Evidence from the scientific literature supporting the environmental component of the Yorta Yorta Management Plan for the Barmah-Millewa forest ecosystem

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Introduction

Friends of the Earth Melbourne is engaged in a campaign to raise the conservation status of the Barmah-Millewa forest ecosystem to National Park level, to be administered under a joint management arrangement with the Yorta Yorta Nation, the traditional owners and custodians of the forest. The Barmah-Millewa forest is located on a floodplain of the Murray River (Dhungalla), bounded by Deniliquin, Echuca and Tocumwal, right in the heart of Yorta Yorta country. The forest is of great conservation significance because it supports large expanses of several poorly reserved vegetation types, it provides habitat for many species which are threatened nationally, in Victoria or in New South Wales, and it is the largest patch of relatively intact species-rich bushland remaining in a region where most land has been cleared for agriculture. The current management regime for Barmah-Millewa includes a number of practices that pose a threat to the biodiversity values of the system, values which are the product of thousands of years of land management by the Yorta Yorta. In an effort to protect this environmental heritage, the Yorta Yorta Clans Group produced a document in 2001 entitled *Management Plan for Yorta Yorta Cultural Environmental Heritage Project*, which outlines policies and actions the Yorta Yorta believe are appropriate for managing remnant bush on their land, including Barmah-Millewa. The aim of this paper is to detail evidence from the scientific literature which supports the Yorta Yorta proposal and which illustrates the importance of Barmah-Millewa to biodiversity conservation objectives. The author hopes that the paper will convince readers that the objectives of the Yorta Yorta coincide with the objectives of conservation biologists. Given this, and given that the Yorta Yorta Nation is committed to conserving Barmah-Millewa as a central part of conserving their cultural heritage and history, it is hoped that readers will agree that placing Barmah-Millewa under Yorta Yorta joint management can only benefit the ecosystem while simultaneously awarding some land justice to a dispossessed people.

What is the Barmah-Millewa forest?

The Barmah-Millewa forest system is situated on the River Murray, spreading out along the Murray and Edwards River floodplains bounded by Echuca, Deniliquin and Tocumwal. It straddles the main Murray River channel and is distributed almost equally between Victoria (Barmah) and New South Wales (Millewa). Most of the 65,000 hectare area is dominated by dense stands of river red gum (*Eucalyptus camaldulensis*), making it the largest river red gum forest in the world (Robinson 1998). The system also includes significant patches of species-rich box woodland, unique moira-grassland communities and rushlands (Chesterfield 1986; Ward 1999), as well as diverse aquatic communities dwelling in the permanent waterways, in semi-permanent billabongs and throughout the floodplain when the Murray floods (Hillman 1986; Pressey 1986; Parson 1991).

Barmah-Millewa is currently divided up into several different reserves, including four state forests, one state park and a number of other, smaller reserves including regional parks and special protection zones, and it is managed by a number of different administrative authorities. This division of authority is partly because it is located on a political (state) boundary, partly because it is a riverine ecosystem encompassing both aquatic and terrestrial environments and partly because it is managed for multiple uses, including conservation, grazing, timber harvesting and quarrying. For simplicity's sake, in this paper, the term Barmah-Millewa forest will be used to encompass all native biological communities and vegetation types in the area, all of the riparian, aquatic and terrestrial environments, and all of the contiguous reserves. Most of this paper will focus on the Victorian reserves for the sole reason that most published literature on the topic relates to them, but because the Barmah-Millewa is essentially one ecosystem which has been divided up only for administrative reasons, the issues discussed will almost always equally apply to the New South Wales reserves.

What's so great about Barmah-Millewa?

Barmah-Millewa is one of the most significant native vegetation remnants in the Mid-Murray region. It is included in the Directory of Important Wetlands in Australia, has been placed on the Register of the National Estate and the Barmah Forest is listed as a wetland of international significance under the Ramsar Convention (Wetlands International website; Leslie 2001). Most of the 65,000 hectare area is classified as wetland, because under natural conditions it regularly experiences lengthy inundations when the Murray floods (Dexter 1978). This flood regime supports the extensive red gum forests as well as the flood-dependent moira grasslands, rushlands and the intricate network of billabongs (Parson 1991; Ward 1999). Situated on a floodplain, Barmah-Millewa contains very little topographic variation, but the slightly elevated 'ridges' that experience flooding infrequently or never support woodlands dominated by grey box (*Eucalyptus microcarpa*), yellow box (*Eucalyptus melliodora*) or black box (*Eucalyptus largiflorens*), which can have a species-rich herb and shrub understorey (Chesterfield 1986; Ward 1999). This contrasts with the understorey of the red gum forests, which is relatively species-poor and composed mainly of grass, sedge and rush species (Chesterfield 1986; Ward 1999). At least 37 threatened plant species are found in Barmah-Millewa, four of which are found nowhere else in Victoria: silky heads (*Cymbopogon obtectus*), violet swainson-pea (*Swainsona* *adenophylla*), fat spectacles (*Menkea crassa*) and upright sunray (*Rhodanthe stricta*) (Robinson 1998; NRE 2001). Altogether, the forest provides a home to 491 plant species, of which 354 are native (MDBC 1992).

The forest is also rich in animal life (LCC 1985). It provides significant habitat for waterbirds: about 54 species have been recorded breeding there (Leslie 2001), including at least ten species that are vulnerable, endangered or critically endangered in Victoria (NRE 1999, Leslie 2001). At least 13 species protected under migratory bird agreements that Australia holds with Japan and China are known to frequent the forest (JAMBA 1981; CAMBA 1986; Leslie 2001). Ornithologists in the past have estimated the abundance of colonially-nesting waterbirds in a given season to be in the order of millions at Barmah-Millewa (Mattingley 1908 & Barrett 1931 cited in Leslie 2001), and the area has been described as the 'largest egret colony in southern Australia' (Pizzey 1961 cited in Leslie 2001). Bird diversity generally is also high, with 206 species recorded in the forest (Forests Commission 1977). The forest includes the only remaining Victorian breeding grounds of the superb parrot (*Polytelis swainsonii*) (Webster & Ahern 1992), a bird that is listed as endangered in that state and vulnerable nationally (NRE 1999). The nationally endangered regent honeyeater (*Xanthomyza phrygia*) has also been recorded in the forest, as have many other bird species that are threatened nationally, in Victoria and/or in New South Wales (NRE 1999; Directory of Important Wetlands in Australia 2001; NPWS 2001).

In the past, the Barmah-Millewa floodplain was a productive breeding ground for native fish species (Hibbins 1991; McKinnon 1997), and at least 13 native fish species still reside there, including the endangered trout cod (*Maccullochella macquariensis*) (McKinnon 1993; 1997). Three mammals threatened in both Victoria and New South Wales reside in the forest (squirrel glider *Petaurus norfolcensis*, brush tailed phascogale *Phascogale tapoatafa*, large footed myotis *Myotis macropus*) (Law & Anderson 1999; Directory of Important Wetlands in Australia 2001). Altogether, the Barmah forest contains 51% of the threatened species found in eastern Northern Victoria (Robinson 1998).

Clearly, Barmah-Millewa is an important ecosystem to reserve for the conservation of threatened species. It is also a significant site for the conservation of ecosystem diversity. In the 1997 National Forest Policy Statement (NFPS), the commonwealth, state and territory governments of Australia have agreed that at least 15% of all pre-European forest and woodland communities should be reserved for conservation (JANIS 1997). In a study looking at the eastern Northern Plains of Victoria, Robinson (1998) found that only 1.5% of the *remaining* extent of riverine red gum forest, 4% of riparian red gum forest and 3% of yellow box-white cypress-pine woodland was reserved and secure from threatening activities. This is obviously much less than 15% of the pre-European extent. If the Barmah-Millewa forest were reserved as a national park, it would contribute substantially to the fulfilment of NFPS criteria.

Aside from its value as a vital and biodiverse habitat, Barmah-Millewa also performs ecological services important to humans. As a natural floodplain, it is important for flood mitigation, protecting agricultural lands downstream from floods (Dexter 1979; Forests Commission Victoria 1983; State Working Group on River Murray Water and Forest Management 1984; MDBC 1998). The floodplain is a net importer of nitrogen- and phosphorous-based nutrient compounds, removing such nutrients from the river water (Leitch 1989; McKinnon 1997; MDBC 1998) and thus reducing the probability of algal blooms occurring in the Murray (Robertson 1998). Floodplain vegetation and soils assist in the filtration of water to remove sediments (MDBC 1998), salts (Allen 1979) and organic carbon (Robertson *et al* 1999) thus improving water quality for downstream users. The complex nutrient cycling performed by the floodplain results in the release of nutrients back into the food chain and the river system to support river biodiversity (MDBC 1998; Glazebrook & Robertson 1999).

For all of these reasons, environmentalists have argued for at least 18 years that the conservation status of Barmah-Millewa should be raised to national park level (Johnson 1984; Robinson 1998). The Land Conservation Council's investigation into the Murray Valley area in the early 1980s led to the creation of Barmah State Park and the setting aside of two reference areas in the Barmah forest in 1987 because of the area's high conservation value (LCC 1985; DCE 1992). Other authors have commented on Barmah-Millewa's status as the only or the most secure habitat for threatened species or unique species assemblages (Beauglehole 1986; Chesterfield 1989). Undoubtedly, it is the economic importance of the forest rather than the lack of conservation significance that has prevented Barmah-Millewa from being reserved as a national park.

The Yorta Yorta Approach to Land Management

Cultural and archaeological evidence suggests that the Yorta Yorta people and their ancestors have occupied the Barmah-Millewa forests for over 13,000 years (Yorta Yorta Clans Group 2001) and possibly for over 60,000 years (Wayne Atkinson, pers.comm.). Of all their traditional lands, they have identified Barmah-Millewa as one of four general regions that hold special significance for their environmental and cultural values (Yorta Yorta Clans Group 2001). Barmah-Millewa remains an important source of bush foods, medicinal plants and artefact material (Yorta Yorta Clans Group 2001). More than 300 cultural sites have been recorded from the forest, and they provide an ample illustration of the ways in which the Yorta Yorta interacted with and used the wetland environment to make a living (Yorta Yorta Clans Group 2001).

