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Australasian Journal of Environmental Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjem20

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To cite this article: Colin Pardoe & Dan Hutton (2020): Aboriginal heritage as ecological proxy in south-eastern Australia: a Barapa wetland village, Australasian Journal of Environmental Management, DOI: 10.1080/14486563.2020.1821400

To link to this article: https://doi.org/10.1080/14486563.2020.1821400

Published online: 30 Sep 2020.

AUSTRALASIAN JOURNAL OF ENVIRONMENTAL MANAGEMENT
https://doi.org/10.1080/14486563.2020.1821400

Aboriginal heritage as ecological proxy in south-eastern Australia: a Barapa wetland village

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ABSTRACT
Aboriginal archaeology has a central role to play among the myriad government agencies and professional disciplines involved in land and water management of the Murray River Basin in south-eastern Australia. In this study, we examine managed water flows against the archaeological record which provides secure evidence of how people lived at the Murray River floodplain wetlands before European colonisation. Seasonal residential patterns and economic activities of large populations have been reconstructed using archaeological, environmental, and hydrological information. The result is a picture of people living in large groupings – villages and hamlets – around water bodies that we suggest are ecological 'hot spots' within the forest. In identifying the preferred locations of village sites, we present the case for modification of environmental water delivery from large area forest flooding to targeted smaller water bodies that form ecological hot spots throughout the river floodplain landscape. Traditional Aboriginal land use in the form of the distribution of Aboriginal sites can act as an environmental proxy to inform heritage, land and water management policy and practices that seek to restore the health of the Murray River.

KEYWORDS
Barapa; archaeology; environmental water; fish breeding

Introduction

Location and research context

The Murray-Darling Basin contains 20 per cent of Australia's total agricultural land and produces 35–40 per cent of the total gross value of the nation's agricultural output. It once supported Aboriginal Australia's densest population (Pardoe 1994, 2006); today it is the food bowl of the country.

The Murray-Darling Basin Authority (MDBA) is the independent statutory authority responsible for all planning decisions related to sustainable use of the Basin's water resources. Since irrigated agriculture uses 80 per cent of the Basin's water resources, there has been a major focus on buy-back schemes and directing these into environmental flows to restore the health of the river systems. Management strategies generally have pre-European conditions as targets for restoration of wetland ecosystems and river

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flows. The Basin Plan also recognises the importance of harnessing local Aboriginal traditional knowledge in natural resource management (MDBA 2014).

A major water management strategy, The Living Murray Program, established six representative and significant 'icon sites' as a focus for environmental flows and landscape restoration, including the whole river channel itself (Figure 1). They were selected for their high ecological value and cultural significance (MDBA 2011a). The Gunbower-Koondrook-Perricoota Forest (icon site 2 on Figure 1), totalling 50,000 ha on both sides of the River Murray, was selected as one of these sites (MDBA 2016a, 2016b). Management of this icon site is complex and involves many government instrumentalities (Parsons, Thoms, and Flotemersch 2017). Koondrook-Perricoota, Millewa and Werai Forests form the NSW Central Murray Forests Ramsar site, nominated as a Wetland of International Importance under the Ramsar Convention in 2002 (Harrington and Hale 2011). It is managed by the Forestry Corporation of New South Wales but water allocations are held by the Commonwealth Environmental Water Office, Department of Environment and Energy. Between 2010 and 2013, as part of landscape restoration, a 5 m tall 45 km levee and other structures were constructed to provide environmental flows (eWater) to the forest, the intention being 'to mimic natural flooding events' in the Koondrook-Perricoota Forests (Forestry Corporation NSW 2015, 2; Murray-Darling Basin Authority 2018a).

Barapa Barapa Aboriginal people are traditional land owners on both sides of the River and share responsibility for Perricoota Forest with their Yorta Yorta neighbours. In 2015, with the support and interest of the Barapa Barapa and Forestry Corporation of New South Wales, we conducted an archaeological survey of one small swamp in

Figure 1. Pollack Swamp is part of the Gunbower-Koondrook-Perricoota Forest icon site (number 2 on the map). Source: Licensed from the Murray–Darling Basin Authority under a Creative Commons Attribution 4.0 Licence.

the floodplain to investigate traditional Aboriginal life in a wetland ecosystem (Pardoe and Hutton 2016).

Pollack Swamp, the subject of our study, is a 220 ha swamp situated in a 700 ha Flora Reserve in Koondrook Forest. It is locally known as The Pollack, derived from the Barapa Barapa word *Pulitj* meaning swamp (Hercus 1992).

During natural flooding events water enters the swamp via Pollack Creek, fed from the neighbouring Barbers Creek and via a second small channel from Barbers Overflow. The main swamp was originally open water, remaining so until the inlet channels were blocked off and the reed beds cleared in the 1970s for agriculture. Both channels were reopened later allowing flood waters to once more enter the swamp. Reductions in flooding frequency, depth and duration enabled River Red Gum (*Eucalyptus camaldulensis*) to colonise the open swamp. Currently only a few hectares of open water remain. It had previously been recognised as a significant breeding site and drought refuge for Ibis and threatened Egret species. The last recorded colonial waterbird breeding event at the Pollack was in 1992/3 (Disher 2000; Gabriel 1884).

