 421(February), pp.20–23.

Brayshaw, H.C., 1977. *Aboriginal Material Culture in the Herbert/Burdekin District, North Queensland*. James Cook.

Bunbury,W. H. 1930. *Early Days in WesternAustralia*. London: Oxford University Press.

Campbell, J.B., 1979. Settlement patterns on offshore islands in Northeastern Queensland. *Australian Archaeology*, (9), pp.18–32.

Campana, Steven E ; Thorrold, S.R., 2001. Otoliths, increments, and elements: keys to a comprehensive understanding of fish populations? *Canadian Journal of Fisheries and Aquatic Sciences*, 58(1), pp.30–38.

Carmody, J., 1981. *Early Days of the Upper Murray*, Wangaratta: Shoestring Press.

Clemente, I., 2012. More Than 7,500-Year-Old Fish Traps Found in Russia. *Science Daily* pp.3–5.

Clune, G. & Harrison, R., 2009. Coastal shell middens of the Abydos coastal plain, Western Australia. *Archaeology in Oceania*, 44, pp.70–80.

Colley, S., 1987. Fishing for facts. Can we reconstruct fishing methods from archaeological evidence? *Australian Archaeology*, pp.16–26.

Colley, S., 1990. The analysis and interpretation of archaeological fish remains M. B. Schiffer, ed. *Archaeological Method and Theory,* 2(1990), pp.207–253.

Connaway, J.M., 2007. *Fishweirs: A World Perspective with Emphasis on the Fishweirs of Mississippi.*, Jackson, Mississippi: Mississipi Dept of Archives and History.

Connor, J.O., Mahony, D.O. & Mahony, J.O., 2003. *Downstream Movement of Adult Murray Darling Fish Species that movement Murray-Darling Fish Species with particular reference to the impact of weirs on that movement*.

Coutts, P.J.F., R.K.F. and P.H., 1978. Aboriginal Engineers of the Western District, Victoria. *Records of the Victorian Archaeological Survey*, 7, pp47.

Curr, E.M., 2001. *Recollections of squatting in Victoria: then called the Port Phillip District, (from 1841 to 1851)* 2nd ed., Echuca: Rich River Printers. (first published 1883)

Dargin, P., 1976. *Aboriginal Fisheries of the Darling-Barwon Rivers*, Dubbo: Brewarrina Historical Society.

Dawson, J., 1881. *The Australian Aborigines*, Melbourne: George Robertson.

Disspain, M., Wallis, L. a. & Gillanders, B.M., 2011. Developing baseline data to understand environmental change: a geochemical study of archaeological otoliths from the Coorong, South Australia. *Journal of Archaeological Science*, 38(8), pp.1842–1857.

Dixon, R.M.W., 1976. Tribes, languages and other boundaries in northeast Queensland. In N. Peterson, ed. *Tribes and boundaries in Australia*. Canberra: Australian Institute Aboriginal Studies.

Disspain, M., 2012. Morphological and chemical analysis of archaeological fish otoliths from the Lower Murray River, South Australia. *Archaeology in Oceania*, 47, pp.141–150.

Dortch, C.E., 1997. New perceptions of the chronology and development of Aboriginal fishing in South-Western Australia. World Archaeology, 29(1), pp.15–35.

Dortch, C., 2002. Evaluating the relative and absolute ages of submerged Aboriginal sites at Lake Jasper in Western Australia's lower south-west. *Australian Archaeology*, (55), pp.8–17.

Dortch, C.E., 2012. New perceptions of the chronology of Aboriginal development in south-western Australia. *Archaeology*, 29(1), pp.15–35.

Duncan-Kemp, A. 1933. *Our sandhill country: nature and man in south-western Queensland*, Sydney: Angus and Robertson.

Elsdon, T.S., Wells, B.K., Campana, S.E., Gillanders, B.M., Jones, C.M., Limburg, K.E. & Secor, D.E., Thorrold, S.R., Walther, B.., 2008. Otolith chemistry to describe movements and life-history measurements of fishes: hypotheses, assumptions, limitations, and inferences using five methods. *Oceanography and Marine Biology: an Annual Review*, 46, pp.296–330.

Ebner, B., Scholz, O. & Gawne, B., 2009. Golden perch Macquaria ambigua are flexible spawners in the Darling River. *New Zealand Journal of Marine and Freshwater Research*, 43, pp.571–578.

Erickson, C.L., 2000. An artificial landscape-scale fishery in the Bolivian Amazon. *Nature*, 408(November), pp.190–194.