Because of the importance of preserving their heritage and traditional knowledge, the Yorta Yorta have made a commitment to conserving the biodiversity of Barmah-Millewa *in toto*. Yorta Yorta culture insists on a mutualistic relationship between humans and the environment:

> The Yorta Yorta see the forest and all of its encompassing features [including all species and abiotic factors] from a holistic viewpoint. The forest nurtured their ancestors and provided them with the means for their everyday survival and well being. In turn, the Yorta Yorta looked after the forest and nurtured it for the future, and when these practices and methods of forest management and care are measured against more recent events, it is clear that they have an excellent track record that stands firm in its own right. (Yorta Yorta Murray Goulburn Rivers Clans Incorporated 1990 cited in Yorta Yorta Clan Groups 2001: 7)

The biodiversity present at Barmah-Millewa today, and that which was present at the time of European colonisation, which non-indigenous environmentalists and conservation biologists value so highly, is the best evidence available of the Yorta Yorta track record of land management. The strong links which Yorta Yorta people have maintained with their traditional lands over the past 170 years despite dispossession have allowed them to maintain and document their rich knowledge of the entities and processes which are important in the Barmah-Millewa system and their traditional management practices (Yorta Yorta Clans Group 2001; Wayne Atkinson pers.comm; Indira Narayan, pers.comm.). This puts them in a good position to reclaim their role as caretakers of the land. The author hopes that illustrations of the agreement between their approach and a conservation biology approach to land management will remove any lingering doubt in non-indigenous minds about the ability of the Yorta Yorta to manage their land for a sustainable future.

The Yorta Yorta emphasise the differences between their approach to land management and the approaches of authorities currently managing Barmah-Millewa. The current division of authority between catchment management authorities, Parks Victoria, the Victorian Department of Natural Resources and Environment, State Forests of New South Wales and so on creates ecologically false distinctions between land and water, between one side of the river and the other, and between areas of conservation significance and those of less conservation significance, rather than managing the ecosystem as a single diverse unit (Yorta Yorta Clans Group 2001). In contrast, the Yorta Yorta traditionally made no such distinctions (Yorta Yorta Clans Group 2001). Similarly, contemporary reserve design discussions in conservation biology state the importance of integrating all ecosystem elements into reserves, for example constructing reserves around natural boundaries such as water catchments rather than cutting across such features with arbitrary geometric boundaries (Burgman & Lindenmayer 1998).

The Yorta Yorta state that their approach to land management incorporates an understanding about the interdependence of all biotic and abiotic aspects involved in a system, and therefore brings together plant and wildlife ecology, hydrology, environmental and conservation issues and heritage matters into one complex, holistic viewpoint (Yorta Yorta Clans Group 2001). This is paralleled in conservation biology by the growing recognition that management for the integrity of ecosystem processes is an important aim in itself that goes hand in hand with management for biodiversity (Burgman & Lindenmayer 1998). In contrast, the current management regime of Barmah-Millewa is designed not to conserve ecosystem integrity but primarily to maximise economic outputs such as timber production. For example, in the section of the current *Barmah Management Plan* that justifies the grazing of domestic stock in the Barmah State Forest on the grounds that it assists in fire prevention by reducing fine fuel load, it is stated: '...it is not possible to use fuel reduction burns and maintain existing uses such as timber production' (DCE 1992: 56). The presence of stock and the absence of control burns have conservation implications for the neighbouring Barmah State Park, which is supposedly not managed for timber production primarily. In the *Proposed Mid-Murray Forest Management Plan 2001*, the removal of non-merchantable mature overwood trees that are not required for habitat purposes is recommended as a strategy for maximising timber production (NRE 2001 cited in Lacey 2001). Again, this has implications for hollow nesting species that do not distinguish between state forest and state park when choosing a nest site. These issues will be discussed in more detail below, but suffice it to say, conflicting priorities in the management of neighbouring reserves can lead to degraded ecosystems all round. A more integrated approach is certainly required if conservation outcomes are to be achieved.

The Yorta Yorta Proposal

Having stated in the *Management Plan for Yorta Yorta Cultural Environmental Heritage Project* (Yorta Yorta Clans Group 2001) that they would manage Barmah-Millewa holistically, as a single unit, for the ongoing conservation of all the biotic and abiotic features of the ecosystem, the Yorta Yorta go on to target five major environmental issues which they see as specific management priorities. Those issues are:

1. water regulation and quality

2. stock grazing

3. timber harvesting

4. recreation and tourism

5. erosion control.

For each issue, the *Management Plan* outlines relevant goals, policies and actions to be undertaken. The remainder of this paper will address each of these issues in turn, discussing the proposed actions in the light of evidence from the scientific literature.

Water Regulation and Quality

Proposed actions (summarised from Yorta Yorta Clans Group 2001):

- Restore a water regime that emulates natural wetting and drying fluctuations, through the use of environmental water allocations.

- Ensure that the Ramsar agreement is upheld.

- Nominate the Barmah-Millewa Forests for World Heritage listing.

- Reduce input of nutrients, sediments and herbicides into our waterways in order to improve water quality and waterway health.

- Establish substantial buffer zones around wetlands to give them adequate protection from degrading processes.

- Maintain existing vegetative cover to help ensure natural water cycling processes and the maintenance of long-term water quality.

- Protect groundwater aquifers and recharge zones from potential sources of contamination.

Restoring a natural water regime

The regulation of the Murray River by construction of a series of dams, weirs, levees, block banks and regulators, as well as by snag removal and channelisation, has dramatically altered the way water flows through the Barmah-Millewa floodplains (Dexter 1978; Leitch 1989; MDBC 1992; McKinnon 1997; Kingsford 2000). Before European colonisation, the Barmah-Millewa forests would flood almost every year between August and December as rain and snow melt increased, with a peak in October, followed by a dry period through summer until the following winter (Dexter 1978; 1979; Walker 1985; Leitch 1989; MDBC 1992). When the river was in flood, water was forced into the forest as it pooled behind the Barmah Choke, the narrow river channel that runs through the forest (Kingsford 2000), and spread through the forest via a network of runners or effluent streams, which overflowed in sheets as they filled (Parson 1991). Floodwaters were necessary to sustain the ecosystem, because mean annual rainfall to the area (460mm) is far exceeded by mean annual evaporation (1530mm) (Glazebrook & Robertson 1999), and underground aquifers, which trees rely on for water after flood recession (Bren 1987), require floodwaters to replenish them (Bren 1989). The floodwaters were so plentiful that they allowed the growth of red gum to heights of 45 metres, where elsewhere the species grows only to around 12 metres (Parson 1991).

The flood regime was responsible for maintaining ecosystem diversity in Barmah-Millewa. The slight topographic variation in the forest system meant that the exact timing, duration and depth of natural inundations varied slightly across the landscape, and this temporal and spatial heterogeneity accounts for the variation in vegetation types (Chesterfield 1986; Ward 1999). Grey box woodlands grew where the floods never reached, yellow box woodlands could stand the occasional slight inundation and black box woodlands grew where floods were rare (Chesterfield 1986). The understorey species in these woodlands varied with flooding conditions, for example, tangled lignum (*Muehlenbeckia florulenta*), which likes to be flooded every 3-10 years (Craig *et al* 1991), was common under black box (Ward 1999), while grey and yellow box woodlands supported a rich array of shrubs, annuals and tussock grasses (Chesterfield 1986). Red gum, which has evolved a number of anatomical and physiological adaptations to inundation and drought (Bren 1989), grew where flooding occurred most years for a prolonged period, but where there was a complete drying out of the soil at least every 18 months (MDBC 1992). Six months wet/six months dry flood cycles drive out all other woody species but red gum (Bren 1987). The red gum understorey varied with flood duration (Leitch 1989), but mostly it consisted of species of vegetatively producing monocots that could stand prolonged inundation followed by drought stress (Chesterfield 1986). The warm summer temperatures and soil moisture following a flood promoted luxuriant growth in understorey grasses, while winter rains had no effect on their growth because the plants are dormant in winter (Chesterfield 1989). Where the land was flooded every year for at least two months, and where floods were too deep and/or too long for red gum seedlings to survive, grass plains formed, dominated by moira grass (*Pseudoraphis spinescens*) (Ward 1991; MDBC 1992; Bren 1999). Moira grasslands were the first to flood each year and the last to recede (Ward 1991). Rushlands grew in the areas that endured inundation for extended periods of time (Kingsford 2000), from 8 to 33 months (Leitch 1989).

The wet-dry cycles also maintained diversity within more wholly aquatic communities. Before regulation, there were few permanent wetlands in the Murray-Darling Basin (Briggs *et al* 1997), but there were many semi-permanent wetland habitats such as backwaters, billabongs, cowals, lagoons, marshes and swamps (MDBC 1998) which filled and dried with the river level (Briggs *et al* 1997). These wetlands, particularly the billabongs, often contained communities of organisms which were taxonomically distinct from those in the mainstream and which were highly diverse (Hillman 1986; Parson 1991). This was partly because the low turbidity of the billabong environments allowed the extensive growth of macrophytes, which provided an array of microhabitats for animals including zooplankton, microcrustaceans, rotifers and insect larvae (Hillman 1986; Parson 1991). These organisms were important food items for higher order animals, including juvenile fish (McKinnon 1997), waterbirds, particularly when breeding (Llewellyn 1983; Maher & Carpenter 1984; Briggs *et al* 1997), bats (Law & Anderson 1999), water rats (Woollard *et al* 1978) and turtles (Chessman 1988). The natural wetting and drying cycles maintained the diversity of these semi-permanent wetlands because there was insufficient wet time for any species of plant, invertebrate or fish to become dominant (Pressey 1986; Briggs *et al* 1997). Periodic floods were also important because they 'liberated' billabong fauna into the mainstream, replenishing the diversity there and providing preferred food items to mainstream-dwelling native fish (McKinnon 1997).

Wetting and drying cycles maintained nutrient cycling and primary production on the floodplain. Periodic inundation facilitates the fast breakdown of terrestrial litter by bacteria and aquatic invertebrates, for whom it is an important food source, releasing the nutrients held in litter into the aquatic food chain (Pressey 1986; Leitch 1989; Glazebrook and Robertson 1999). It also allows nutrients and sediments from the river to accumulate in floodplain soils, increasing soil fertility (Leitch 1989; Glazebrook & Robertson 1999). Macrophytes and biofilm organisms, the main primary producers for the riverine system, relied on periodic inundation to grow (Glazebrook & Robertson 1999). On the other hand, periodic drying stimulates the breakdown of accumulated soil organic matter for use by terrestrial organisms and prevents the accumulation of harmful reduced ions in the soil (Pressey 1986). It allows the growth of terrestrial and marginal vegetation that also contributes nutrients to the system (Pressey 1986).

