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Local ecological knowledge and wise use of ephemeral wetlands: the case of the Cowal system, Australia

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Abstract Ephemeral wetlands are important ecologically but are often jurisdictionally complex and under-studied. Forms of local knowledge, including local ecological knowledge (LEK) and farmer knowledge, are increasingly recognised as able to complement other scientific knowledge for planning and management. This paper contributes to the discussion on the value and potential use of local knowledge by considering the Cowal system, an ephemeral wetland in dryland Australia. The Cowal system's hydrological regime is highly variable, with drying and wetting cycles influenced by distant rainfall events. There is limited historical scientific data available for the system. Semi-structured interviews were undertaken with local landholders who privately own the land within the Cowal system. The aggregated results showcase their knowledge and understanding of the ecological functions of the Cowal system, highlight some current ephemeral wetland management activities and indicate their concerns for the future. LEK is shown to be a valuable source of historical and planning data. For example, their combined memories and family records of the Cowal system provide the only historical record of the timeline of the wetland's filling and drying, and support their concerns about the alteration of the natural hydrological regime because of developments in the catchment area. The research suggests that LEK should be actively sought by scientists, managers, and planners of wetlands, especially where baseline and systems information is scant.

Keywords Local knowledge · Local ecological knowledge · Inland ephemeral wetlands · Wetland management · Lake Cowal · Nerang Cowal

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Introduction

Wetlands are recognised as one of the most valuable and important ecosystem types in the world; however, there are accelerating rates of wetland habitat loss and degradation, both globally (Millennium Ecosystem Assessment 2005; Dudgeon et al. 2006; Waterkeyn et al. 2008; Davidson 2014; Davies et al. 2021) and within Australia (Finlayson et al. 2011). To ensure the wise use and conservation of wetlands, it is essential that scientists and managers develop a comprehensive understanding of ecological processes in wetlands, conduct evaluations of wetland degradation and losses, and implement effective conservation plans and monitoring programs (Finlayson 2012).

Notwithstanding their name, wetlands may be only periodically wet, that is, they may be ephemeral. Inland ephemeral wetlands support a high level of biodiversity and provide valuable habitat for endemic and rare species (Capon 2003; Deil 2005). Despite their ecological, social, and economic significance, the quality and number of ephemeral wetlands is threatened by intensive anthropogenic pressures resulting in their rapid disappearance (Deil 2005; Calhoun et al. 2017). The driving factors of climate change and human population growth have tremendous potential for altering rainfall and runoff patterns. For example, human infrastructure such as roads and towns, and practices such as agriculture can significantly affect the stability of the regional hydrology and the availability of water resources in the future (Kingsford et al. 2016). Ephemeral wetlands are important ecologically but are often jurisdictionally complex and under-studied (Wilson et al. 2011). For example, monitoring of inland ephemeral wetlands has had less attention than studies of more permanent wetlands (Rhazi et al. 2012). For many global inland ephemeral wetlands, scientific data and historical ecological information is patchy or unavailable (Finlayson and Spiers 1999; Mediavilla et al. 2020), and subject to science budget constraints. One way to increase understanding of these wetlands is for scientists and policy makers to recognise and value local knowledge.

'Local knowledge' can refer to understandings, beliefs, and practices; it is usually site-specific and co-evolves with anthropogenic and environmental changes (Berkes et al. 2000; Zent 2001; von Glasenapp and Thornton 2011). Local ecological knowledge (LEK) is usually associated with a specific group of people who have been on the land for generations and who possess a broad and detailed knowledge of their local ecosystems stemming from ongoing and extensive interactions as part of that system (Ghorbani et al. 2013). LEK may be particularly valuable in relation to understanding and managing ephemeral wetlands located in remote areas where comprehensive scientific data collection may be impractical (Barsh 1997; Ferguson et al. 1998). Local knowledge as an information source needs to be taken into consideration in conservation plans and management decisions (Corburn 2002). An increasing number of researchers have paid attention to LEK and have emphasised the significance of LEK in various ecological and environmental studies (Davis 2005; Isaac et al. 2009; Mamun 2010; D'Antonio et al. 2012; Joa et al. 2018; Sousa et al. 2020).

While LEK is most often associated with the knowledges of Indigenous peoples, it can also be reflected in understanding of local phenomena derived from more recent human–environment interactions over a few generations (Raymond et al. 2010), including those associated with farming communities. The knowledge and experience of local communities have been acknowledged as important resources for the environment conservation and management (e.g. Pretty and Ward 2001; Pretty 2003; Pretty and Smith 2004; Marchessaux et al. 2023) and resource use planning (Millar and Curtis 1999; Chen et al. 2016; Aswani et al. 2018). In this paper we use LEK in a broad sense of local environmental knowledge that is gained experientially over time.