Flecker, P.O., 1951. Remains of Aboriginal habitation on the Great Barrier Wall. *North Queensland Nauturalist*.

Flood, J., 1999. *The Riches of Ancient Australia* 3rd ed., Brisbane: University of Queensland Press.

Frankel, D., 1982. Earth Rings at Sunbury, Victoria. *Archaeology in Oceania*, 17, pp.83–89.

Frankland, K. 1990. Booral: A preliminary investigation of an archaeological site in the Great Sandy Strait region, south-east Queensland. B A (Hons) thesis, Department o f Anthropology and Sociology, The University of Queensland, Brisbane.

Fuller, R., Hamacher, D. & Norris, R., 2013. Astronomical Orientations of Bora Ceremonial Grounds in Southeast Australia. *Australian Archaeology*, (77), pp.27–30.

Furlani, D., 2007. Otoliths of common Australian temperate fish : a photographic guide, Collingwood, Vic.: CSIRO.

Garlake, P.S., 1973. *Great Zimbabwe*, London: Thames and Hudson.

Gerritsen, R., 2001. Aboriginal fish hooks in southern Australia: Evidence, arguments and implications. *Australian Archaeology*, 52(52), pp.18–28. Available at: http://www.jstor.org/stable/10.2307/40287518 [Accessed February 26, 2012].

Ghaleb, B., 1990. *An Ethnoarchaeological Study of Mabuiag Island, Torres Strait, Northern Australia*. Institute of Archaeology, University College, London.

Gibbs, M. 1987. Aboriginal gatherings in the west coastal region of southwest Western Australia, an ethnohistorical study. BSc Hons dissertation. Perth: University of Western Australia.

Giles, E., 1964. *Australia twice traversed : the romance of exploration, being a narrative compiled from the journals of five exploring expeditions into and through central South Australia and Western Australia, from 1872 to 1876*, Adelaide: Libraries Board of South Australia.

Gilmore, M., 1986. *Old Days: Old Ways*, Sydney: Angus and Robertson.

Godwin, L., 1988. Around the traps : a reappraisal of stone fishing weirs in northern New South Wales the first. *Archaeology in Oceania*, 23(2), pp.49–59.

Gott, B., 1999. Cumbungi, Typha species: A staple Aboriginal food in southern Australia. *Australian Aboriginal Studies*, (1), pp.33–50.

Graham, R. & Harris, J., 2005. *Floodplain Inundation and Fish Dynamics in the Murray-Darling Basin: Current Concepts and Future Research: a Scoping Study*.

Gramsch, B., 1973. *Das Mesolithikum im Flachland zwischen Elbe und Oder*, Berlin: Deutscher verlag der Wissenschafen.

Gribble, J., 1975. *Pre-Colonial Fish Traps On the South Western Cape Coast, South Africa*.

Heather, A., 1883. *Running rings around Moreton. Towards and understanding of the location of earth circle sites in the Moreton region, south-east Queensland*. University of Queensland.

Hiatt, B., 1965. *Kinship and Conflict*, Canberra: Australian National University Press.

Hiscock, P. & Mowat, F., 1993. Midden variability in the coastal portion of the Kakadu region. Australian Archaeology, 37, pp.18–24.

Hotchin, K. 1980 Three previously unrecorded Aboriginal stone alignments on the Hopkins River, Western District. *Records of the Victorian Archaeological Survey* 10: 119-30.

Howitt, A.W.W., 1906. *The Native Tribes of South-East Australia.* London. Macmillan.

Humphries, P., King, A.J. & Koehn, J.D., 1999. Fish, flows and flood plains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental Biology of Fishes*, 56(1), pp.129–151.

Humphries, P., 2007. Historical Indigenous use of aquatic resources in Australia's Murray-Darling Basin, and its implications for river management. *Ecological Management & Restoration*, 8(2), pp.106–113.

Jack, R.L., 1921. *Northmost Australia: Three Centuries of Exploration, Discovery, and Adventure in and Around Cape York Peninsula, Queensland - Volume II*, London: Simpkin, Marshall, Hamilton, Kent and Co.

Jansen, A., 1991. *County & Parish Maps of N.S.W.*, Emu Plains: Genial Editions.

Jenkins, R.A., 2006. *From Midden to Sieve: The Impact of Differential Recovery and Quantification Techniques on Interpretations of Shellfish Remains in Australian Coastal Archaeology*. University of Queensland.