The natural flooding regime is believed by scientists to have played an important role in maintaining populations of native fish in Barmah-Millewa. In his five year study of fish communities in the Barmah forest, McKinnon (1997) found that the diversity and density of native fish was greatest during larger, more 'natural' flood events (compared to smaller, more regulated events). He attributed this to a number of factors: increased food production on the floodplain, greater habitat availability, the triggering of cues to spawn by rising water level, and increased migration to the forest from elsewhere in the river system because barriers that were normally in place (such as weirs) were drowned out by the flood. Earlier authors also found that rising water levels can trigger spawning in species such as the silver perch (*Bidyanus bidyanus*) (Koehn & O'Connor 1990), which is critically endangered in Victoria (NRE 1999), and the vulnerable golden perch (*Macquaria ambigua*) (Morison 1989; NRE 1999). Those species lay pelagic eggs which are carried into the floodplain by floodwaters (Morison 1989), or which are carried downstream in the river (Cadwaller 1978), thus necessitating upstream migration of adult fish at spawning time from up to 900 kilometres away (Cadwaller 1978; McKinnon 1997). Floods that endure for a reliable length of time are vital for fish species such as the western carp gudgeon (*Hypseliotris klunzingeri*) and the freshwater blackfish (*Gadopsis marmoratus*), which lay their eggs on aquatic vegetation, hollow logs or debris, where they are vulnerable to desiccation if there is a sudden drop in water level (Cadwaller 1978; Koehn & O'Connor 1990). In addition, native species such as the murray cod (*Maccullochella peelii*), freshwater catfish (*Tandanus tandanus*) and trout cod depend on floodwaters to trigger the growth of abundant food stocks for their young (Morison 1989). Other species, such as the crimson-spotted rainbowfish (*Melanotaenia fluviatilis*), take advantage of the additional habitat and food provided by the floodplain to boost their numbers by spawning (Morison 1989).

Frogs also relied on the natural flooding regime to provide a plentiful food supply and dense cover in rushland vegetation (Leitch 1989). Permanent billabongs disadvantage frogs because they allow the growth of fish, which eat frog eggs and larvae (Healey *et al* 1997). The reliability of floodwaters was important to frogs, because sudden changes in water level can expose their eggs to desiccation or can sweep them away (Leitch 1989). Healey *et al* (1997) noted an increase in frog abundance when the water level of the wetlands they were studying rose after rain. Some tortoises too need semi-permanent water bodies for food and breeding. *Chelodina longicollis*, a resident of Barmah-Millewa, has a preference for water bodies that are shallow, ephemeral and/or distant from the main Murray channel because they are less likely to contain fish competitors (Chessman 1988). Tortoises lay their eggs above the high water mark in autumn, when the forest was usually dry under natural conditions (Leitch 1989).

Many waterbirds were also dependent on the flood regime to breed successfully. The floods brought an increase in food for waterbirds (Llewellyn 1983; Pressey 1986; Briggs *et al* 1997; Briggs & Thornton 1999): not only were billabong fauna, fish and fish larvae abundant as noted above, but terrestrial organisms were flushed into the water and yabbies may have become more active (Llewellyn 1983). An important food source for waterbirds in the Murray-Darling system is chironomid larvae, in particular *Chironomus tepperi* (Maher & Carpenter 1984). Successional changes in chironomid species have been observed to occur in wetlands post-flooding, with *Chironomus tepperi* being most abundant early on and chironomid production dropping off rapidly after two years of continuous inundation (Maher & Carpenter 1984). This indicates the importance of wetting and drying cycles to successional processes supporting the floodplain food chain. Nests surrounded by water also offered waterbirds some protection from disturbance (Loyn 1989) including by predators (Carrick 1962). Mature river red gums in and around the wetland environment were important to many waterbirds for nesting (Briggs & Thornton 1999), cover and perching (Llewellyn 1983), and as noted above, wetting and drying cycles promote red gum growth. The duration of floods was clearly important to waterbirds too, as several species have been noted to abandon their nests before completing their breeding activities if there is a drop in the water level (Carrick 1962; Briggs & Lawler 1991; Briggs & Thornton 1999; Leslie 2001).

River regulation has resulted in changes to the natural wetting and drying cycles of Barmah-Millewa. There has been an overall reduction in the frequency and duration of flooding. According to some estimates, the forest is now flooded in less than half as many years as it was under natural conditions (Leitch 1989), and the flood duration has been cut by an average of one month per year (Leitch 1989). The average area of the forest reached by a flood event has decreased significantly (Leitch 1989). The timing of floods has also changed. Winter floods have decreased in frequency and duration (Walker 1985; Dexter *et al* 1986; Leitch 1989) while summer floods have increased in frequency (Dexter 1979; Walker 1985; Dexter *et al* 1986; Leitch 1989; Ladson 2001). Spring floods have become more variable (Leitch 1989), having once been very reliable (Dexter 1979). The water level in the Murray is kept artificially high in summer for irrigation purposes, but if irrigators cancel their water orders (for example, if it rains), the excess water enters the forest (Dexter 1979; Ladson 2001). Regulators have been built along the Murray channel throughout the forest to prevent this from happening (Forests Commission 1977), but they are inefficient at keeping out summer floods (Chesterfield 1986; Ladson 2001). Some places that were once semi-permanent wetlands have now become permanent wetlands because of regulators and/or summer floods (Briggs *et al* 1997). Barmah Lake, for example, would normally dry out from February through to winter, but now remains wet until May or throughout the year (Leitch 1989), making it good habitat for exotic fish species and bad for native fish (Wharton 1970). The general reduction in flows through the forest has meant that some rushlands that were once flooded for up to 33 months at a time are now rarely flooded for more than 9 months continuously (Leitch 1989).

This has had a profound effect on the forest. The reduction in frequency, duration and depth of floods on the moira grass plains has allowed red gum stands to encroach upon them (Bren 1989; Ward 1991), reducing their area by 55% from 4500 hectares to about 1500 hectares in just 50 years (Ward 1991; MDBC 1998). Summer floods have allowed communities dominated by giant rush (*Juncus ingens*) or upright milfoil (*Myriophyllum crispatum*) to encroach on the moira grasslands too (Chesterfield 1986; Ward 1991). The superior ability of upright milfoil to capture flood sediments means there is a risk that soil will build up in the moira grass plain drainage basins, which will allow red gum to encroach more rapidly (Ward 1991); indeed it has been suggested that the moira grasslands will be extinct by 2050 if natural water regimes are not restored (Bren 1999). The work of Ward (1991) showed that the reproductive potential of moira grass is related to stem length, which is influenced by flood timing, depth and duration. Moira grass needs at least five months of inundation to attain a substantial length, and only large specimens flower. Floods that start too early in winter or that recede too early have been shown to decrease sexual reproduction (Ward 1991), which is usually vital for maintaining genetic diversity and adaptive ability in populations (Breckwoldt 1986). Floods that recede too slowly in summer scald the ground (Ward 1991). Ward (1991) recommended that floods at least 0.5 metres deep that endure for at least five months and recede quickly in summer are required to sustain and increase the extent of moira grasslands.

Less frequent flooding has been implicated in the decline in abundance of common reed (*Phragmites australis*) and cumbungi (*Typha angustifolia*) (Kingsford 2000), which were once prolific in the forest and dominant in reedbeds (Chesterfield 1986). It has caused a decline in the condition of red gum stands (Kingsford 2000), since the best quality stands of red gum are those that are inundated most regularly (Forests Commission 1977; Dexter 1979). Regular floods are important for keeping down the numbers of gum leaf skeletoniser moth (*Uraba lugens*) by promoting naturally occurring pathogens and by removing good conditions for pupation (Chesterfield 1986; Parson 1991). While this moth has as much right as the next organism to exist in the forest, it has the potential to outbreak in plague proportions if natural ecological checks (such as the flood regime) are not in place, and in plague proportions it can defoliate up to 60,000 hectares of forest at one time (Parson 1991). Regular flooding is also crucial for keeping down weed numbers: inundation has been shown to reduce or eliminate exotic weed species that threaten community integrity (Ward 1991).

The impact of river regulation on waterbird breeding has been well documented. Breeding colonies of avocets, stilts, grebes, coots, terns and swans in Barmah-Millewa had been virtually eliminated by 1980, because of the decline in non-emergent macrophytes due to water regulation (Leslie 2001). Breeding numbers of several other waterbird species have also declined because of the reduction in nest security and food with shorter floods (Leslie 2001). In particular, the critically endangered little egret (*Egretta garzetta*) and intermediate egret (*Ardea intermedia*) and the endangered great egret (*Ardea alba*), which is protected under international migratory bird agreements (JAMBA 1981; CAMBA 1986), have declined in numbers by at least one order of magnitude, despite their former huge colonies (Leslie 2001). Egrets and some other birds need five to eight months inundation with winter/spring floods to successfully complete breeding (Briggs & Thornton 1999) and they do not like heavily controlled breeding environments, which tend to contain fewer aquatic plants and invertebrates (Briggs *et al* 1997). As noted above, erratic changes in water level such as sudden rises and early recession can cause nest abandonment, and such changes are much more common under regulation than under natural conditions (Leitch 1989). Breeding straw-necked ibis (*Threskiornis spinicollis*) and Australian white ibis (*Threskiornis molucca*) are still relatively abundant in Barmah-Millewa, but their numbers have also declined by around one order of magnitude because of a reduction in flood duration (Leslie 2001). This is bad news for farmers, because ibis have always played an important role in controlling plague locusts in the region (Hibbins 1991), as their nesting time (August) coincides with locust emergence (Carrick 1962).

Leslie (2001) argues that the impacts of river regulation on waterbirds were not fully recognised until the 1970s because it took that long for habitat structure and ecosystem function to collapse and for relic bird populations to expire. He contends: "the provision of an effective environmental flow strategy for the River Murray during the next decade will govern whether or not egret breeding persists in the forest" (34). Colonial waterbirds develop traditional attachments to nesting sites; if sites are left to deteriorate further then even a later reinstatement of a natural flooding regime may not entice them back (Leslie 2001). Briggs & Thornton (1999) recommended deep spring floods of 5-8 months duration with ample drying time between floods to encourage waterbird abundance and diversity. Their earlier work found that there was some variation in nesting site preferences among waterbird species, with birds such as cormorants, darters, herons and spoonbills (all of which also nest at Barmah-Millewa) preferring sites that were inundated for long periods or permanently (Briggs *et al* 1997). For this reason they recommended management for a mosaic of wetland environments with some areas of prolonged flooding (Briggs & Thornton 1999).