Landscape history

The region that includes Koondrook-Perricoota Forest was very different before the 1840s. The major waterways in the Murray-Darling Basin were lined by open Red Gum forests that gave way to plains covered by Salt and Blue Bush. In this part of the Mid Murray, the rivers fan out into a network of anastomosing creeks, with lagoons and swamps lined by what the European explorer Mitchell described as ‘a sea of reed beds bounded only by the horizon’ (Mitchell 1838, 2:136; Hawdon 1952 [1838]). The Aboriginal groups living in the area were described as ‘the aquatic tribes’ or ‘the reed bed natives’ (Mitchell 1838, 2:142; Clark 2000).

We know from ethnographic sources that this was a densely populated part of Aboriginal Australia. The Barapa are described as tall, well-built and athletic with a rich diet high in aquatic resources including a wide range of fish and fowl (Hinkins 1884; Krefft 1865). In the Mid Murray reed beds, Aboriginal people had ready access to an abundance of fish for eight months of the year, supplemented by kangaroo, emu, possum, and wallaby (Beveridge 1883). Widely documented fishing methods include the use of fish traps, weirs and dams, nets of various lengths and gauges, spearing from canoes or underwater, and less commonly hook and line and poison (Beveridge 1889; Curr 2001 [1883]; Phillips 1893; Gilmore 1934; Humphries 2007).

A range of aquatic plants were eaten including Water ribbon (*Cycnogeton procerum*), sedges (*Juncus spp*), Common reed (*Phragmites australis*) and Nardoo (*Marsilea spp*) (Zola and Gott 1992). Bulrushes (*Typha spp*; *cumbung*i and *wongal* to the Barapa) formed the staple carbohydrate food throughout the Basin. Aboriginal people managed the rushes via controlled, seasonal mosaic burning to allow young shoots to grow in the spring (Curr 2001 [1883]; Gott 1999b). Shoots and flowers were a delicacy but rhizomes, roasted in earth ovens, were eaten all year especially in summer when starch levels were highest (Beveridge 1883; Gott 1999a). The fibrous matter left after chewing the rhizomes was spun into string to make nets, bags and other essential items of material culture (Krefft 1865; Beveridge 1889). Reeds were also used to make compound spears that were an important trade item.

Environmental changes following European settlement of this region of the Murray River in the 1840s transformed the landscape putting an end to Aboriginal land management and firestick farming. The initial pastoral occupation with hundreds of thousands of cattle and sheep resulted in destruction of native vegetation, including the reed beds, the introduction of exotic plant and animal species and compaction of soils, leading to increased runoff of water (Curr 2001 [1883]; Scott 2001). By the 1850s, sawmills were operating in the forests supplying wood for housing, steam boat fuel and wharves, props for the Victorian goldfields, cobbles for Melbourne streets and by the 1870s railway sleepers (Priestly 1965; Coulson 1995).

Land acts in the 1860s and 1870s promoted agriculture and land division, especially along the rivers and creeks. The remaining reed beds were cleared and ploughed. Local drainage works, the construction of large holding dams upstream and major irrigation works from the 1920s onwards transformed and controlled the flood regime.

Changes since the 1980s have proven even more severe; broad-acre laser-planing has accelerated removal of water for irrigation, leaving barely one fifth of the water available for a restricted river floodplain. Since regulation of the River Murray, both the frequency and duration of flooding has been dramatically reduced resulting in a 90 per cent decline in native fish communities (MDBC 2003), an 80 per cent reduction in waterbird breeding events (Leslie 2001) and a 72 per cent decline in waterbird numbers in the last three decades (Kingsford, Bino, and Porter 2017).

The changes wrought by Europeans in the last 175 years have rendered the landscape created by Aboriginal people largely invisible. The speed of change and the lack of records have made it difficult for today's land managers to establish a baseline for a pre-colonial environment. The hydrological evidence on which environmental flows are based was first collected 140 years ago and omits the changes that occurred in the first 50 years of colonisation.

The archaeological survey

The initial aim of our project was archaeological: we wanted to understand how and where Aboriginal people lived in this particular wetland area in the past. Earth mounds and scarred trees are the most common archaeological features visible in the Murray Basin, a region known for its lack of stone. Mounds are simply the by-product of long-term residence in particular places: people building houses, cooking in earth ovens, and living in exactly the same place repeatedly for long periods. They are often situated on raised natural features, such as levee banks, and are identified by dark organic soils and vegetation that differ from the surrounding area. They are largely circular and contain ash, charcoal, baked clay cooking bricks used in earth ovens, burnt animal bone, mussel shell, other domestic material and the detritus of daily life. Sometimes they contain burials. Depending on their environmental context, mounds functioned principally as ovens for cooking, for processing plants for string, as habitation sites, or all three. They have been dated to within the last 4000 years (Downey and Frankel 1992; Martin 2006, 2011). The greatest concentration of earth mounds is along the waterways and wetlands of south-eastern Australia which were productive areas with variety, density and stability of food resources. By mapping the distribution of mound residences in one discrete area, we aimed to explore residential patterning and economic life in the forest.