While it is posited that local knowledge, including LEK, can contribute to conservation of ephemeral wetlands (Pitt et al. 2012), the mechanisms for that contribution are not well understood or documented. This paper adds to our understanding of the value and potential roles of local knowledge in wetland conservation via exploration of a single case centred on the Cowal system, the largest natural inland ephemeral freshwater wetland in New South Wales (NSW), Australia. Other authors have referred to the system as the Lake Cowal area/the Cowal region (e.g. FloraSearch 2008), or the Lake Cowal system (e.g. Austin and Nix 1978; Lake Cowal Foundation 2014), but in this paper we will use the term the Cowal system when referring the entire ephemeral wetland system, and we will use individual names when referring to specific parts of the ephemeral wetland system.

Study area and methods

Study area—the Cowal system

The Cowal system is situated in the Lachlan River catchment of NSW, Australia (Fig. 1), and is typical of the ephemeral inland wetlands of the area (Lake Cowal Foundation 2014). The Cowal system comprises 13,000 ha for Lake Cowal and 4355 ha for the adjacent Nerang Cowal. The Cowal system is fed by water inflows from Bland Creek and Sandy Creek during heavy rainfall events, and from the Lachlan River when it floods. The Cowal system is located on

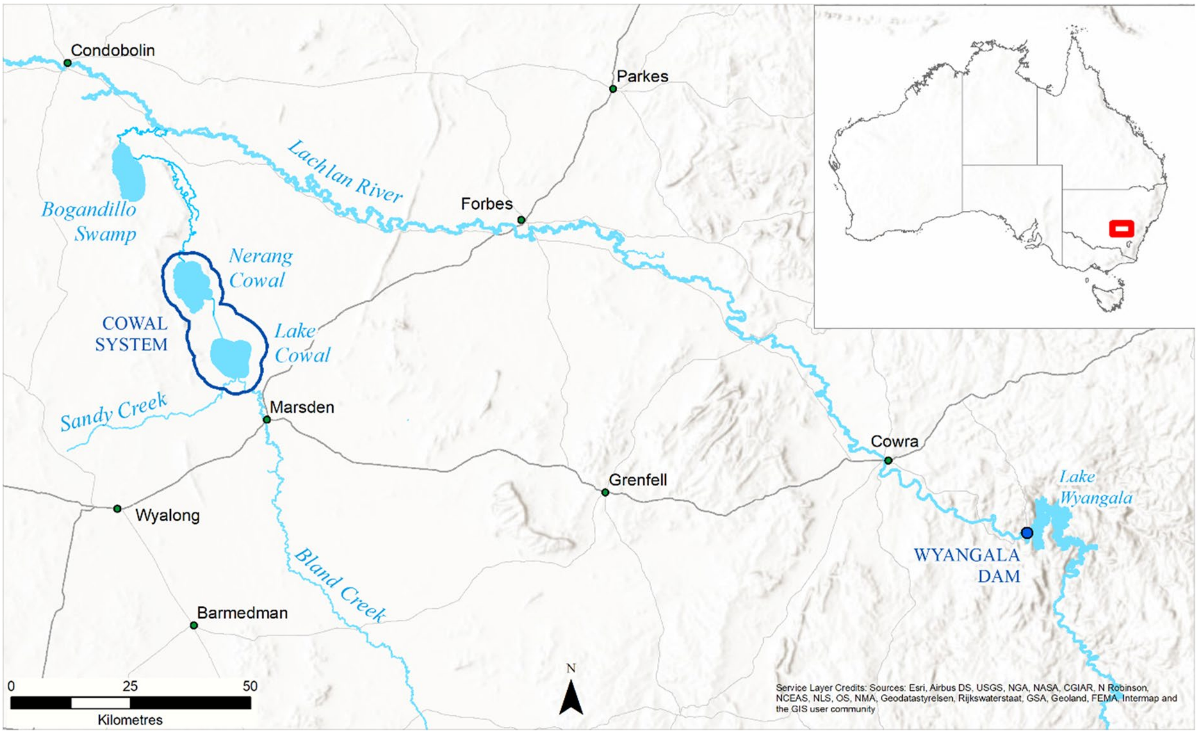

Fig. 1 Location of the Cowal system comprising Lake Cowal and Nerang Cowal in New South Wales, Australia

the border of the semi-arid and the temperate regions in south-eastern Australia, which are subject to cool, wet weather in winter and hot, dry weather in summer (Austin and Nix 1978). The Cowal system has a hydrological regime with periodic drying and wetting cycles, sometimes lasting for years at a time (Lake Cowal Foundation 2014). Apart from during extreme drought events, most of the time the 'sump' of Lake Cowal (local term used to refer to the deeper area showing in Fig. 2) does not completely dry out. Nerang Cowal, located north of Lake Cowal, is shallower and experiences more variable wetting and drying cycles than the sump (Carnegie 2015).

The wetland system in the Lachlan River catchment is more productive than the main river and has higher biological diversity (Benger 1997). Lake Cowal, in particular, is an important habitat for significant concentrations of waterbirds and migratory bird species (Lawler 1989; Lachlan Riverine Working Group 2014). Due to the significant numbers of waterbirds that visit the ephemeral wetland, the Australian Heritage Commission listed Lake Cowal on the Australian Register of the National Estate in 1992 (Department of the Environment, Water, Heritage, and the Arts 2008). Lake Cowal has also been included in the Directory of Important Wetlands and listed as a Landscape Conservation Area by the National Trust of Australia because of the high diversity and number of species that inhabit the ephemeral wetland (Australian Heritage Commission 1998). The Cowal system is also a significant area for social and cultural values. In particular, the Cowal system is the spiritual region and cultural grounds for the local Traditional Owners, Wiradjuri people, and although the area was settled by Europeans in the mid-1800s, the land was never ceded (Bhatia 2002).