Regulation has had multiple deleterious effects on aquatic fauna. Small, regulated flood events have only benefited local fish populations because large, natural-style flood events are required to allow long distance native fish migrations to occur (McKinnon 1997). Tag-recapture studies have shown that most of the native fish breeding in Barmah-Millewa during occasional large flood events have migrated from up to hundreds of kilometres away (McKinnon 1997), so small floods will not lead to large-scale recruitment. Most native fish require a specific water temperature range in order to breed successfully (Cadwaller 1978), so out of season floods may not be appropriate for them. Nor will water released from the bottom of weirs, which is generally colder and less oxygenated than inflowing water (Wharton 1970; Koehn & O'Connor 1990). Levee banks effectively reduce the floodplain area along the Murray (Cadwaller 1978) and restrict the movement of fish across the floodplain and between the floodplain and the mainstream (McKinnon 1997). Such movement may be necessary for juvenile growth (Morison 1989), so levee banks have a deleterious impact on native fish development.

The practice of 'locking in' floodwaters with regulators to reduce the total amount of water required to flood the forest has dramatic impacts on fish and other aquatic organisms. McKinnon (1997) recounts a 1992 flood event, where flooding along the Murray and Goulburn rivers was so extensive that waters were held on the floodplain for a prolonged period and went stagnant. Dissolved oxygen dropped dramatically and potentially toxic polyphenolic compounds accumulated in the water (McKinnon 1997). Oxygen levels were low because there was a reduction in the mixing of waters and because of a high oxygen demand by decomposers, factors which would disperse if flows were increased (McKinnon 1997). As a consequence of this 'blackwater' phenomenon, there was a major fish kill, including a kill of some natives such as murray cod and catfish, and murray crayfish (*Euastacus armatus*) emerged from the river *en masse* (McKinnon 1995; 1997). McKinnon (1997) recommended that flooding should be protracted, deep (to 1 metre) and continuous to flush out lentic water bodies and the whole of the floodplain adequately, and should be followed by a fast early recession, in order to create an ideal environment for fish.

The majority of fish now living in the forest are exotics, primarily european carp (*Cyprinus carpio*) which comprised 44% of the catch during McKinnon's five year study, but also substantial numbers of goldfish (*Carassius auratus*), redfin (*Perca fluviatilis*) and mosquitofish (*Gambusia holbrooki*) (McKinnon 1997). The impacts of these fish on the forest environment are discussed in detail in another section of this paper, but there is a great deal of evidence to show that they keep native fish numbers down by competition and predation. The regulated flood regime suits the breeding requirements of these exotic species. They are able to breed without flood events, but can also take advantage of the abundance of food and habitats available during floods (Morison 1989). In McKinnon's study, carp recruited in both October and December, so summer floods add to carp numbers while contributing nothing to native species (McKinnon 1997). Barmah-Millewa is an ideal spawning ground for carp, as are irrigation channels (NRE no date a), so it may be difficult to control their numbers by simply changing the watering regime. On the other hand, introduction of a flooding cycle that mirrors the natural cycle as closely as possible would boost the number of natives, who might then have more of a fighting chance of eventually excluding exotic species by competition.

Robertson *et al* (1999) argue that alterations to environmental flow regimes have been the most important agents of change to the riverine carbon cycle since European colonisation. The transfer of carbon between floodplains and rivers has been dramatically altered by the changes in the way the two environments are connected (Robertson *et al* 1999). Glazebrook & Robertson (1999) have commented that summer/autumn floods decrease litter standing stocks in low-lying areas, increasing the C:N:P ratios and reducing the amount of nutrients available to support spring biological production. This affects primary producers (macrophytes and biofilm) and through them the whole food chain (Glazebrook & Robertson 1999).

Restoration of natural wetting and drying cycles in Barmah-Millewa is essential in order to prevent the further loss of moira grasslands, rushlands, aquatic vegetation, breeding waterbird colonies, native fish stocks, frog and turtle populations, invertebrate diversity, nutrient cycling, successional processes and primary production systems. They are necessary to maintain ecosystem, species and genetic diversity in the forest. Some steps have already been taken by management authorities to improve the environmental flows through the wetlands. Barmah-Millewa currently receives an environmental water allocation of 100GL, which has been used twice, in spring 1998 and spring 2000 (Ladson 2001). This amount of water is insufficient to flood the forest alone, but it is useful as a 'top up' to natural floods (Ladson 2001). Summer floods still occur in the forest, although an agreement between the Victorian and New South Wales governments means that they are diverted to the Barmah forest and the Millewa group of forests in alternate years to reduce permanent inundations on either side (Ladson 2001). Levees, block banks and regulators are still in place and still prevent floodplain waters from wholly mixing with the mainstream. In all, the current flooding regime is still insufficient to fully maintain the biodiversity and ecological processes of Barmah-Millewa. Floodplain areas are part of large, integrated systems (McKinnon 1997), so their proper management necessitates a holistic rather than piecemeal approach.

Since most of the water entering the forest during a flood comes out again downstream (Dexter 1978; Johnson 1984), allocating more water to Barmah-Millewa would not mean 'losing' all that water to the environment. Lack of water is not a solid argument against restoring environmental flows. The main problems are (1) the levees, block banks and regulators which increase flow efficiency past the wetlands (Kingsford 2000), and impede flood recession and thus risk water stagnation (McKinnon 1997), and (2) the seasonal changes in flow regime to suit irrigators. The issue of irrigation uses is a big one that must be solved on a regional or even national basis and is beyond the scope of this paper. But it is a problem that affects more than just Barmah-Millewa because of the impacts that irrigation can have on the water table and salinity. Australians certainly need to consider adopting more sustainable farming practices if we are to continue farming at all in this country. As a part of that discussion that needs to happen, we should be considering the physical deregulation of waterways for the sake of the environment. The Yorta Yorta are standing firm on the issue of water regulation on their lands and will have a leading role to play in those discussions. As for the more localised issue of levees, block banks and regulators: their eventual removal will no doubt be a very positive move for the biota of Barmah-Millewa. At the moment, they are all that stands between the forest and summer flooding, which is clearly very damaging to the ecosystem. Creative solutions to this problem are required urgently. The management of Barmah-Millewa for conservation, as a national park, instead of for resource use, may spark a renewed interest in the issue within the Australian public and appropriate solutions may be found.

Ramsar Convention

The Barmah Forest was listed under the *Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat* in 1982 because of the huge numbers of water birds nesting there, for the significant numbers of threatened species it harbours, and for its "ecological, recreational, tourist, scientific, educational, cultural, scenic and aesthetic features" (Wetlands International Website; Yorta Yorta Clans Group 2001, 113).

Not all conditions of the *Ramsar Convention* have been upheld under the current management of Barmah-Millewa. Article 3.1 of the convention states that the contracting parties shall formulate and implement their planning so as to promote the conservation and wise use of wetlands (Ramsar 1971). The reservation of most of Barmah-Millewa for forestry does not promote its conservation, as will be discussed in detail in a later section of this paper. Nor is forestry listed as a 'wise use' of wetlands under Ramsar criteria (Ramsar 1971; annex to Recommendation 4.10 of the 4th meeting of the contracting parties 1990). Grazing is included as a potential wise use of wetlands (Ramsar 1971), but it is also listed under the Directory of Important Wetlands in Australia as a potential threat or disturbance to Barmah-Millewa (2001; also Robertson 1998), so the stock-grazing regime as it currently stands may not qualify as a wise use. As has been described in the section above, the regulation of water through the forest also has adverse implications for conservation.

Article 3.2 states that each contracting party plus the IUCN should be informed if the ecological character of a wetland is changing (Ramsar 1971). However, a review of wetland inventories written under contract to the Bureau of the Ramsar Convention in 1999 found that the wetland inventory processes, methods and information in Australia were inadequate, and no inventories provided quantitative information on changes in the extent of wetlands (Finlayson & Davidson 1999). Clearly there have been substantial changes in ecological processes and the extent of some vegetation types, as outlined above, and the detailed investigation and documentation of this coupled with relevant action would seem to be an appropriate response if the Ramsar Convention is to be upheld by Australia.

Article 4.4 states that the contracting parties should endeavour through management to increase waterfowl populations on appropriate wetlands (Ramsar 1971). The huge colonies of breeding waterbirds in the past and the present must qualify Barmah-Millewa as an appropriate wetland. Management activities have led to a reduction in waterfowl populations as has already been shown. This includes a reduction in populations of bird species protected under international migratory bird agreements, such as the great egret, cattle egret (*Ardea ibis*), glossy ibis (*Plegadis falcinellus*) and red-necked stint (*Calidris ruficollis*) (JAMBA 1981; CAMBA 1986; Leslie 2001).

The Montreux Record of the Ramsar Convention (Resolution VI.1 passed at the 6th meeting of the contracting parties, 1996) is the principal tool for highlighting those sites where an adverse change in ecological character has occurred, is occurring, or is likely to occur (Ramsar 1971). The reductions to waterbird and native fish populations plus the reduction in area of the moira grassplains in Barmah-Millewa certainly constitute adverse changes in ecological character. This has been recognised by some scientists within Australia: there is currently a proposal to list the aquatic ecological community in the natural drainage system of the lower Murray River catchment as an endangered ecological community (Fisheries Scientific Committee 2001; NRE no date b). It may also be appropriate to list Barmah-Millewa on the Montreux Record so that its situation receives international attention.

World Heritage Listing

Sites can be nominated for World Heritage listing for either their cultural or natural values, or for both (World Heritage Convention 1972). The large number of archaeological sites at Barmah-Millewa alone (Yorta Yorta Clans Group 2001) may warrant the forest's nomination for its cultural values, but an examination of that possibility is beyond the scope of this paper. In terms of natural values, Barmah-Millewa may meet three of the four criteria for nomination. Those criteria are:

(i). be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; or

(ii). contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; or

(iii). contain the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation. (World Heritage Convention 1972)

Criterion (i): The Barmah-Millewa floodplain formed around 30,000 years ago when land west of the Cadell fault, which reaches from Deniliquin to Echuca, rose 15 metres above the surrounding lands, cutting across the course of the ancestral main Murray channel (AHC 1992). The raised fault forced the ancestral Murray River to divert to the south (the present Murray course) and the north (the present Edwards River) (AHC 1992). Before these diversions were able to carve out new river channels, the Murray waters backed up towards the east, creating a broad shallow lake system (MDBC 1992) that eventually became a floodplain. It is this floodplain and the unique fluvial geomorphology of the area that has enabled the Barmah-Millewa forest to develop, because normally red gum forms open woodland or a narrow strip of riparian vegetation, not a dense forest (Parson 1991). The strong association between red gum and floods at Barmah-Millewa gives the place unique flora and ecology that is not representative of red gum forests generally (Chesterfield 1989). Thirty thousand years is not a long time in geological history, indeed it is recent enough that the story of the Cadell fault uplift and subsequent huge flood remains a part of Yorta Yorta culture (Wayne Atkinson, pers.comm.). The great changes that have taken place on the Barmah-Millewa floodplain since the uplift suggest that the system may still be in the process of change – may still be undergoing 'ecosystem evolution'. We residents of the year 2001 are privileged to be alive at this time to witness such a dynamic system. Viewed from this perspective, Barmah-Millewa has great scientific importance, and can be considered to present a significant example of on-going ecological and biological processes in the evolution and development of terrestrial and fresh water ecosystems and communities. It also has unique global status as the largest river red gum forest in the world (Robinson 1998).