Between 2014 and 2015 we conducted detailed ground surveys of an area 4 × 3 km that included the 1.6 km diameter Pollack Swamp and the surrounding area south and east of Barbers Creek. Some mounds were adjacent to current water bodies but many appeared randomly distributed throughout the forest with no obvious proximity to water. This preliminary ground survey was greatly assisted by LiDAR [Light Distance And Ranging] mapping (Clarke, Gibson, and Apps 2010). LiDAR comes into its own in a flood plain context with minimal elevation and slight topography where water movement can be affected by minor impediments or earthworks. It allowed us to map the mounds against landform features measuring less than 1 m such as meander scrolls and levee banks as well as small distributary flood channels (known locally as runners), ponds and other water bodies. Many of these channels and ponds had not held water for many years. A major feature of LiDAR is its ability to map a 'bare ground' surface by removing trees and lower vegetation from the data. This allowed us to map the 153 mounds we recorded against a detailed topography that related them to hydrology and seasonal water flows.

Size, location and clustering of mounds, as well as surface observations of contents, were recorded. In this article we concentrate on mound distribution with regard to local environment and hydrology. We develop the rationale for the use of residential patterning as environmental proxy following a detailed description of three mound clusters at The Pollack.

Mound distribution at the Pollack

A total of 153 mounds are distributed in clusters around the swamp and between the swamp and Barbers Creek. The preferred locations are on the edge of standing water such as lagoons and ponds as opposed to the larger channels. They are often built on higher ground such as natural levees that contribute to their height or on slightly elevated areas that form islands in times of flood. Over time the mounds provide more raised ground above the floodwaters.

In many locations the relationship between mounds and water was immediately apparent as they are distributed in linear fashion along levees bordering the water courses, around the western swamp margin and along Pollack Lagoon and inlet channels. In other areas, particularly north of the swamp, there is no obvious water course and the mounds are distributed across the floodplain in seemingly random fashion. Only by mapping the mounds against LiDAR were we able to clarify the relationship between mounds and water (Figure 2). Hillshade and stretching have been employed to highlight minor features, such as plough and irrigation lines. Elevation of sand hills to the west of the Swamp has been clipped. The small channels form anastomosing 'capillary beds' during floods. Laser-planing of paddocks to the west of Pollack Swamp is evident.

Mound distribution at Pollack Swamp can be grouped into 13 distinct clusters ranging in number from two mounds to the larger clusters at the inlet and outlet channels (Table 1). The mounds vary in size from 57 × 18 m to 5 × 5 m. Areas are between 15 and 806 m^2 with an average of 159 m^2. For comparison, residential house blocks in Australian urban centres are currently being released at sizes of between 200 and 500 m^2.

Some of the clusters are linear, such as the mounds along the western shore of the swamp or along the western bank of Barber's Creek. Table 1 presents the number of