Since European settlement the Cowal system has supported several land use activities, including cropping, grazing, and mining (Lake Cowal Foundation 2014). Most of the native vegetation within the Cowal system has been heavily cleared for agriculture (Carnegie 2015). Also influencing the Cowal system is Wyangala Dam, situated upstream in the Lachlan River catchment. Sometimes during wet years, more water will be discharged from Wyangala Dam because of storage releases (Green et al.

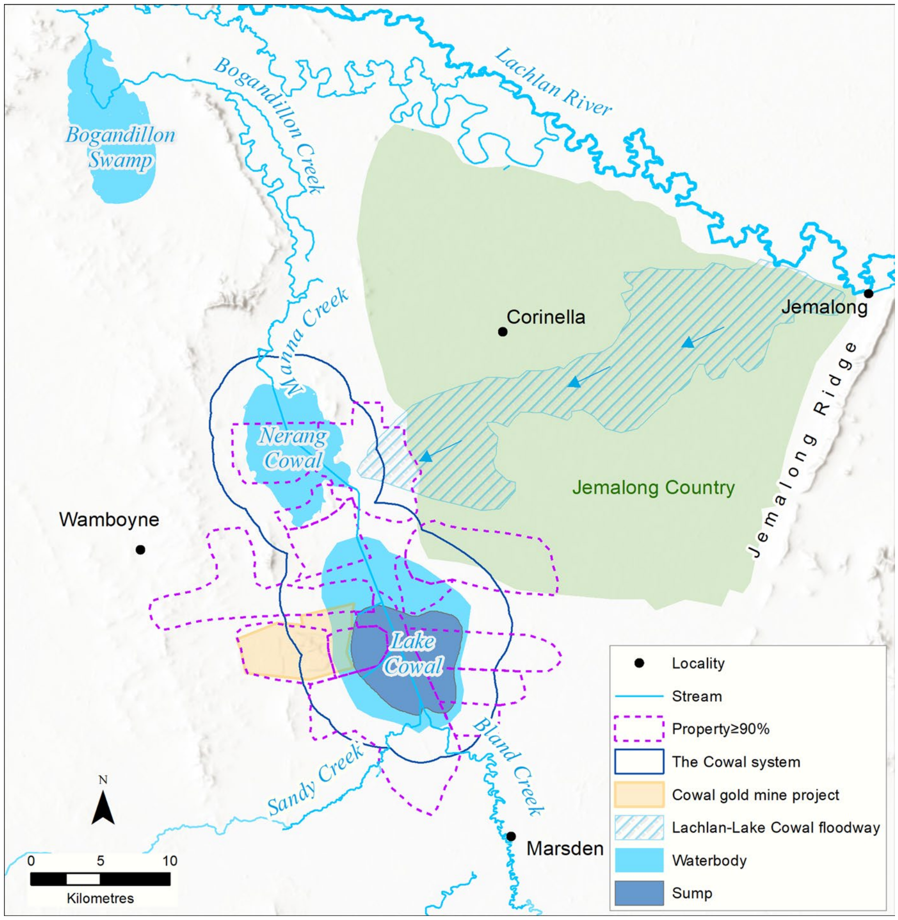

Fig. 2 The combined coverage of all interviewed landholders' properties within the lakebed on the Cowal system is about 90% outlined by purple dotted lines

2011). In such instances, the Cowal system becomes inundated for much longer periods than usual, and the local landholders cannot farm in the lakebed because their land is under water. In contrast, during dry years, Wyangala Dam is used to store water for town water supplies, stock and domestic use, and irrigation supply. Also, the nearby extensive Jemalong Irrigation District Channel is often saline and contains high concentrations of nutrients and pesticides, and the external sediment and nutrient loadings from the channel can be input to the Cowal system via rainfall and runoff (Office of Environment and Heritage 2006). A result of these intensive land uses, and water management is that the Cowal system has declining water quality and a loss of habitat and biodiversity (FloraSearch 2008).

Despite the social, cultural, and ecological importance of the Cowal system, the ecological knowledge availability for the area is limited. Published scientific reports for the ephemeral inland wetland system have focused on the biodiversity assessment and biodiversity offset strategy including flora and fauna survey reports for the purpose of the gold mine construction and expansion (AMBS Ecology and Heritage 2017). The Cowal system provides an ideal case study to explore the potential for local knowledge to contribute to understanding and improved management of inland ephemeral wetlands.

Methods—survey of local ecological knowledge

Local knowledge in this case could come from many sources, including from Wiradjuri peoples, the Barrick Cowal Gold Mine Corporation, and local landholders. Because the land in the Cowal system is privately owned and managed primarily by local farmers, this research focussed on local farmer knowledge. The research was undertaken with approval from the Charles Sturt University Human Research Ethics Committee.