Criterion (ii): As this paper's aim is to write about Barmah-Millewa from a scientific perspective, it is probably inappropriate to comment on the forest's aesthetic values. However, as a kind of intermission in the midst of much scientific jargon, the author will allow herself one paragraph's grace in this regard.

There are stories the Yorta Yorta tell about the Murray that are magic. In certain seasons, the river water used to be so clear you could see right to the bottom almost all the way across (Wayne Atkinson, pers.comm.). Fish were so plentiful in the river that a person could dive down to below a red gum snag and tickle a fat murray cod's belly, making it rise to the surface (Wayne Atkinson, pers.comm.). The land is vibrant and lush and, to the non-indigenous visitor, gives an impression of a pre-land-theft Yorta Yorta lifestyle that was incredibly rich and bountiful. Even now, the Murray in the forest is exquisite as mist rises above the water at dawn on winter mornings, and flocks of thousands of deafening corellas paint the red gum white. Those twisted, grand old trees are spectacular, growing, as they do, straight up out of the floodwater. The author defies anyone to go camping in the forest for just one night and not call it beautiful.

Criterion (iii): As has already been mentioned, Barmah-Millewa is a very important piece of remnant bush for the conservation of threatened species. Some of the threatened species it harbours, for example the regent honeyeater and the trout cod, are endangered nationally (Environment Australia 2001), and being Australian endemics, are therefore endangered globally, so they do have international value to science and conservation. The thirteen migratory birds protected under international agreements (JAMBA 1981; CAMBA 1986) that breed or reside in the forest also have global conservation significance. However, whether or not these species qualify as having 'outstanding universal value to science or conservation' is another matter. Exactly what qualities species need to possess to fit this description is unclear from the convention itself (World Heritage Convention 1972). The species mentioned by name under 'official' brief descriptions of World Heritage sites, which presumably fit the description, are almost all vertebrates and are mostly large mammals (World Heritage Convention 2001). This may indicate that organisms need to be appealing to the general public of the world to be of world heritage significance (ie to have outstanding universal value). Species which are 'valuable' from a strictly scientific perspective may have little universal appeal, for example the mite *Brevipalpus phoenicis* has recently captured scientific interest because it is asexual and haploid (Weeks *et al* 2001), a condition that has not been observed in any other animal (Paul Sunnucks, pers.comm.). Despite its outstanding scientific value, the universal appeal of *Brevipalpus phoenicis* is questionable, and if it were threatened with extinction it seems unlikely that its habitat would receive a World Heritage listing to protect it. This aside, Barmah-Millewa has a good chance of capturing the interest of the public and UNESCO anyway, because many of its threatened species do have charismatic 'cuddly-furry' appeal. The great egret, for example, was over-hunted in the nineteenth and twentieth centuries for its magnificent lacy breeding plumes, which are still coveted internationally (Tan 2001).

Reduce inputs of nutrients, sediments and herbicides

The range and amount of chemical compounds and sediments present in waterways has significant implications for carbon fluxes (Robertson *et al* 1999). Increased input of sediments and nutrients into the Murray River wetlands can shift primary production from macrophytes and biofilm to phytoplankton (Robertson *et al* 1999), with resultant impacts on organisms such as some waterbirds and fish that rely on macrophytes for food (Koehn & O'Connor 1990; Glazebrook & Robertson 1999; Leslie 2001). Some authors refer to the low turbidity of billabongs as an important characteristic for maintaining local biodiversity (Hillman 1986; Parson 1991), so increased sediments may adversely affect billabongs. Channel siltation and pesticides in water have been implicated in the decline of some River Murray crustaceans, such as the murray crayfish, *Euastacus armatus*, which is possibly extinct below Mildura (Horwitz 1990). Abundant sediment can smother the eggs of the Macquarie Perch (*Macquaria australasica*), a species that is endangered in Victoria (NRE 1999), whose eggs are deposited directly onto the substrate (Koehn & O'Connor 1990). The current management plan for the Barmah Forest (DCE 1992) outlines concerns that a number of wetlands are silting up rapidly and that the Murray is becoming broader and shallower. It implicates erosion by boat wash as a major cause, compounded by the fact that the river water is continually high in the summer months (DCE 1992), but stock-grazing and the siltation activities of carp may also be important causal factors, as will be discussed in more detail below.

Buffer zones around wetlands

The role of buffer zones in protecting habitat that is surrounded by significantly altered landscape is well documented in conservation biology. The IUCN has suggested that buffer zones managed in an ecologically sustainable manner should surround reserves in order to adequately conserve biodiversity (SAG 1995 cited in Burgman & Lindenmayer 1998). In the case of Barmah-Millewa, degrading processes that should be buffered against include grazing, land-clearing, timber harvesting, erosion and salinity. Irrigated land south of Barmah-Millewa was found to have a water table sitting approximately 2 metres below the surface in 1988, compared with the Barmah Forest, which had a water table approximately 11-14 metres below the surface (Ife 1988). The irrigation mound was expanding towards the river including the forest area, which has clear implications for forest health (Ife 1988). The creation of a non-irrigated buffer zone around the forest would hopefully prevent or diminish the impacts of irrigation and other threats to the system.

Maintain existing vegetative cover for the sake of water cycling and quality

Riparian, riverine and aquatic vegetation plays an important role in bank and shoreline stabilisation (Parson 1991) and buffers soil against erosion (Kauffman & Krueger 1984). It also intercepts materials from overland flows (Robertson 1998), filters out nutrients (Parson 1991) and buffers waterways from other surrounding activities (Koehn & O'Connor 1990). Emergent or overhanging vegetation reduces evaporation by shielding water surfaces from solar radiation and drying winds (Anon. 1962). The integrity of vegetation in wetlands is therefore crucial for maintaining water cycling processes and quality.

Protect aquifers from contamination

The geology of Barmah-Millewa is relatively simple: most soils are cracking clays and loams that are lacustrine in origin (Bren 1999), but aquifers occur as sandy soils amongst the clays (Bren & Gibbs 1986). Aquifers are an important source of water for forest vegetation, particularly red gum, after floods recede (Bren 1987), and the best quality stands of red gum occur either where there is regular flooding or on top of aquifers (Dexter 1979). Yellow box trees may also rely on aquifers, as they tend to grow on sandier soils in the forest (Ward 1999). The protection of aquifers is therefore important in protecting the health of the forest.

Conclusion

There is a great deal of evidence in the scientific literature to support the Yorta Yorta's list of priorities regarding water issues. Most of the available literature on environmental issues in Barmah-Millewa examines the effects of water regulation (pers.obs.), which many authors (eg Robertson 1998) consider to be the biggest threat to the ecosystem. In this regard, the Yorta Yorta and conservation biologists are in agreement about what needs to be done by managers.

Stock Grazing

Proposed action (summarised from Yorta Yorta Clans Group 2001):

- Remove stock grazing from the riparian zone, around the Moira and Barmah Lakes, and from all areas listed as Ramsar wetlands and National Estate Registered places of natural value.

Cattle are currently grazed in the Barmah Forest under agistment and licensing arrangements (DCE 1992). They are supposedly excluded from Ulupna Island, the two reference areas in the forest and other sensitive zones by fences and a herdsperson, for conservation reasons (LCC 1985; DCE 1992). When the Land Conservation Council proposed the creation of Barmah State Park in 1985, it recommended that cattle be removed from the Park within three years of the acceptance of the proposal (LCC 1985). This was watered down by the time the *Barmah Management Plan* was written (DCE 1992), but the *Plan* recognised the Victorian government's Wetlands Conservation Program intention that 'Grazing on publicly owned wetlands of high value will be phased out within five years of a wetland being recognised as being of high value'. Since the *Barmah Management Plan* and, for that matter, the *Ramsar Convention*, describe Barmah as a high value wetland, it follows that grazing should have been phased out at least in the State Park if not in the whole forest by, at the very latest, 1997. The *Plan* compromises on this by stating "management must ensure grazing does not have a significant detrimental effect on wetland values" (55). This implies that some exclusion measures should be put in place to limit the cattle's access to the State Park.

In practice cattle get into all of these areas, and basically have the run of the park. Fences around the western reference area were found to be in a serious state of disrepair in August 2001, and the area was full of cowpats (Indira Narayan, pers.comm.). The moira grass plains in the western portion of Barmah State Park were found to be full of cattle in July 2001(pers.obs.). Their cowpats covered the grass plains and their pats and pugs had created a mudslick of the shoreline of Hut Lake, which was seriously devegetated (pers.obs.). Ulupna Island in 1972 had suffered little from grazing (Muir 1974) and supported a very rich flora of 178 species (Muir 1974; LCC 1985); now low flows in Ulupna Creek allow cattle to cross regularly onto Ulupna Island to graze (Peter Barker, pers.comm.; DCE 1992). Several sites of cultural significance in the park have also been fenced to exclude cattle, but cattle get in anyway: cows were grazing on the Bucks Sandhill site in April 2001, for example (pers.obs.). Cattle numbers are supposed to be reduced over winter to lessen the impact they have on the box ridges, where they retreat to during floods (DCE 1992). In fact numbers are only reduced during prolonged droughts or floods, and usually supplemental feeding occurs instead of removal when all other available forage has been consumed (Leslie 2000). The management of cattle is indeed very lax in the Barmah Forest.

Graziers are allowed to run cattle in the forest for three reasons: (1) fire prevention, (2) to generate income for graziers and (3) for 'cultural' reasons, or to be more specific, because stock grazing has been going on in the forest since the 1840s (DCE 1992). As this paper is examining scientific evidence which supports the Yorta Yorta management proposal, the author will restrict political arguments regarding grazing to the two sentences that follow, and will admit that these arguments are her opinion only. The issue of socioeconomic inequality between the few graziers that have access to the forest and those that must graze only on their own land warrants attention: the agistment fee graziers pay per head of cattle in Barmah probably doesn't offset that inequality of access, and the use of public forests for the private gain of graziers has been debated by public officials since at least the 1880s (Fahey 1987). As for the cultural importance of grazing, it is the author's firm opinion that 60,000 years of cultural continuity or even 13,000 years of cultural continuity should take precedence over 160 years of cultural continuity on stolen land.