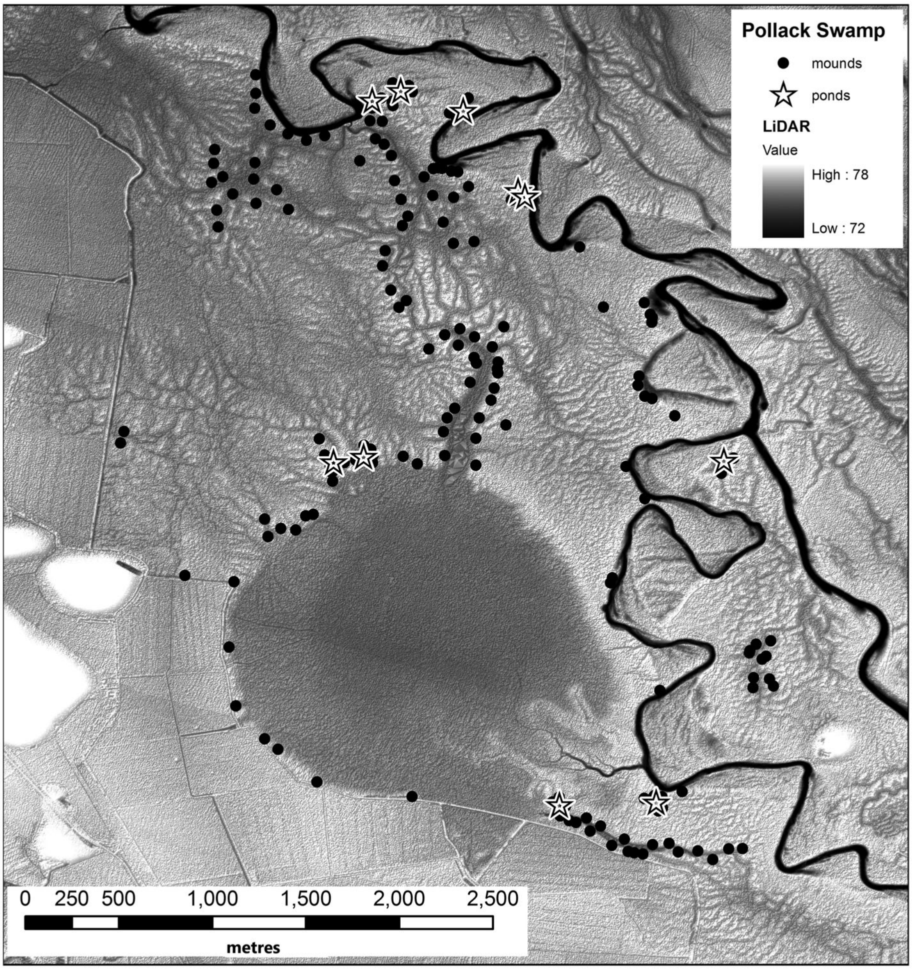

Figure 2. Mound distribution at Pollack Swamp on a LiDAR base, $n = 153$.

mounds per cluster, the average mound area, and the total cluster area. The NW Pond sites have been summed in a separate line to allow comparison with the larger residential clusters. All mounds were assessed in terms of their proximity to water and potential resources but the table clearly identifies those locations within the study area which were of highest value to Aboriginal people – the most desirable real estate. Three of the main residential areas are described in more detail. The size and density of mounds provides evidence of sustained activities by large numbers of Barapa residents over long periods of time.

The Lagoon

During floods, the Swamp fills from the south-east via Pollack Creek and the Southern Inlet, and flows exit north via Pollack Lagoon and other flood channels to re-join Barbers Creek. Both the Lagoon and the Southern Inlet retain standing water throughout the year and both have the largest number and total area of mounds (Table 1). The

Table 1. Number of mounds by cluster and area.

Cluster	Number of mounds per cluster	Average area (m^2)	Total cluster area (m^2)	Max	Min	SD
Pollack Lagoon [includes the Neck]	23	291	6682	806	64	189
Pollack Southern Inlet	21	172	3609	266	85	54
NW Pond 1	6	252	1515	572	69	170
NW Pond 2	5	412	2060	521	254	144
NW Pond 1 + 2	11	325	3575	572	69	172
Western Shore	14	128	1787	256	57	55
Lagoon to Barbers Lane	22	91	1994	236	38	50
Pulitj Hollow	12	123	1479	289	69	62
Barbers North	7	177	1240	222	129	38
Barbers Creek West Bank	23	88	2022	344	15	72
Tommys Crossing Pond 1	4	98	390	178	40	64
Tommys Crossing Pond 2	3	154	461	232	100	69
Tommys Crossing Pond 3	3	65	194	80	35	26
Barbers Creek South Pond	6	69	417	116	42	26
not clustered	4	131	524	230	46	78
Total / average	153	159	24,375	806	15	128

Notes: The analysis below focuses on the three main residential areas where the size and density of the mounds provides evidence of sustained activities by large numbers of Aboriginal people over long periods of time.

Lagoon extends north of the Swamp for almost 1 km and holds water between 2.0 and 2.5 m deep through the year. At its widest it is 91 m with an average of 70 m.

The Lagoon has the largest cluster of dwellings with 23 evenly spaced mounds, averaging 78 m apart, and with an average area of 291 m^2 (Figure 3). This cluster also contains the largest mounds, slightly oval in shape to maximise water frontage. The largest mound measures 806 m^2, equivalent to a very good sized house block in urban Australia

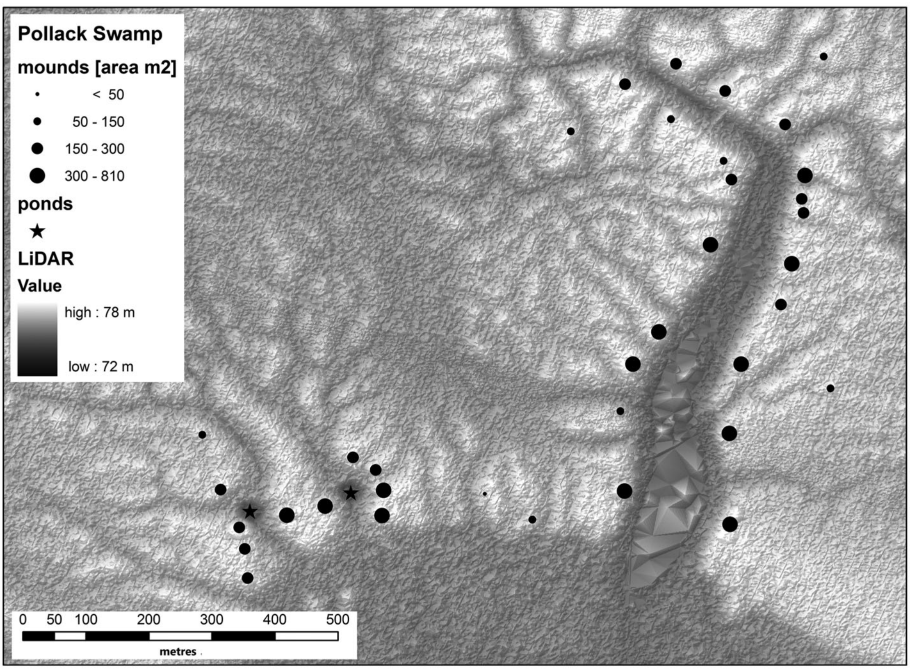

Figure 3. Enlarged map of Pollack Lagoon and North-West Ponds, the two largest residential areas on the northern edge of the swamp.