An important resource for this study is Carnegie (2015). This book was written to preserve the local history and cultures and ensure that information is not lost through generation change, and it and its author provided an entry point for research design and participant recruitment.

Landholders who own or manage agricultural properties within or surrounding the Cowal system were invited to participate in the research via a single semi-structured interview with author Liu. All nine landholders agreed, with interviews occurring in March 2015. Each participant outlined their property boundary and the combined coverage of their properties within the lakebed of the Cowal system is about 90% (Fig. 2). Of the nine interviewed landholders, seven landholders had lived in the area for several generations, one had moved to the area in 1992, and another had been farming in the area since 2000.

Semi-structured interviews have a flexible structure (Denzin and Lincoln 2011) that enables conversations around people's life experiences, perceptions, knowledge, understandings, perspectives, interpretations, and interactions (Mason 2004). In this case the interview conversations were based on questions relating to any historical and current environmental characteristics of the Cowal system, their farming activities, and their expectation for the future of the ephemeral wetland system. The length of interview ranged between 40 and 60 minutes and all were audio recorded then orthographically transcribed into verbatim written text. Along with the participants' observation and memories, some shared artefacts including photos, books, newspapers, records, maps, and dairies during the interviews. NVivo® software assisted with analysis of the transcripts, which sought both direct information and deductively determined themes. In the sections below, C1–C9 has been assigned to distinguish each interview participant.

The observed extent of water filling of the Cowal system was translated from analysed interview data plus available records at Wyalong Post Office, and historical texts, photos, and diaries, and published book of 'Right around Lake Cowal' (Carnegie 2015) based on resident recollections, combined into a figure for the historical hydrograph.

Results

Hydrological data

Some new and immediately useful ecologically related information was collected. For example, longitudinal data are important for understanding change in the inland ephemeral wetlands, but historical data of fluctuations in storage volume (i.e. rise or fall in water level) and occurrences of spilling for the Cowal system have not been officially recorded, and there are no hydrological gauges to monitor breakout flows to the Cowal system from the Lachlan River catchment or inflows from Bland Creek and Sandy Creek. It is not possible to provide actual figures of the percentage of the Cowal system that was filled historically in the absence of hydrological gauges to monitor breakout flows to the system.

With compiled data from the multiple sources described above, we created the hydrograph showing longitudinal data for most period from 1883 to 2015 on extent of water filling of the Cowal system (Fig. 3). In our interpretation, 100% filling of the Cowal system represents that both Lake Cowal and Nerang Cowal were filled with water. Less than 75% filling of the Cowal system represents that only the sump of Lake Cowal was filled with water. Between 1883 and 1921, the records from landholders provided patchy data about the extent of filling of the Cowal system, then information from the interviews and other records about the extent of filling in the Cowal system was collected for every year from 1922 until 2015. The compiled data from all the landholders revealed a hydrological regime with periodic drying and wetting cycles (Fig. 3). The 'Millennium drought' that occurred in 2000s was mentioned by all interviewed landholders. While anecdotal, many of the records used to compile Fig. 3 were independently sourced from more than one landholder. For example, two landholders spoke of multiple flooding events in the 1950s, including 1950, 1952, 1954, 1956, and 1959. Three landholders discussed the several flooding events in the 1960s, including 1960, 1961, and 1962. The flooding events of 1973 and 1974 were discussed by two landholders, and three landholders spoke of the several flooding events in the 1980s, including 1983 and 1985. More recent data were often independently provided by more interview participants;