Kearney, R., Kildea, M.A., 2001. The status of Murray cod in the Murray-Darling Basin.

Kenyon, A.S., 1928. The Aboriginal Protectorate of Victoria. *Victorian Historical Magazine*, 12, pp.134–72.

Koehn, J., Stuart, I. & Crook, D., 2001. Linking the ecological importance of downstream fish movements to management of Murray-Darling Basin fish populations. , pp.67–78.

Lawerence, R., 1971. Habitat and economy: A historical perspective. In: Aboriginal Man and Environment in Australia. In D. J. M. and J. Golson, ed. *Habitat and economy: A historical perspective. In: Aboriginal Man and Environment in Australia*. Canberra: Australian National University Press.

Leichhardt, L., 1964. *Journal of an overland expedition in Australia from Moreton Bay to Port Essington : a distance of upwards of 3000 miles, during the years, 1844-1845* Facsimile, Adelaide: Libraries Board of South Australia.

Lewes, E., 1924. The Goredi near Llanddewi Aberarth, Cardiganshire. *Archaeologia Cambrensis*, 74(397-400).

Lintermans, M. and Phillips, B., 2003. *Downstream Movement of Fish in the Murray- Darling Basin. Statement, Recommendations and Supporting Papers. In Downstream movements of fish in the Murray-Darling Basin*. Canberra: Murray-Darling Basin Commission, p. 104.

Lintermans, M., 2007. Fishes of the Murray-Darling Basin : an introductory guide, Canberra: Murray-Darling Basin Commission.

Lockerbie, John 2013. *Qatar Society* http://catnaps.org/islamic/society2.html

Kelsie Long, et.al. ., 2014. Fish otolith geochemistry, environmental conditions and human occupation at Lake Mungo, Australia. *Quaternary Science Reviews*, 88(March), pp.82–95.

Losey, R.J., Nomokonova, T. & Goriunova, O.I., 2008. Fishing ancient Lake Baikal, Siberia: inferences from the reconstruction of harvested perch (Perca fluviatilis) size. *Journal of Archaeological Science*, 35(3), pp.577–590.

Lourandos, H., 1980. Change or stability?: Hydraulics, hunter-gatherers and population in temperate Australia. *World Archaeology*, 11(3), pp.245–264.

Lourandos, H., 1994. The great'Intensification Debate': Its history and place in Australian archaeology. *Australian Archaeology*, (39).

Lourandos, H., 1997. *Continent of Hunter Gatherers*, Cambridge: Cambridge University Press.

Lupo, K. & Schmitt, D., 2002. Upper Paleolithic net-hunting, small prey exploitation, and women's work effort: A view from the ethnographic and ethnoarchaeological record of the Congo Basin. *Journal of Archaeological Method and Theory*, 9(2), pp.147–179.

Lunt, I.D. & Spooner, P.G., 2005. Using historical ecology to understand patterns of biodiversity in fragmented agricultural landscapes. *Journal of Biogeography*, 32(11), pp.1859–1873.

Mathews, R.H., 1897. Message sticks used by the Aborigines of Australia. *American Anthropologist*, 10(9), pp.288–298.

Mathews, R.H., 1903. The aboriginal fisheries at Brewarrina. *Journal and Proceedings of the Royal Society of New South Wales*, 37, pp.146–156.

Memmott, P., R. Robins and E. Stock 2008 What exactly is a fish trap?: Methodological issues for the study of Aboriginal intertidal rock wall fish traps, Wellesley Islands region, Gulf of Carpentaria, Australia. In Connolly J. and M. Campbell (eds) *Comparative Island Archaeologies*, pp.73-96. British International Series S1829, Oxford: Archaeopress.

McNally, L., 2013. Unspoilt stretch of Murray-Darling to be conserved. *Australian Broadcasting Corporation*, p.1. Available at: http://www.abc.net.au/news/2013-04-22/unspoilt-stretch-of-murray-darling-to-be-conserved/4642472.

McClenachan, L. & Kittinger, J.N., 2012. Multicentury trends and the sustainability of coral reef fisheries in Hawaiʻi and Florida. *Fish and Fisheries*.

McNiven, I.J. et al., 2012. Dating Aboriginal stone-walled fishtraps at Lake Condah, southeast Australia. *Journal of Archaeological Science*, 39(2), pp.268–286.

Miller, C., 2006. *The Geoarchaeological Setting of the Sebasticook Lake*

Fish Weir Newport, Maine. University of Maine.