today. The mounds are arranged in a fashion reminiscent of houses along a street, with 13 on the east side of the lagoon and 10 on the west, built on the natural levees that line the Lagoon. There is a mapping artefact in the bed of Pollack Lagoon at the south, although the deeper channels on either side are clearly visible.

Most of the mounds were built on either side of small distributary channels that cut (or have been cut) through the levees. These are ideal places for the construction of weirs as the rising floodwaters spill through them to spread across the floodplain and then back. Sixteen of the 23 mounds are also situated facing one another across the channel forming eight pairs. While some of the positioning is clearly determined by the minor topography of levee elevation and side channel placement, it makes sense to consider these pairs as contemporary. Perhaps maintenance and use of a fish or duck net constructed across the channel, or thrown across daily, would most efficiently require a residence on either side. The South Australian Museum holds fish nets from the Murray River averaging 27 m long (18–40 m) and 1.5 m (0.9–2.5 m) deep. Duck nets are usually 100 m long by 2 m deep, the mesh being 5–10 cm wide. Thomas Mitchell, the first European explorer to pass through the area on 3 June 1836, came across such a net:

> The natives had left in one place a net suspended across the river between two lofty trees, evidently for the purpose of catching ducks and other waterfowl. The meshes were about two inches wide, and the net hung down to within five feet of the surface of the stream. In order to obtain waterfowl with this net some of the natives proceed up, and others down, the river to scare the birds from other places and, when any flight comes into the net, it is suddenly lowered into the water, thus entangling the birds beneath until the natives go into the water and secure them. (Mitchell 1838; entry 3 June 1836)

The larger mounds in this cluster are closer to the swamp where the Lagoon is deepest. Digging clay for heat retainers may have contributed to deepening of these channels encouraging speculation that the deeper channels on either side of the Lagoon are man-made. Together with the smaller cluster of dwellings round the North-West ponds (below), the Lagoon comprises the residential centre of Pollack Swamp.

The Southern Inlet

The Southern Inlet that funnels water from the Barbers Creek Overflow and averages 20 m wide is smaller than the Lagoon but also retains standing water. This southern cluster consists of 21 mounds, with 10 on the northern side closer to the swamp, and 11 on the southern side. The average sizes of the mounds and the total residential area are smaller than the Lagoon. Unlike the mound positioning on the Lagoon, however, these mounds are staggered rather than directly opposite one another. The placement of these mounds is regular, rather than random or clustered, and only two are sited either side of channels. Since this water body is much narrower than the Lagoon, it is possible that residences directly opposite one another would have been avoided in the interests of privacy (Memmott 2007; Allen 2010).

North-west ponds

Apart from the Lagoon and Southern inlet channel, the largest mounds were found in two clusters (NW Pond 1 and 2) in a rather different form of residential grouping

(Figure 3). It became apparent that the six and five mounds were organised respectively around shallow depressions that form ponds in two small channels of similar size and depth at the north-west edge of the swamp (Figure 3). Each cluster contains a pair of larger mounds facing one another across the pond. The ponds are visible as wider and deeper structures within a flood channel.

The ponds have an average net depth of 0.6 m with average dimensions of 36 × 30 m and average capacity is 0.34 ML. Although they were clearly visible on the ground, we did not connect these depressions with the mounds until we inspected the area on the LiDAR mapping which suggests that they are incongruous features, not naturally formed at these locations in channels. These depressions were formed by the residents digging clay for use as heat retainers in the ground ovens that are a major component in mound building. These shallow pools would make good holding ponds for fish as the flood waters recede, requiring only a weir on either end.

In the 1840s, a European settler in the Mid Murray observed Aboriginal people cooking in earth ovens on mounds and estimated that ‘at least a barrowful of fresh clay is required every time the oven is heated to replace the unavoidable waste by crumbling, which is by no means inconsiderable, in consequence of the clay being used in an unwrought state’ (Beveridge 1889, 34). It was clear to him that continued use of the mounds, as residences and for cooking ‘over a series of years, perhaps indeed centuries’, would result in very large mounds. At the same time, the amount of soil dug out to build the ovens, ‘accounts fully for the depressions always found about the bases of these ovens’ (Beveridge 1889, 33).

We mapped a further seven clusters of mounds grouped around ponds (varying between 0.5 and 1.0 m in depth) that had been excavated within channels. Although shallow and inconspicuous, they are clearly part of each larger residential complex. No similar features are seen in waterways away from earth mounds.