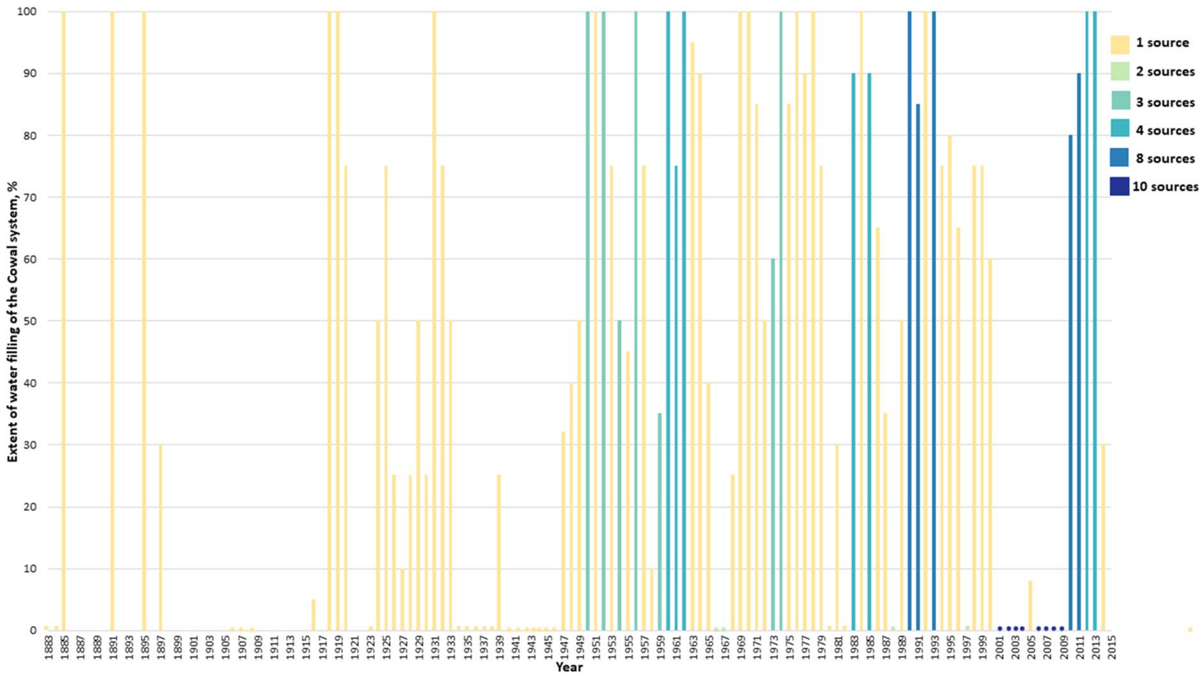

Fig. 3 The observed extent of water filling of the Cowal system between 1883 and 2015 based on local knowledge and anecdotal evidence provided by local landholders in the area. Dots indicate the Cowal system was completely dry in those years. The blank indicates that there is no available information of water filling of the Cowal system for those years. 100% filling of the Cowal system represents that both Lake Cowal and Nerang Cowal were filled with water. Less than 75% filling of the Cowal system represents that only the sump of Lake Cowal was filled with water. Dark blue dots indicate from ten sources, blue bars indicate from eight sources, aqua bars indicate from four sources, teal bars indicate from three sources, lime dots indicate from two sources and gold bars/dots indicate from one source

seven spoke of the several flooding events in the 1990s, including 1990, 1991, and 1993, that Lake Cowal was full in 2010 and 2011. That the Cowal system was full in 2012 and 2013 was mentioned by three landholders.

Understanding of environmental characteristics

As well as providing information that enabled the construction of Fig. 3, the interview participants highlighted key features and ecological processes contributing to the essential characteristics of the environmental condition of the Cowal system. They made observations related to soils, surface hydrology, water quality, flora, and fauna. Table 1 presents these, with in each case a verbatim quote from an interview participant as an example of the evidence.

Perceptions of environmental management

In addition to their system and ecological knowledge, the interview participants had strong perceptions and opinions about the environmental management of the Cowal system. This included reflection on the hydrological regime, external salt loadings, native vegetation composition, weed invasion, carp and wide animals, and mine operation and management. These are summarised, with sample direct quotes, in Table 2.

Concerns for the future

Landholder concerns for the future of the Cowal system were also expressed, as summarised in Table 3.

Table 1 The characteristics of the environmental condition of the Cowal system recognised by local landholders, including hydrological, physico-chemical, and ecological characteristics

Environmental understanding	Ecological processes	Interview evidence
Hydrological characteristics	Attribution of primary surface water inflows to Lake Cowal	The water comes anywhere from the Jemalong irrigation areas or down on the Bland Creek. They come into Lake Cowal and then it floods, and they come to Nerang Cowal…and then it continues…it eventually gets back to Lachlan. (C3)
	Periodic drying and re-inundation water regime	It's completely dependent on rainfall in different areas of the catchment. So, it could fill from the river only, or it could fill from the river and the Bland Creek, or it could fill from Bland Creek only…And sometimes it might fill over a short period of time, so a week or two weeks, at other times, like this last fill, it might take two or three years to fill right up… So, there's no pattern to it, it's just highly variable. (C9)
	Drying timescales	Well, you see once the lake fills, even without much runoff, it takes about three years to dry, this was Lake Cowal itself… But Nerang Cowal, when it spills is about four foot six and it spills into Manor Creek…So Nerang Cowal then, it takes more than one year, well more than one summer, say 18 months. (C8)
Physico-chemical characteristics	Algal bloom	I've seen blue-green algae up in the northern end up near Bogeys Island and we do get algal bloom… It actually can get quite bad in the summer. It usually appears when the lake level is probably getting down, only about four-foot depth in a bit of hot weather. It's got that chemical type of smell comes across and when you look out, everything's sort of pale green… That's been going on forever sort of thing when the lake water level gets down to a certain level. (C5)
	Turbidity	The water quality seems to vary according to where the flows come from that fills it. So, if the water comes from the Lachlan River, mostly from river flood, the water's generally clearer…But when it comes from the Bland Creek it's usually more turbid, so muddier. (C9) It wasn't always turbid. Particularly up on the end where there was more because there was more Canegrass [Eragrostis australasica] up this end and Lignum bush, and further up again there are trees, more vegetation and that. (C8)
	Sedimentation	So, where the river water meets the lake water, you can actually see the different colours in the water. Well, I would think that because the lake water is black soil, it stirred up the black soil in the lake that it has that sort of colour in it whereas the river water would be coming in, it'd be more of a red soil water, so you'd have different sediments in the water which would make it different colours. (C2)
	Soil type	I think it was what I really liked about the property was the good soil types and the lake was definitely a part of that …it's got a lot of various soil types which makes it quite a diverse farm and it's a very good grazing property. The lighter soils, they will produce grass quicker; then the heavier soils are better hung on when it's dry. (C1)