This leaves the issue of fire prevention. Stock grazing (hereafter called simply 'grazing') is advocated as a fire prevention method based on the idea that cattle reduce the fine fuel load in the forest (DCE 1992). Whether there is any truth to this idea is unclear because it has not been well studied (Silvers 1993). The one study that has been carried out in Barmah Forest to address the question produced mixed results. In 1993, Silvers compared the levels of fine fuel load present in plots that excluded all grazing mammals, including rabbits and kangaroos, plots that excluded only cattle and horses and plots that allowed access to all grazing animals, in eight different vegetation types in the forest. In only two vegetation types (moira grasslands, red gum with wallaby grass (*Austrodanthonia* spp.) understorey), cattle and horse grazing caused a significant reduction in fuel loads. In three vegetation types (giant rush, red gum with an introduced species understorey, black box woodland), grazing had no impact on fine fuel loads. In the remaining three vegetation types (grey/yellow box woodland, red gum with terete culm-sedge (*Carex tereticaulis*) understorey, red gum with terete culm-sedge/warrego summer-grass (*Paspalidium jubiflorum*) understorey), grazing by cattle and horses had a fuel reduction impact either equal to or less than the impact of kangaroos and rabbits (Silvers 1993). Silvers mentions a lack of replicates as a shortcoming of the study, so her results are inconclusive, but the study does not suggest overwhelmingly that stock grazing is a useful fire prevention tool. Moira grassland, for example, is not likely to be the site of major fires, since it is inundated for long periods of time and contains no woody species (Ward 1991). Red gum forest with a wallaby grass understorey, the only other vegetation type for which cattle grazing reduced the fuel load, is also probably unlikely to pose a major fire risk. In 1986, the New South Wales Forestry Commission stated that control burns were rarely carried out in red gum forests because fine fuel loads were generally low, the absence of shrubs made crown fires rare, and what fuel there was (fine grass and reed foliage) was usually green or flooded during high fire danger periods (cited in Parson 1991). Flooding itself may also reduce fuel loads before summer because red gum litter is broken down more quickly by bacteria and invertebrates when it is inundated (Leitch 1989). If kangaroos and rabbits can keep fuel loads down elsewhere in the forest, for example in the box woodlands where there is a shrubby understorey, then there seems to be no reason to keep cattle in Barmah-Millewa at all.

The reasons why it is considered necessary to prevent fires must also be questioned. Fires have been a natural and anthropogenic feature of the Barmah-Millewa landscape, and indeed of southeastern Australia, for many thousands of years (DCE 1992; ABRS 1999; Yorta Yorta Clans Group 2001). Many Australian plants rely on fire to reproduce (McIlroy 1978), and some Australian animals have a preference for habitat of a certain age-since-last-fire (Wilson 1990; Richards *et al* 1999). Since the forest ecosystem was shaped by the Yorta Yorta's regular burn regime, it is a strong possibility that biodiversity values at Barmah-Millewa would be best maintained by reintroducing fire to the system. Black box, for example, may benefit from fire: it has limited germination under a canopy but adult trees are fire tolerant (Parson 1991), so burning may encourage recruitment. Grazing, in contrast, significantly reduces seedling survival in black box (Parson 1991). The main reason why current managers wish to exclude fire seems to be to prevent losses to the timber industry (Forests Commission Victoria 1983; LCC 1985; DCE 1992). The LCC (1985) stated that control burns were an acceptable management practice in conservation areas. State Forests of New South Wales is currently investigating the use of control burns in assisting the recovery of native ground layer plants to recover from grazing effects (cited in Leslie 2000). Were Barmah-Millewa managed for conservation instead of timber production, there would be nothing to stop the implementation of a control burn program. The Yorta Yorta are interested in reinstating their traditional fire regime in the forest as a tool for ecosystem and species management (Indira Narayan, pers.comm.).

While there is no reason to keep cattle in Barmah-Millewa, there are plenty of reasons to exclude them. It is implicitly understood by natural resource managers that grazing has a disturbing impact on natural environments. This is revealed in admissions that an absence of grazing in certain areas has left them "in a relatively undisturbed condition" (Forests Commission Victoria 1983: 27), that grazing is incompatible with conserving and protecting ecosystem components "in a relatively natural state" (LCC 1985: 16), and that grazing should be removed from environmentally sensitive areas (Leslie 2000), but this understanding has not led to the enforced removal of stock from native forest. Even when grazing impacts have been articulated explicitly, stock have not necessarily been removed. For example, the management recommendations for the protection of the superb parrot within Barmah-Millewa included the removal of grazing from box woodland within 10 kilometres of known parrot nesting colonies where significant ecological damage was likely to result (Webster & Ahern 1992). This would take in almost all box ridges throughout the whole forest system. Not only has this not occurred, but the box ridges are often the most heavily grazed sites in the forest, because they provide the only refuge during floods (Chesterfield 1986).

Grazing has been shown to impact adversely on many plant communities in Barmah-Millewa. Before European colonisation, the area included vast expanses of rushland dominated by cumbungi and common reed (Chesterfield 1986). The decline of those rushlands has been attributed to selective grazing by stock (Chesterfield *et al* 1984 cited in Fahey 1987; LCC 1985; Chesterfield 1986; MDBC 1992). Grazing may also be partially responsible for the encroachment of red gum on the moira grass plains. Ward (1991) found that grazing impacted on moira grass recruitment by affecting stem length and hence flowering ability, by disturbing plants before they can take root in the substrate after flooding, and by reducing photosynthetic ability, thus reducing stores for survival during the post-flood rapid growth period. The work of Dexter (1978) showed that cattle grazing promotes red gum regeneration by reducing the ability of other species to compete with red gum seedlings. Grazing can kill submerged plants by interfering with the oxygen supply to roots and tubers (Ward 1991), which may also affect native fish by simplification of their habitat (Koehn & O'Connor 1990). The presence of aquatic vegetation assists in the formation of microhabitats in the floodplain for juvenile fish as well as buffering against surrounding activities and providing nutrients to the system (Koehn & O'Connor 1990). The species-richness, stem densities, biomass and percentage cover of aquatic plant communities have all been found to increase when cattle are removed from a wetland (Robertson 1998). If vegetation is removed from a wetland community by grazing and is not given an opportunity to re-establish, it may be unable to return even after grazing is removed if soil seed banks are lost (Robertson 1998). The loss of habitat vegetation due to grazing has also been implicated in the demise of crustaceans (Horwitz 1990), waterbirds (Loyn 1989), mammals (Parson 1991), woodland birds (Leslie 2000), aquatic invertebrates (Robertson 1998), terrestrial invertebrates (Leslie 2000) and frogs (Healey *et al* 1997). This is because breeding habitat may be absent or depauperate or predation risks may increase without adequate shelter (Robertson 1998). Healey *et al* (1997) found that densities and diversity of frog species was correlated with the number of riparian plant species present at a site.

Chesterfield (1986) implicated grazing, particularly grazing in dry years, in the increased abundance of 'unpalatable' terete culm-sedge in the red gum understorey, the decline in cover and diversity of shrubs on box ridges, the disappearance of some plant species and the increased abundance of exotic plants. During a prolonged drought from 1913-1915, it was documented that stock removed all reeds, tussocks and small trees from the forest, along with the leaves from trees as high as they could reach (Hibbins 1991). Since plants have different abilities to recover from complete defoliation (Wilson 1990), it is not unlikely that such an event could cause localised extinctions. The Yorta Yorta Clans Group (2001) noted several recent declines in plant abundance. They stated that bulbine lily (*Bulbine bulbosa*), which used to be common in the forest, was not found in a recent survey, that ruby saltbush (*Enchylaena tomentosa*) was found in black box woodlands on roadsides outside the forest but not within the forest, that quandong (*Santalum acuminatum*) had disappeared from the forest altogether and that other plant species were only found in small populations within the forest (Yorta Yorta Clans Group 2001). They did not attribute this decline to a specific cause, but it is possibly the result of recent grazing pressure. In particular, the occurrence of ruby saltbush by the road, where cattle presumably could not access it, but not in the forest, where cattle could access it, suggests the influence of grazing.

As with her work on fuel reduction, Silvers (1993) obtained mixed results from her studies on the effect of grazing on understorey species diversity. In some ungrazed or non-ungulate-grazed plots, she found that the incidence of introduced grasses decreased while the diversity of native ground species increased after stock were excluded, with some species only occurring where there was light or no grazing (Silvers 1993). At other sites, removal of grazing prompted greater diversity of both weeds and natives (Silvers 1993). At still other sites, grazing decreased grass cover and increased the abundance of herbaceous species (Silvers 1993). The conflicting results of this study make it difficult on a superficial level to recommend that grazing should be stopped outright, since some native species appeared to benefit from it. However, it is highly likely that management practices such as control burns would have the same regenerative effects, since the plants in question evolved with fire and without ungulate grazers. Further studies are urgently required to investigate this question.

Generally, Silvers found a positive relationship between weed occurrence and grazing pressure (Silvers 1993). Grazing may increase weeds by increasing mineral nitrogen in the soil (Leigh 1974), by facilitating the spread of seeds or fruit in faeces (Leigh 1974; Ward 1991) or by substitution after impairing the competitive ability of native species, which are not used to the heavy, continuous grazing exerted by stock (Leigh 1974; Parson 1991). Some authors support only a partial reduction in stock grazing, arguing that a complete cessation of the practice would lead to an increase in weed abundance (Doug Robinson, pers.comm.). Again, this hypothesis has not been studied within Barmah-Millewa, so remains hypothetical. It should certainly be tested, and again, further studies are urgently required here. But since the conjectured benefits of continuing grazing – increased abundance of native herbaceous species in some vegetation types and decreased abundance of weeds – are unproven and somewhat speculative, and since they probably do not outweigh the costs of stock grazing, they cannot be used as a solid justification for continuing grazing in Barmah forest. Alternate methods of weed control such as the reintroduction of a near-natural and extensive flood regime, the reintroduction of traditional burning methods and manual removal of weeds should be investigated and trialed.