Summary of mound distribution

The situation of the 23 largest mounds along Pollack Lagoon to the north was no surprise as it was an area where standing water could be seen most of the year. The location of the mounds on either side of the Southern Inlet to the south-east was also to be expected. The position of the mounds more sparsely distributed along the shallower western shore was clarified by the LiDAR which clearly situated them at the high water mark on the margin of the swamp when full, but close to the gently receding waters and a sequence of plant species, useful for both food and manufacture of nets, mats, baskets and decorative items. Interpretation of the North-West ponds also only became possible with LiDAR which allowed us to investigate the complex relationship between mounds, small channels and ponds.

The number, size and density of earth mounds in the study area, and their distribution in clusters raised above low lying ground that would have been subject to inundation, supported a hypothesis that large numbers of Barapa Aboriginal people lived for many months of the year in permanent residences in the reed beds of the Mid Murray. In exploiting the resources of the wetland ecology, they had practised a form of aquaculture over thousands of years. LiDAR, accounts written by Europeans in the 1840s, and the earth mounds themselves provide evidence of sedentary village life for up to five months of the year with resources capable of supporting a large population from early spring to the onset of winter. Although the relationship between mounds and water was not evident during the survey, we were keen to test our hypothesis against the next flood event.

Testing the archaeological model

A managed environmental flow of eWater into Pollack Swamp in 2015 allowed us to examine the relationship between water flows and Aboriginal residential patterning. Research continued through a natural overbanking event that flooded the forest in the spring of 2016 followed through to the recession in 2017.

2015 Ewater allocation

The Forestry Corporation of New South Wales is responsible for implementing and monitoring Environmental Flows. Pollack Swamp had received no inflows for three years and in Spring/Summer 2015, 500 ML of environmental water was allocated to improve forest vegetation and wetland health. The specific aims of the event were: to provide water to stressed River Red Gums; to encourage recruitment of terrestrial and aquatic flora; to provide drought refuge for water birds; and to support a breeding event if triggered. During the event, the volume, extent, depth and duration of the water, along with water quality, temperature and oxygen levels were monitored at the central reed bed and in the Lagoon. Vegetation, waterbird, fish and frog responses were also monitored as indicators of wetland health.

The amount of 500Ml had been estimated from the flow model created by the Murray-Darling Basin Authority (MDBA 2011b; Tuteja and Shaikh 2009). It soon became clear this volume was insufficient. The allocation did not approach the North-West ponds mound cluster and did not fill the Lagoon, the two preferred Barapa residential areas. At the end of 15 days, the water had receded to half of its modelled area: from 150 to 75 ha. A further 1000 ML was used over the next few weeks, but never filled the swamp to the level suggested by LiDar topography and the placement of the mounds. While dry ground may have contributed to the discrepancy, the modelled flow is clearly biased. The flow model is used for today's situation, including weirs, dams and regulators, but as a model of the pre-regulation system, has been unable to take account of early changes, particularly soil compaction from sheep that took place in the first decade of European settlement and the clearance of the reed beds. The eWater triggered plant growth and the results showed a good crown response among some of the Red Gums, an increase in native frogs, fish and crustaceans, and a significant number of local water birds capitalising on the event, with some breeding successfully. No migratory birds were seen and as the water receded, it was apparent that many of the chicks had failed to thrive. Even three times more water than originally modelled by MDBA was insufficient in extent and duration to demonstrate a relationship between water flow and Barapa villages.

2016 A natural overbanking event

The 'once in a generation' Basin-wide floods of September 2016 resulted in an overbanking event that covered the floodplain and showed the system in operation. An environmental water delivery to the Pollack of 1.5 GL had been planned for that spring but delivery was postponed to assess the extent of natural flows into The Pollack.

Fieldwork between October and December 2016 was conducted by canoe, replicating the way Aboriginal people travelled through the landscape, transporting food and firewood to their island homes. As we paddled through the floodwaters, along main channels leading to lagoons and swamps, into smaller side channels bordered by earth mounds and across ponds, we recorded a sequence of plants and animals as they responded to the overbanking. As the shallow waters warmed, the aquatic breeding cycle began.

The Swamp filled and overflowed, isolating the mounds and reproducing the extent of floodwater anticipated in our residential model. Given the upstream regulation of water flows, the timing and volume of the flood was not completely natural, but for the first time we were able to observe the filling of ponds, a previously unnoticed feature of the mound complexes. The flood also clarified the position of many mounds either side of small side channel, indicating the obvious placement of weirs. Pollack Lagoon, the principal Aboriginal residential area according to the archaeological evidence, filled completely with water that lasted throughout 2017. The two excavated ponds at the centre of the large North-West mound clusters filled with water to a net depth of 0.6 m below the base of the channel and a maximum depth of 1.7 m. The average net depth of all ponds was 0.8 m. Again, the water lasted all year.