Table 1 (continued)

Environmental understanding	Ecological processes	Interview evidence
Ecological characteristics, including flora and fauna	Changes in composition of aquatic vegetation	Since it's dried, I haven't seen any Nardoo [Marsilea drummond] there was a lot of it last time. (C5) The only thing that used to be on the surface sometimes was the Azolla [*Azolla filiculoides*]. You can see Azolla, probably when the water was getting shallower. (C9)
	Waterbirds	Like it was dry for 12 years, and as soon as it started raining, and like the lake started filling in 2012…the birds and that, just massive amounts of them just came in, all sorts…And when they do all come and nest… There's pelicans, swans, ibis and ducks and there's a lot of snakes, and a lot of wildlife. I've seen this same sort of thing in the 1970s floods. (C7)
	Weeds	And up until probably 15–20 years ago we didn't see any of that, that Chinese Lantern [Physalis alkekengi], then it started in the middle of the lake where the deep was and now it's coming right up into the shallow end of the lake… It can move 200 m in a day. (C2)
	European carp	[X] had an inland fishing licence and in 1973 he caught his first carp. It went dry some years ago and the same thing happened, and the fisheries people reckoned that year that tens of thousands, and maybe 100 000 carp there. All the carp were probably five kilos… (C8)

Samples of verbatim quotes of these characteristics are shown in the table. C1–C9 has been assigned to distinguish each interview participant

Discussion

The sustainable use of ecosystem resources requires that management plans and practices take into account the importance of LEK, institution flexibility and organisation adaption (Berkes et al. 2000). The results presented in this case study show that local landholders in the Cowal system have a broad knowledge of the lake ecosystem and its dynamics. This level of understanding is not surprising given that they have frequent and extensive interactions with the environment. The larger question is how this type of information can be incorporated with other scientific data. This case suggests LEK data can be useful for providing (1) historical data; (2) current baseline information; and (3) systems understanding.

Historical data

Understanding the historical sequence of filling and drying of the Cowal system can help with predicting management needs of the future. Such help is needed as there is no scientific or official monitoring of this key aspect of the system, and the hydrology is complex. There are no hydrological gauges to monitor breakout flows to the Cowal system from the Lachlan River catchment or inflows from Bland Creek. The nearest automatic stream gauges are on Lachlan River at the Jemalong Weir and the mid reaches of Bland Creek at Marsden (discontinued in 2004). While there is discharge data available at Jemalong Weir from 1948, it is only partially useful as breakout flows from the Lachlan River catchment to the Cowal system will flood the Lachlan-Lake Cowal floodway through the Corinella area and then reach to the northeast of the system. In the same way, flows from Bland Creek to the system will inundate the adjacent floodplains before reaching the south of Lake Cowal. It is not possible to monitor the water filling without the hydrological gauges to monitor breakout flows to the Cowal system itself. Similarly, while there are two weather observation stations nearby the Cowal system, one is at West Wyalong located 43 km southwest of the system and another is at Forbes located approximately 60 km northeast of the system. Because the sources of the filling water are remote from the site itself, and quite hydrologically complex, it is not possible