Mitchell, T.L., 1837. *Three Expeditions into the Interior of Eastern Australia; with descriptions of the recently explored region of Australia Felix and of the present Colony of New South Wales Vol. 1*, London: T. and W. Boone.

Modjeska, C.J.N., 1977. *Production among the Duna*. Australian National University.

Mountford, M, 1939, 'Aboriginal Methods of Fishing & Cooking as used on the Southern Coast of Eyre's Peninsula, South Australia', *Mankind* 2 (7): 196-200.

Murray Darling Basin Authority 2012. *Murray Darling Facts*.

Museum Lolland-Falster, 2014. Danish finds reveal rare glimpse of Neolithic life. *Past Horizons*, (August 2013), pp.1–3.

Noe-Nygard, N., 1983. The importance of aquatic resources to Mesolithic man at inland sites in Denmark. In C. Grigson and J. Clutton-Brock, ed. *Animals and Archaeology:2 Shell Middens, Fishes and Birds*. pp. 125–142.

Kelsie Long, Nicola Stern, Ian S. Williams, Les Kinsley, Rachel Wood, Katarina Sporcica, Tegan Smith, Stewart Fallon, Harri Kokkonen, Ian Moffat, R.Grun, 2014. Fish otolith geochemistry, environmental conditions and human occupation at Lake Mungo, Australia. *Quaternary Science Reviews*, 88(March), pp.82–95.

O'Connor, S. & Veth, P., 2005. from Lene Hara Cave, East Timor establish complex fishing technology was in use in Island South East Asia five thousand years before Austronesian settlement. *Antiquity,* 79(304), pp.249–256.

O'Sullivan, A., 2004. Place, memory and identity among estuarine fishing communities: interpreting the archaeology of early medieval fish weirs. *World Archaeology*, 35(3), pp.449–468.

Out, W., 2008. Selective use of Cornus sanguinea L. (red dogwood) for Neolithic fish traps in the Netherlands. *Environmental Archaeology*, 13(1), pp.1–10.

Out, W., 2011. What's in a hearth? Seeds and fruits from the Neolithic fishing and fowling camp at Bergschenhoek, The Netherlands, in a wider context. *Vegetation History and Archaeobotany*, 21(3), pp.201–214.

Pardoe, C., 2003. The Menindee Lakes: a regional archaeology. *Australian Archaeology*, (57), pp.42–53.

Pate, F., 1995. Stable carbon isotope assessment of hunter—Gatherer mobility in prehistoric South Australia. J*ournal of archaeological science*, pp.81–87.

Pate, F., 2000. Bone chemistry and palaeodiet : Bioarchaeological research at Roonka Flat , lower Murray River , South Australia 1983 - 1999. *Australian Archaeology*, (50), pp.67–74.

Pederson, L., 1995. 7000 years of fishing: stationery fishing structures in the Mesolithic and afterwards. In Anders Fischer, ed. *Man and the Sea in the Mesolithic, Coastal Settlement above and below Present Sea Level*. Oxford: Oxbow.

Pugach, Irina, Frederick Delfin, Ellen Gunnarsdóttir, Manfred Kayser, and M.S., 2013. Genome-wide data substantiate Holocene gene flow from India to Australia. *Proceedings of the National Academy of Sciences of the United States of America*, 110(5), pp.1803–8.

Reid, D.D., Harris, J.H. and Chapman, D.J., 1997. NSW Inland Commercial Fishery Data Analysis, Sydney.

Richards, Michael P., Rick J. Schulting, R.E.E.H., 2003. Sharp shift in diet at onset of Neolithic. *Nature*, 425, p.366.

Richards, M. & Schulting, R., 2006. Touch not the fish : the Mesolithic-Neolithic change of diet and its significance. *Antiquity*, 80(308), pp.444–458.

Richardson, N., 1983. A Preliminary Report on Background Research for the Moonie to Jackson Pipeline Archaeology Project, Brisbane.

Roberts, A., 2010. *Aboriginal Women's Fishing in New South Wales A thematic history*

Robinson G. A., 2000. The Journals of George Augustus Robinson, Chief Protector, Port Phillip Aboriginal Protectorate, Vols 1– 6., Ballarat: Clarendon, Heritage Matters.

Ross, P.J., 2009. *Ngarrindjeri Fish Traps of the Lower Murray Lakes and Northern Coorong*. Flinders University.

Roughley, T.C., 1968. *Fish and fisheries of Australia*, Sydney: Angus and Robertson.