Grazing can also cause a decline in native animal species by competition (Parson 1991; Ward 1991) or disturbance (Webster & Ahern 1992). The superb parrot builds its nests in mature red gum but forages in box woodlands up to 9 kilometres away (Webster & Ahern 1992). The changes to vegetation structure and composition caused by stock-grazing on box woodlands seriously threaten the integrity of the woodlands, and thus the survival of the superb parrot (Webster & Ahern 1992). Occasionally, cattle compete directly with superb parrots for food. For example, the pale-fruit ballart (*Exocarpos strictus*) provides important fledgling food for the parrot, but is extensively grazed by cattle in dry years (Webster & Ahern 1992). Cattle may also disturb parrots and prevent them from foraging, thus increasing their overall foraging time (Webster & Ahern 1992). Many species of terrestrial vertebrate retreat to box ridges during floods, just as the cattle do, and they rely on box ridge integrity to survive (Loyn 1989). Cattle grazing on the box ridges may therefore adversely affect other vertebrate species by competition or disturbance.

Stock are also known to compact soils, increase runoff, erode riverbanks and increase siltation in waterways (Arnold 1977; Kauffman & Krueger 1984; Koehn & O'Connor 1990; Wilson 1990; Parson 1991; Robertson 1998; Robertson *et al* 1999). Crustacean populations have suffered as a result of this (Horwitz 1990), often by the direct destruction of burrows by pugging (McKinnon 1997). Other aquatic or terrestrial invertebrates may also suffer from habitat destruction (Ward 1991) or direct mortality (Robertson 1998) by pugging. Soil compaction can destroy mammal burrows or make soil unsuitable for burrowing (Parson 1991). Bank erosion and increased turbidity can make conditions unsuitable for platypus populations (Wharton 1970). Plants may have difficulty re-establishing where soils have been compacted, particularly wet soils (Arnold 1977; Naeth *et al* 1990). Grazing often removes the cryptogamic crusts that stabilise the soil surface, reduce leaching and support native organisms, further increasing runoff and erosion (Parson 1991). Some authors contend that the entire soil profile of Barmah-Millewa has been changed by stock from light loams to compacted clays (MDBC 1992).

Increased turbidity and siltation as a result of erosion, faeces and other bodily wastes, or because of reduction in filtration by aquatic vegetation (because of vegetation removal) can alter nutrient cycling processes (Ward 1991). It has already been noted that turbidity and siltation can change the food chain structure and function, faunal recruitment success and consumer composition by shifting primary production from macrophytes and biofilm to phytoplankton (Robertson 1998; Robertson *et al* 1999). Increases in nutrient loads can increase algal blooms (Robertson 1998). Faecal waste may also contain harmful microorganisms and cause disease in aquatic species (Kauffman & Krueger 1984; Parson 1991; Robertson 1998).

In all, stock grazing seems to have had a harmful impact on many native Australian ecosystems, including other wetlands (Arnold 1977; Silvers 1993; Finlayson & Davidson 1999), and including Barmah Millewa (Chesterfield 1986; Ward 1991; Silvers 1993). Some authors make the point that kangaroos are equally capable of defoliating an area in times of drought, and may therefore need to be periodically culled (Wilson 1990; Leslie 2000). The Yorta Yorta have a long history of managing Barmah-Millewa sustainably, that is, in such a way that all species maximise their chances of survival into the future without impinging on the survival chances of others. Since part of their motivation in management is to conserve food species, they have a vested interest in maintaining healthy vegetation communities, and also in keeping kangaroo population sizes at a manageable level by culling, just as they have always done (Yorta Yorta Clans Group 2001). In environmental impact terms, kangaroos and cattle are different, because kangaroos impact on a narrower range of forage species than cattle and they don't degrade soil by trampling around water points (Wilson 1990). Clearly, before European colonisation, the Yorta Yorta had kangaroos and other grazing animals under control, or the lush vegetation of Barmah-Millewa at that time would not have existed.

One of the high priority actions to be undertaken as part of the current *Barmah Management Plan* (DCE 1992) is the monitoring of grazing impacts using reference areas for comparison. Since at least one of the reference areas no longer excludes cattle because the fences are in disrepair, this is clearly not possible. The evidence contained in this paper suggests that cattle do have an adverse impact on forest biodiversity, but the lack of long term monitoring experiments casts a level of uncertainty on this conclusion. However, this should not be used as an excuse to do nothing. Most current environmental legislation, at the international, national and state levels, contains a clause embracing the Precautionary Principle (Rogers *et al* 1997) (eg the Rio Convention on Biological Diversity 1992, the Inter-Governmental Agreement on the Environment 1992, the Environment Protection and Biodiversity Conservation Act 1999, the Victorian Biodiversity Strategy 1997). This principle states: "a lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation" (IGAE 1992 cited in Rogers *et al* 1997: 344). By applying the precautionary principle to the situation of Barmah-Millewa, legislators should agree that stock ought to be removed from the forest.

Timber Harvesting

Proposed action (summarised from Yorta Yorta Clans Group 2001):

- Phase out timber harvesting and silvicultural operations.

Red gum is an important source of timber for sawlogs, sleepers, piles, landscape chipwood, firewood and charcoal (MDBC 1992). The long-lasting timber from grey and black box is harvested for fence posts (MDBC 1992). Commercial harvesting of live trees takes place in the forest under licence, as does commercial harvesting of firewood timber (DCE 1992), but unlicensed collection of fallen timber is also permitted (*Riverine Herald* 13th July 2001). Timber from the Barmah-Millewa forests has been harvested extensively since the 1860s (DCE 1992). The demand for red gum timber was so high in the 1870s that the section of the Barmah Forest from the river to two miles inland was wholly or partly worked, and the then Victorian Secretary for Agriculture estimated that the forest would be entirely used up within 4-6 years (Fahey 1987). This overworking of the forest has resulted in the existence at present of extensive areas of even aged stands which all regenerated in the 1870s and 1880s (Dexter 1979). This obviously does not reflect a natural distribution of age classes, and this has implications for the Barmah-Millewa biota, which requires a diversity of age classes (Dexter 1979).

Logging of live trees still takes place in the forest, and is often associated with practices such as ringbarking and poisoning of non-merchantable mature trees to maximise young tree growth (Lacey 2001). Ringbarking in the past has altered understorey vegetation (Chestefield 1986) and destroyed habitat trees (Webster & Ahern 1992). In box-ironbark woodlands, live timber harvesting has altered vegetation structure and composition (Robinson & Traill 1996).

Current forest management authorities recognise the need for the conservation of habitat trees, but with one qualification. Only the bare minimum number of habitat trees need be conserved (Lacey 2001). This policy does not recognise the possibility that for tree-dwelling organisms to thrive, they need to have their choice of a range of habitat trees, and they also need room to colonise more habitat trees if they increase their numbers. McIlroy (1978) found a relationship between the number of different types of hollows and the numbers of hole-nesting mammals and birds, and also found that many animals were highly selective in the type of cavities they used. A shortage of suitable home sites and the resultant competition is the main limiting factor for some populations of hollow nesting mammals (McIlroy 1978). The superb parrot is a good example of an animal that is choosy about nesting cavities: parrots prefer to live in broken hollow limbs (spouts) or in holes in limbs of large, mature, healthy eucalypts adjacent to watercourses (Webster & Ahern 1992). Hollows do not form in red gums until they are at least 140 years old (Parson 1991), so it must take a long time for a range of hollows to form in a forest. Considering that red gum forest has the highest proportion of hole nesting birds of any vegetation type in Victoria, harbouring parrots, ducks, falcons, cockatoos, treecreepers, pardalotes, kingfishers and owls (Loyn 1985 cited in Parson 1991), a lot of trees with hollows are required to cater to the needs of all the animals present. Microchiropteran bats, possums and gliders also nest in tree hollows (Parson 1991). In Barmah-Millewa, squirrel gliders and brushtailed phascogales are the most significant tree nesting mammals (LCC 1985). The carpet python (*Morelia spilota variegata*), which is endangered in Victoria, also relies on large hollow trees in the Barmah Forest (DCE 1992). It stands to reason then that the longer the forest is left alone, the more diverse the hollow tree population is, and the more diverse the community will be.

Logging in the vicinity of habitat trees can also have an adverse effect on animals. Superb parrots have been observed to become agitated and to refuse to enter their hollows when humans are around (Webster & Ahern 1992). They would almost certainly be disturbed by logging activity taking place below them, even if the trees being logged were not important for habitat.

Large, mature trees are not only important for providing homes, they are also important suppliers of food. Old trees can supply an abundance of nectar and insects, as well as catering to the more specialised palate with food sources such as peeling bark, rotten wood, and the grassy gaps between big trees, some of which regent honeyeaters rely on (Robinson & Traill 1996). Destroying such trees simply because they are of no economic value clearly conflicts with conservation imperatives.

Logging even some distance away from habitat trees can impact on species. Superb parrots rely on box ridge communities for foraging (Webster & Ahern 1992), which means they need the trees to be intact. Logging has been identified as a threat to box ridge integrity, and the cessation of logging (as well as grazing, mentioned above) on all box ridges within 10 kilometres of known superb parrot nest sites was recommended by Webster & Ahern (1992), which should mean timber harvesting should cease on almost all box ridges within the Barmah-Millewa forest.

It has been estimated that to maintain viable populations of large mammals that cannot move out of a habitat patch, reserves should be at least 6,000 hectares in size, possibly 20,000 hectares (Tyndale-Biscoe & Calaby 1975). If that were the case for a hypothetical hollow-nesting species, then it is arguable that 20,000 hectares of forest should be reserved from logging to give the population the best chance of surviving into the future.

The collection of ground wood is just as much of a concern as the logging of live trees, if not more so. Mac Nally & Parkinson (1999) have estimated that 85% of pre-European amounts of coarse woody debris on the Murray floodplains is regularly removed for firewood and timber harvesting – in other words only 15% remains. It is well established that fallen wood provides significant habitat for terrestrial organisms (Parson 1991), including the carpet python (DCE 1992). Laven & Mac Nally (1998) found that woodland birds occurred significantly more frequently and in greater diversity in areas containing fallen timber than in areas without, possibly because fallen wood offered more food, more foraging opportunities and/or more shelter from predators.

Fallen wood is also an important part of aquatic environments on the floodplain. Because red gum logs don't rot under water, they can last there for thousands of years (NRE no date c). Red gum snags in waterways have been compared to ocean reefs because they are relatively permanent habitats (NRE no date c), providing a substrate for fish eggs and shelter for fish (Wharton 1970; Cadwaller 1978). The removal of snags for flood mitigation since the early 20th century (Wharton 1970; Hibbins 1991) has been disastrous for native fish populations (McKinnon 1997), and authorities have started returning snags to waterways (NRE no date c). But coarse woody debris on the floodplain itself (ie, not just in permanent waterways) is also important habitat, for example for aquatic invertebrates (Walker 1985). It enhances the detention and concentration of organic matter on the floodplain, facilitating its use locally (Kauffman & Krueger 1984), and it reduces flow rates, causing longer flood durations and more widespread flooding and natural ponding of floodwaters (Ward 1991). It also assists in the formation of "pools, scour holes, gutters and general undulations in the substrate", which is the key to fish diversity: streams with simplified habitat are often dominated by generalised exotic fish, whereas high quality, complex habitat waterways are more likely to harbour native species (Koehn & O'Connor 1990). General debris on the substrate increases the number of potential nesting sites for freshwater blackfish (Cadwaller 1978). Floodplain debris also washes into rivers under natural flooding regimes (Mac Nally & Parkinson 1999), diversifying instream habitat.