Table 2 Management issues of the Cowal system perceived by local landholders

Impacts of management	Interview evidence
Impacts of alteration of the hydrological regime	In the '50 s or'60 s, there were formed to object to unlicensed banking, particularly along the Bland Creek, and some of the banks were licensed and some weren't…and I think there's still banks on the Bland Creek that are not licensed…no one's ever gone to see, and they've got to push them down. The lake was a natural system, it was never banked, and it worked well. At times there was massive bird breeding on it. So then once you start altering a system, you never know what happens. (C8)
Potential salinity threat	A lot of the underneath groundwater is salty. The issue we have here, I believe a lot of the salt that comes in down the Bland. See, the Bland goes right up to Young and Cootamundra and those areas, and there are salting issues, especially around Young…and that water can all wash down into Lake Cowal. It can get very salty in the lake because when the lake is drying up, everything's concentrated…They just wanted to put all their wastewater from irrigation in there, but they got stopped from doing that. (C2) There was an issue at that time was the Jemalong irrigation area; there was a massive salt mound, which was moving southwards toward the lake. The salt mound was being fed by the irrigation which is associated with that land use. (C9)
Change in native vegetation composition	It was a combination of open clear country, some lignum, some cane grass, but not monoculture. Now, what happens when you lock country like that up, it becomes a monoculture because on one end of the lake, because the person ran cattle and the flooding suited the gum suckers, it just became an impenetrable forest of gums… It's no good for anything. (C8)
Weed invasion	Bathurst Burrs [Xanthium spinosum] are forever coming here. They come from up country and they just flood on the edge of the lake…And I wish the Local Land Services board would spray there because a lot of the Burr washes in off the road. Local Land Services own outside our place, a stock route, and when we get a big flood or rain event all the Burrs wash into our country and make a mess. (C3)
Carp and wild animal invasion	While salt, lippia and carp have been physical issues in the lake… If wild pigs get into the lake, you won't recognise it in a few years' time because they are just such a destructive animal. They dig up all the soil, they root up all the trees… we've got wild cats, rabbits, Lake Cowal turkeys, the emus, foxes… Landcare thinks they're the greatest thing, but I don't like wildlife corridors… because I just felt that that would just spread destruction all over the place. If they had done that when they first got here and there was a lignum wildlife corridor there, all this stuff here would've gone in the bushfire, so people say you can't have isolated areas. I think sometimes isolated areas can preserve stuff as much as they can destroy it. (C2)
Various concerns about the operation and management of the gold mine	*Ongoing activities* The major change at Lake Cowal is that great big wall on the other side that beams light out, and makes noise, and shakes my house. (C7) *Groundwater table and salinity* The biggest risk to Lake Cowal is the underground water table… And the fact that you've got that big hole there, and when the mine finishes they say it's going to take 200 years to fill up, naturally, so that takes the pressure off the underground water table. (C4) The waste rock that's there is highly saline, so there's a threat there to the lake. (C9) *Weeds* I think under conditions now with the mine shutting a lot of it up and that, the lake will be worse off. It does concern me that too much of it will be locked up and not managed as well as it could be and then it will become a monoculture. (C8) *Closure and landscape stability* Well our main concern is the cyanide because it could ruin all our land…And I've even heard of people that were working there getting sick, so they just quit… And they're on the west and that's where the wind usually blows from. (C3) I'm very concerned in the long term about what will happen with the area that has been mined, and the impact that might have on the lake. Well, it's about whether what we end up with after mining's finished and the rehabilitation's done, whether the final landform is completely stable. (C9)

Samples of direct quote of these management issues are shown in the table. C1–C9 has been assigned to distinguish each interview participant

to model the filling from rainfall records. The narratively derived information compiled in Fig. 3 is therefore valuable for future management and planning.

The figure compiled from landholder records may not be as accurate as historical gauged data, but that gauged data does not exist. Prior to 1950, most of the records were from only one or two sources. After that the narratively derived data can be used with more confidence because information about the extent of filling in the Cowal system is available for every year from 1950 until 2015, derived from the interviews and other records. Together these sources provide a continuous record. Additionally, many of the records were independently verified by multiple landholders, increasing the reliability of information on key events.

Table 3 Perceived concerns for the future of the Cowal system sighted by local landholders

Influences	Concern	Interview evidence
Influences within Lake Cowal	Farming enterprise on the lakebed	Lake Cowal used to be a grazing area with some crop, and it's now a cropping area with some grazing. And that's been a major change over the last 20 years. (C9) It is different from 1992…this farm was mainly grazing here then and now we're probably 50/50. (Why?) You can make more money out of growing wheat. It all comes down to dollars. (C3)
	Farming practice	In the lake we just direct drill the seed in. Rains on the lake can't run anywhere conserving moisture so it's got to go in. It's good farming practices…you look after your soil better; it looks after you … (C3) Some people used to get in there and smash the soil up as much as they could, so that they had a couple of inches of fine soil there that they could get a good germination and everything…The trouble with smashing up the soil is that you tend to ruin the soil structure. Well, when it rains it just goes all sloppy and it doesn't help the plants at all. (C2)
	Usage of fertilisers	There is deficiency of phosphorus and sulphur in soils for sunflowers…Before we put up to 100 kg per hectare when we were growing really big crops. When I'm taking a fair bit off, this year I put 50 to 70 kg per hectare. (C4) I haven't been using synthetic fertilisers on my whole property for about seven years now. I see a benefit to the soil, because synthetic fertilisers are made up of a lot of salt and it is all detriment to the soil. (C1)
External influences to Lake Cowal	Water flow regulation	Because after they put the dam in, so before the dam I probably got more flooding…They've extended the wall and increased the size of the dam probably about 1970, that the floods have changed. (C6) I think it's had water in it more often. Certainly, the last 25, 30 years, it's probably been full more regularly than what it had been prior to that. (C4) Back in the '70 s and '80 s it was underwater quite a lot, and it was kept full by humanmade floods… a lot of farmers didn't have the lakebed for their farm because it was under water and so it was to their detriment. (C1)
	Rising of groundwater table	And the trouble with this is that we have water table problems underneath, and the irrigation channel that goes from the Lachlan River through all this Jemalong country is actually built on an old gravel creek bed and it leaks, so it leaks water into the water table. The channel also goes through a place called the Wilbertroy Forest, and the soil is very sandy. So, by keeping the water in that channel there's more water going through that sand into the water table… When the lake fills, it actually pushes the soil down to create more pressure underneath, so when it's dry it comes up a bit. (C2) All these dead trees down here the only thing that killed them was water… The other dead trees, they were blaming salt and all this sort of business for a while, but it's not salt, it's waterlogging. (C5)