A dense wall of mosquitoes collapsed after about 15 days following the flood peak as water invertebrates, then fish, started to breed and consume the mosquito larvae. These small fish are or were locally abundant, but many are endangered or locally extirpated (Ellis et al. 2013; Todd et al. 2017; Vilizzi et al. 2013). We were not able to monitor fish during this time, but noted that the fishing birds – the migratory colonial Egrets and Herons – arrived shortly after the collapse of the mosquitoes (Figure 4).

Water ribbon (*Cycnogeton procerum*) appeared floating on the surface by the time the flood peaked. Its chestnut-like tuber was of great value to the Barapa as it could be harvested relatively early in the season (Zola and Gott 1992). While it occurs in channels throughout the forest, we noted large stands close to large mound clusters.

Waterbirds were first observed in September with the arrival of large numbers of ducks: Australian Shelduck (*Tadorna tadornoides*), Wood Duck (*Chenonetta jubata*), Grey Teal (*Anas gracilis*), Pacific Black Duck (*Anas superciliosa*) and Chestnut Teal (*Anas castanea*). It was the arrival of large numbers of colonial migratory waterbirds, though, and their first successful breeding event in 25 years that triggered most emotion among local residents. The first Nankeen Night Heron (*Nycticorax caledonicus*) in full breeding plumage was recorded in late October and ground surveys through the summer estimated the colony to cover 9.5 ha and contain 500–600 nests. Nankeen Night Herons (*Nycticorax caledonicus*) (66% of nests) were the predominant species, followed by White-necked Herons (*Ardea pacifica*) (20%), Eastern Great Egrets (*Ardea modesta*) (8%) and Intermediate Egrets (*Ardea intermedia*) (6%). This confirmed the important role played traditionally by these small swamps in the maintenance of species diversity within the forest ecosystem (Disher 2000). Most of these species had not been seen since 1996 (Hutton 2017). In 1840, immigrant Europeans named the nearby town of Deniliquin after a senior Barapa man, Denilikoon. His totem was recorded as Yabil Yabila, the Nankeen Night Heron. Mr Norman Moore, a Barapa descendant of

Figure 4. An Eastern Great Egret flies over The Pollack. Photo by Dan Hutton.

Denilikoon, saw these birds returning in 2016 for the first time in a generation and watched as they grew their courting plumage, built nests and began to lay.

The development time from egg to independent juvenile for some waterbird species within the colony was known to be up to 100 days (Marchant and Higgins 1990) which gave a target date in early March 2017 for maintenance of the water. By December it was apparent that the regulated timing of the flood in late spring and the rapid recession threatened successful completion of the breeding cycle. In addition to normal summer evaporation rates, significant additional water had been lost through high transpiration rates from the infestation of River Red Gum saplings. An additional 1 GL water was delivered into the Swamp from mid-December with a further 224 ML from mid-February until natural recession was considered capable of supporting the completion of the waterbird breeding cycles (Hutton 2017).

In the dry it had been difficult to explain the placement and function of certain mounds and ponds, particularly among the 'capillary beds' of channels to the north of the swamp. With the overbanking, the hydrology of the ponds became clear, as did the pairing of mounds on either side of channels, and the likely position of weirs. Levee banks, usually tree-less, now stood out as dry land roads. Seen this way, Pollack Swamp and its environs operated as a coherent, functional unit – a village. We could envisage the summer landscape described by one of the first settlers in the area in the 1850s:

> All over the submerged country, cooking mounds stand up out of the flood, perfect little islands, looking bright, green, and refreshing to the eye, by reasons of the dense growth of succulent saltbush, dillines (dillon bushes) and giant mallow, with which they are prettily dressed. (Beveridge 1883, 37–39)

He described people living on these mounds for up to five months of the year, raised above the flood waters by centuries of oven building, and feasting on fish, crustaceans, water fowl and eggs.

Discussion

Our study of Pollack Swamp began as an archaeological investigation but has important implications for environmental conservation and water management. Rivers are complex social-ecological systems with many different stakeholders, making trade-offs and compromises essential (Parsons, Thoms, and Flotemersch 2017). Conservation efforts for the forests and floodplains of the Murray River come down to allocation of one scarce resource: water. With 80 per cent of the water taken for irrigation, we cannot hope to recreate a pre-European environment or mimic natural flooding events throughout the Basin (Forestry Corporation NSW 2015). The time for restorative ecological planning is past. Flooding of forests is no longer an option. The Living Murray initiative has acquired 500 GL of environmental water to deliver water to all six icon sites. As we have demonstrated, Pollack Swamp alone would require 2 GL on a regular basis to re-establish the spawning grounds of native fish (particularly the small species), to maintain the rookeries of endangered birds, and to maintain many of the small plants and animals that were essential to traditional ecosystems.

Focussed distribution to targeted locations will maximise the ecological value of scarce water to deliver best results, as measured in part by the diversity and density of species, and to ensure sustainability of vegetation, fish and waterbirds. To a degree this is already happening (MDBA 2018b) and our contribution is to suggest a method for the identification of critical locations. The distribution of Aboriginal sites can act as an environmental proxy to help water managers identify those water bodies that would provide the best returns. Aboriginal people situated their villages in the most productive areas of the flood plain and returned to these locations year after year. The number, density and distribution of earth mounds correlate with the distribution of species diversity and density and are indicators of the pre-European productivity of swamps and water bodies.