Royal Commission on Fisheries. (1894–96) *Royal Commission on Fisheries. Supplement report of the Royal Commission appointed on the 20th November 1894, to inquire and report upon the best means of developing the marine and other fisheries of New South Wales, and as to the better regulation of the fishing industry by law; Together with the minutes of evidence and an abbreviated description of the principal food fishes of New South Wales.* Charles Potter, Government Printer, Sydney, NSW.

Rowland, S. J. 1998. *Aspects of the reproductive biology of Murray cod (Maccullochella peeli).* Proceedings of the Linnaen Society of NSW 120, 147-162.

Rowland, S., 2004. Overview of the history, fishery, biology and aquaculture of Murray cod (Maccullochella peelii peelii). In *Management of Murray Cod in the Murray-Darling Basin - Canberra Worksop 2004*. pp. 38–61.

Rowland, M.J. and S.Ulm., 2011. Indigenous fish traps and weirs of Queensland. *Queensland Archaeological Research*, 14, 1-58.

Rowlands, R. and J.M.Rowlands, 1972. *Aboriginal Stone Arrangements: Report on the Fieldwork in South Western Queensland June-August 1972*, Brisbane.

Satterthwait, L. and A.H., 1987. Determinants of earth circle site location in the Moreton region, Southeast Queensland. *Queensland Archaeological Research*, 4, pp.5–53.

Satterthwait, L., 1987. Socioeconomic Implications of Australian Aboriginal Net Hunting. *Man*, 22(4), pp.613–636.

Scarre, C., 2011. *Landscapes of Neolithic Brittany*, Oxford: Oxford University Press.

Schell, P., 1995. An Archaeological Survey of the Hopkins River. Unpublished Report for the Framlingham Aboriginal Trust and Aboriginal Affairs Victoria.

Scott, A., 2005. Historical Evidence of Native Fish in the Murray-Darling Basin at the Time of European Settlement--from the Diaries of the First Explorers.

Serjeant, R.B., 1968. Fisher-Folk and Fish-Traps in al-Baḥrain. *Bulletin of the School of Oriental and African Studies* , University of London, 31(3), pp.486–514.

Smith, M. 1983 Joules from pools: Social and techno-economic aspects of Bardi stone fish traps. In M. Smith (ed.) *Archaeology at ANZAAS 1983*, pp.2945. Perth: Western Australian Museum.

Sullivan, A.O., 2001. Foragers , Farmers and Fishers in a Coastal Landscape — An intertidal Archaeological Survey of the Shannon

Estuary Strangford Lough : an Archaeological Survey of the Maritime Cultural, Dublin: *Discovery Programme Monographs 4*, Royal Irish Academy.

Sullivan, M.. and P.J. Hughes, 1982. The Stuarts Point Shell Midden Complex. *Australian Archaeology*, pp.27–34.

Sutton, P., 1985. *Aboriginal ceremonial sites of New South Wales*,

Sturt, C., 1833. *Two expeditions into the interior of southern Australia - Volume I* Facsimile,., London: Smith, Elder and Co.

Sturt, C., 1833. *Two Expeditions in the Interior of Southern Australia Vulume II* Facsimile,., London: Smith, Elder and Co.

Tench, W., 1979. *Sydney's first four years : being a reprint of A narrative of the expedition to Botany Bay and, A complete account of the settlement at Port Jackson*, Sydney: Library of Australian History in association with the Royal Australian Historical Society.

Tindale, N.B., 1974. *Aboriginal Tribes of Australia*, Canberra: ANU Press.

Walters, I., 1987. *Another kettle of fish: the prehistoric Moreton Bay fishery*.

Walters, I., 1988. Fish hooks: Evidence for dual social systems in southeastern Australia? *Australian Archaeology*, 27, pp.98–114.

Welz, A.I., 2002. *Fish Trap Placement!: The Environmental and Cultural Influences in Fish Trap Placement Along the Australian Coastline*. Flinders University of South Australia, Dept. of Archaeology.

Wills, W.J., 1863. *A Successful Exploration through the Interior of Australia: From Melbourne to the Gulf of Carpentaria from the Journals of and Letters of William John Wills*, London: Bentley.

Zaliznyak, L., 1998. The Ethnographic Record, and Structural Changes in the Prehistoric Hunter-Gatherer Economy of Boreal Europe. In *Harvesting the sea, farming the forest : the emergence of Neolithic societies in the Baltic Region*. Sheffield: Sheffield Academic Press, pp. 45–53.