Table 3 (continued)

Influences	Concern	Interview evidence
	Construction of banks and levees	Well, they've got banks 11ft high in places along flood way… the lake floods a lot more because it's just tunnelled straight into Lake Cowal instead of flooding out over a lot of other country. (C3) They put a bank across the end of the Bland Creek to keep it full…Yeah, a lot more water goes into the Bland now than it used to… It pushes the water into the lake and if that bank wasn't there all this area out here, the lake would flood fairly regularly. (C5)
	Climate change	I think just well since the drought anyway they've changed our practices as far as where the water goes. (C1)

Samples of direct quote of these concerns are shown in the table. C1–C9 has been assigned to distinguish each interview participant

Current baseline information

The suggestion of Olsson and Folke (2001) that effective management practices associated with changing environmental conditions depend on a comprehensive understanding of ecosystem dynamics and the acquisition of LEK is supported by this case study. The Cowal system is privately-owned land, and local landholders opportunistically crop or graze their livestock on the lakebed when the lake system is drying. Local landholders in the area advance their farming activities under the changing environment based on their observations, knowledge, and experience. Local landholders consider the Cowal system as a significant part of living in and looking after the country, and the ephemeral wetland system has a valuable cultural heritage for them as well. Our findings indicate that the local landholders' comprehensive and broad knowledge and experience can be used as part of a baseline reference for wetland conservation and restoration management. This includes, for example, the existence of pest plant and animals, water table levels, and salinity. Our findings support those from other studies that have shown that locals who directly gain benefits from wetlands usually have a greater knowledge and experience of the extent of wetland degradation (Finlayson et al. 2005). In the absence of data being regularly collected by government programs, these locally derived data provide the only benchmarks against which to monitor change in the future as recognition of the importance of ephemeral wetlands in a changing climate grows.

Systems understanding

The LEK of the respondents in this study also provides biophysical and social ecological systems insight. Systems understandings underpin the adaptive approach to management and planning needed to negotiate the complexity and uncertainty of the Anthropocene (Schoeman et al. 2014). Seeking local expertise has yielded information on hydrological characteristics of the Cowal system, including where water moves in the system, and historical wetting and drying information. There were also useful observations on algal blooms, turbidity, sedimentation, and soil type variability, along with observations about vegetation and changes over time.

The combined observations suggest some negative changes occurring including weed invasion, and changes to water inflows. Some of the changes were attributed to management of the catchment around the Cowal system, especially the construction of levee banks, and the operation of the Wyangala Dam with impacts. Some considered continued clearing of native vegetation and increased monocultures as a problem, but at least one thought replanting was bringing its own set of issues with it. Management further afield was also considered to negatively impact on lake salinity and the occurrence of water borne weeds. Some of these, and other, problems were attributed to the continued operation of the gold mine.

Concerns for the future encompassed the intensification of cropping when the lakebed is drying, with its attendant issues around soil structure and fertiliser application. However, most of the concerns were about off-farm management practices beyond their influence or control, such as irrigation infrastructure and levee banks, and the impacts of these on both surface and groundwater in the vicinity of the Cowal system. The changing climate was also of some concern.

An embedded and deep understanding of the Cowal system provides some indications of how specific activities such as the construction of infrastructure and farming on the lake beds and near surrounds may impact on the baseline information provided. For example, the presence of Bathurst Burr is noted, but in addition is a story of potential cause and consequence that bring the actions of upstream actors into focus. Understanding why certain actions are undertaken on the drying lake beds can lead to improved guidelines; because this information is dynamic it could help to improve the adaptive capacity of management plans developed for the inland ephemeral wetland system. The case we present in this paper is compelling, but incomplete, as it has centred on only one group of local actors. Learning from the two other important sources of LEK—the mangers of the gold mine, and Wiradjuri Traditional Owners would enhance the range and depth of information compiled, and hence the value of any management planning. The challenge in any situation such as this is to create just and equitable spaces for knowledge sharing and co-design of the future. Experimenting with ways to genuinely incorporate citizens and their systems-based LEK into wetland governing and managing would contribute to the innovative form of conversation and deliberation needed to enable 'real' responses to climate change (Ison et al. 2011).

Conclusion

This research has demonstrated that local landholders who regularly interact with the ecosystem have a substantial understanding and valuable knowledge of its environmental condition. Their collective LEK is deep and rich, and it can complement scientific investigations, thus giving a more comprehensive understanding of past, current and future states of inland ephemeral wetlands.

This research also provides insights into aspects of importance of LEK in inland ephemeral wetland management and conservation and describe how the actual concerns of local landholders that could help to complement existing management and conservation actions dealing with potential impacts of ongoing land uses and projected climate change on ephemeral ecosystem dynamics. The available knowledge base for planning wetland management would have been substantially reduced without incorporating local ecological knowledge.

The research suggests that LEK should be actively sought by scientists, managers, and planners of wetlands, especially where baseline and systems information is scant. Such activity should contribute to innovative, more inclusive, and more systemic governance and management processes.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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