The accumulated knowledge that produced these village sites also offers the best evidence of the extent, timing and duration of floodwaters through the forest and the sequences of plant, bird and animal life. Our study has shown, for example, that specific patterns of flooding are needed for successful breeding of several species of bird taxa and the fish on which they depend. A clear relationship between mound clusters and rookeries is emerging (Hutton 2017).

The village sites provide evidence of Barapa modification of their landscape, as has been documented in south-eastern Australia (Lourandos 1987; Builth 2014; Pascoe 2014; Gammage 2011). Over the centuries, as the mounds are built up above the floodwaters, the excavated depressions at their base become large ponds that prolong the availability of water and have a direct effect on local permanent water sources. The ponds act as water storage through the year following the flood recession and hold small fish which are ready to spawn at the start of the next flood season. Ponds also provide a finer scaled resource for small mammals and reptiles.

An important aspect of our research is the number of people resident at these villages and the resources required to sustain them. Two mounds on either side of a small creek, with an adjacent pond, indicate fine-tuning of land and resource use. This is the family level of spatial organisation. Each household might be considered to consist of a family of parents and children, with perhaps grandparents, uncles and aunts and other relatives resident in houses arranged on the mounds. If only a third of mounds were occupied at any given time, then a total population at the Pulitj could number 250–500 individuals in residence for perhaps five months each year, following the more or less annual spring melt water floods. Since humans are omnivorous apex predators, it becomes clear that such population numbers concentrated in a small area would require substantial food and water resources.

It has proven difficult to translate an ideology of 'connection to country' and Aboriginal cultural values (MDBA 2014) into the kinds of practical management strategies that would reproduce a traditional Barapa landscape, harness local knowledge, and serve our shared goals of restoring the health of the waterways. Our study has provided concrete evidence of Aboriginal water management practices and shown how Barapa people over centuries learned how to live in their wetland environment and how to enhance its productivity. It has translated generalised traditional ecological knowledge into specific, actionable local knowledge. This will allow Barapa people not only to make decisions about country but to participate in the identification of their villages and restoring their landscape. Our discussions with a range of ecologists and water managers has stimulated interest in a multi-disciplinary team approach where Barapa people can play a central role in the management of their land and water based in part on the documentation of their ancestral heritage.

Conclusion

Pollack Swamp until 1845 was a population centre of the Barapa Aboriginal nation. There are 153 earth mounds around the swamp, grouped according to minor topographic features of flood channels and higher ground. The distribution of these mounds is a distillation of 3000 years of Barapa traditional knowledge and land management practices. The earth mounds that have built over that time indicate repeated residence in the same spot. Excavated ponds are to be found at most clusters of mounds, and are the result of digging clay for the small balls used as heat retainers in the ground ovens that are a main feature of the mounds. The ponds would have become storage facilities for fish as well as providing an extra water supply.

Observations in the broader Koondrook-Perricoota Forest show that not all swamps are village sites. Others, like Pollack Swamp, have dense mound concentrations around them, indicating hamlet or village settlements. Large numbers of people, perhaps hundreds in a place like Pollack Swamp, require a lot of food. It is reasonable to infer that people chose their larger centres – villages and hamlets – with food availability as a major criterion. Using the archaeological record as a proxy measure of ecological diversity and density indicates those hot spots that would allow us to target water delivery in order to give the greatest ecological result for restricted water allocations. Environmental water allocations are limited and uncertain, as was seen in December 2019, when an allocation near Echuca was rescinded. Given the limited water available, flooding of forests is not viable. There will never be the amount of water necessary when it is needed. Targeting smaller water bodies would make better use of the limited water that is likely to be available during dry times. A small number of these sites (or hot spots) would need to be carefully selected according to other criteria that would include number of species, the volume of water needed, constraints and cost effectiveness of water delivery, and long-term sustainability. The distribution of Aboriginal sites can act as an environmental proxy to help water managers identify those water bodies that would provide the best returns.

Acknowledgements

The pleasure of wading through the Pulitj has been added to by the hospitality and interest of many people in the local Barham community, particularly Ron and Joy Galway, Graeme and Tanya Heffer, and Roger Knight. More widely, we thank the Barapa community (Neville Whyman, Norman Moore and Sharnie Hamilton to name a few), North Central Catchment Management Authority Victoria (Robyn McKenzie, Bambi Lees), The Murray-Darling Basin Authority, and Office of Environment and Heritage NSW. This study could not have progressed without the assistance of Forestry Corporation NSW, particularly Linda Broekman. Delena Gaffney, partner to Dan, is thanked for her passionate support. Penny Taylor, wife of Colin, indulged these ventures and her contribution warranted co-authorship, but for that dratted glass ceiling. Penny was a great friend and supporter of the Barapa Nation. We dedicate this work to her memory. Nukkin

Disclosure statement

No potential conflict of interest was reported by the author(s).

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