The Yorta Yorta are well justified by the scientific literature in advocating the cessation of timber harvesting in Barmah-Millewa for the sake of promoting biodiversity, particularly of native fauna.

Recreation, Tourism and Feral Species

Proposed actions (summarised from Yorta Yorta Clans Group 2001):

- Prohibit power-boating, trail bikes, bardi grubbing, off-road horse riding and off-road four wheel drive vehicles because of their impacts on heritage areas.
- Control apiculture to minimise the effects of bees on native flora and fauna.
- Eradicate all feral animals within the claimed lands.

Power-boating

Power-boats, including jet skis, speed boats and houseboats, leave a wake that often has substantial erosive potential (LCC 1991). Their wash increases with their speed and power (Liddle 1997), and it may erode plant roots, reduce foliage (Liddle 1997) and increase turbidity (LCC 1991; Liddle 1997). Propellers can kill, injure or damage macrophytes or other organisms they encounter and are far more damaging than oar propulsion (Liddle 1997). Anchored boats that rock to and fro in the wake of other boats can destroy submerged vegetation (Liddle 1997). Boats can impact on wetlands by indiscriminate landing at sensitive sites (Robertson 1983; Moore 1986), and by releasing sewage pollution (Moore 1986) or chemical pollution (Robertson 1983; Liddle 1997), which is deleterious to the aquatic biota (Wharton 1970). Waterbirds can be disturbed by noise (Robertson 1983; Loyn 1989; LCC 1991). Developments undertaken to improve boating conditions can also damage wetlands, for example, shores are modified for landing and launching, reedbeds are dredged for boat channels, and regular passage of large boats may inhibit water weed growth (Robertson 1983). In her 1983 study of the lower Murray lakes, Robertson recommended that power-boating was incompatible with wetland conservation.

Trail bikes, off-road horse riding, off-road four-wheel driving

Trail bikes ridden off-road can tear up soil and destroy vegetation (DCE 1992; Dixon 2001). If tracks are wet, trail bikes can erode them (LCC 1991), making them difficult to drive on (Dixon 2001) and increasing turbidity in waterways (Wharton 1970; Koehn & O'Connor 1990). Horses hooves apply a pressure to the ground 27 times greater than that applied by a human foot, so they reduce ground vegetation faster than walkers (Liddle 1997). Such damage, when done to low productivity vegetation types such as eucalypt forests, can take hundreds of years to recover from (Liddle 1997). Horses do twice the amount of damage to vegetation as trail bikes (Liddle 1997), but both can promote track establishment if ridden off-road (DCE 1992). Horses can contribute to the spread of weeds (DCE 1992). Four-wheel drive vehicles also pose an erosion risk on unsealed tracks (LCC 1991). Where they ford streams they can significantly increase turbidity (Liddle 1997). Recreational vehicles have contributed to the deterioration of some sand dune systems (Robertson 1983). The construction and maintenance of roads more generally can increase turbidity (Wharton 1970), destroy habitat (McIlroy 1978), kill animals such as the tortoise *Chelodina longicollis*, which migrates to billabongs overland (Chessman 1988), and restrict the movement of smaller animals (McIlroy 1978).

Bardi Grubbing

Because bardi grubbing causes "considerable localised soil disturbance and removal of ground vegetation" (DCE 1992), the Yorta Yorta have proposed that it be prohibited because of potential damage it can do to heritage sites. But it can also be deleterious to living organisms. Bardi grubbing has been listed as a potential threat to the long-term viability of box woodlands, in the context of the superb parrot's reliance on box woodlands for forage (Webster & Ahern 1992). Aside from any physical damage to the environment, it is possible that the mere presence of bardi-grubbing humans would agitate the parrot, necessitating an increase in its foraging time (Webster & Ahern 1992).

Apiculture

The potential of honeybees (*Apis mellifera*) to detrimentally affect the native biota of the Barmah Forest was recognised by the Land Conservation Council when it recommended the exclusion of apiculture from reference areas (LCC 1985). Honeybees have a greater foraging efficiency and usually higher numbers than native nectar- or pollen-feeding insects, so can outcompete them when resources are scarce (Anderson *et al* 1989). An extensive overlap in resources accessed by honeybees and native bees has been observed by some authors, who contend that competition can exclude native bees from localised sites and may already have resulted in some extinctions of native species (Pyke & Balzer 1985). Honeybees begin foraging before native species, but authors are in disagreement about whether or not their early foraging eliminates nectar available to native bees (Douglas 1980; Paton 1999). One study examining the impact of honeybees on a South Australian mallee ecosystem found that there was no significant reduction in the abundance of native invertebrates with honeybee presence, but that study presented no data on the diversity of native species (Paton 1999).

Honeybees can adversely affect pollination and therefore recruitment of native plants by a number of means. They may rip flowers or buds to get to nectar (Douglas 1980; Pyke & Balzer 1985), they may collect nectar without touching stamens or effecting pollination (Douglas 1980; Pyke & Balzer 1985), they can cross-pollinate plant species (Douglas 1980), take pollen from wind-pollinated flowers (Pyke & Balzer 1985) or may disrupt pollination systems by visiting only the male flowers of dioecious plants (Pyke & Balzer 1985). In the South Australian mallee study, the only significant effect of honeybee presence observed was increased seedset by *Banksia ornata* plants, which may be good for the *Banksia*, but may have detrimental effects on other species in the community (Paton 1999). Honeybees can have additional impacts if they form feral hives, for example they can take over nest hollows previously inhabited by vertebrates (Webster & Ahern 1992; Paton 1999), but feral bees are generally considered to present weaker competition to native bees than honeybees do (Anderson *et al* 1989).

The question of whether or not to remove honeybees from a community where they have existed for some time remains open. One author suggests that their removal may cause a breakdown in plant pollination if honeybees have taken over the pollination role from native species (Douglas 1980). Other authors argue that if an area is free from feral bees, there are sound reasons for keeping it hive free too (Anderson *et al* 1989), and still others recommend the removal of honeybees as a precaution in the absence of data (Pyke & Balzer 1985). Honeybees can travel up to 11 kilometres from the hive to forage (Anderson *et al* 1989), so if bees were to truly be removed from Barmah-Millewa, there would need to be a substantial bee-free buffer zone placed around the forest. Anderson *et al* (1989) suggest that temporary hives are probably not as damaging as permanent ones, but that ultimately the solution is to plant more trees so apiarists are not so reliant on native vegetation to support their hives.

Eradication of feral animals

Exotic or feral animals have been implicated in the decline of native animals by competition (eg rabbits, carp) and predation (eg cats, trout) (Koehn & O'Connor 1990; Parson 1991). Several feral species are present in Barmah-Millewa, including pigs, foxes, cats, horses, rabbits, and at least eight species of exotic fish (McKinnon 1997), including carp, redfin, goldfish, mosquitofish, and possibly the occasional rainbow trout and brown trout.

Feral pigs have received some blame for the decline in cumbungi rushlands in Barmah-Millewa (Chesterfield 1986), indeed rhizomes of cumbungi, common reed and warrego-summer grass are prominent in their diets, as are frogs, yabbies, fish, freshwater mussels, small marsupials, reptiles and the eggs of groundnesting birds

(Townsend 1981; Tisdell 1982). They also commonly eat tangled lignum (Tisdell 1982), a shrub that was formerly common in parts of Barmah-Millewa (Johnson 1984), and which provides important habitat and sanctuary for waterbirds, fish and aquatic invertebrates during flooding (Craig *et al* 1991). Pigs have affected brolga (*Grus rubicunda*) populations by food competition, habitat destruction and predation of eggs and young (Tisdell 1982). Brolga bred in large numbers at Barmah-Millewa until the early 20th century (Leslie 2001). Pigs have been noted to destroy the habitat of eastern water rats (*Hydomus chrysogaster*) (Tisdell 1982). They destroy wetland habitats by wallowing (Townsend 1981; Tisdell 1982) and prevent understorey regeneration by 'rooting' (Townsend 1981).

Rabbits cause erosion by digging (Wharton 1970) and compete with mammals for food (Wilson 1990). They were partly responsible for the reduction in box ridge flora, especially pre-myxomatosis (Chesterfield 1989). Their prolific numbers assist in maintaining large populations of exotic predators, which has flow on effects for native vertebrates (Wilson 1990).

Cats and foxes have been implicated in the decline of woodland birds (Robinson & Traill 1996). Foxes have also been involved as a major cause in the decline of *Emydura* tortoises by egg predation (Thompson 1983).

Carp appear to have profound effects on aquatic environments in Australia. They can destroy aquatic weed bed habitats and increase turbidity, especially in shallow lakes (Cadwaller 1978). They degrade water quality and create conditions that may favour algal blooms (Recknagel *et al* 1998). Their presence can reduce the diversity of fish, invertebrates, aquatic vegetation and micro-organisms (Recknagel *et al* 1998). They compete with native fish such as silver perch and macquarie perch for food, and also compete for food with larger invertebrates (Cadwaller 1978). They predate frog eggs and larvae (Healey *et al* 1997). As has already been noted, carp are extremely abundant in the Barmah-Millewa waters. They are believed to have assisted in the destruction of cumbungi reedbeds (Chesterfield 1986) and may be one of the factors causing Barmah-Millewa wetlands to silt up (DCE 1992).

Mosquitofish eliminate most or all smaller native fish where they are present and take a dramatic toll on larger species too (Cadwaller 1978). They predate the eggs and juveniles of fish (Koehn & O'Connor 1990) and the eggs and larvae of frogs (Healey *et al* 1997). They greatly reduce numbers of rotifers, crustaceans and insects, causing an increase in phytoplankton (Cadwaller 1978).

Redfin are voracious predators of small fish and compete with murray cod, freshwater blackfish and golden perch for food (Cadwaller 1978; Koehn & O'Connor 1990).

Trout are also voracious predators, and were responsible for habitat fragmentation of mountain and climbing galaxias (Koehn & O'Connor 1990). They have similar diets to murray cod and golden perch so compete with them for food (Koehn & O'Connor 1990). They predate macquarie perch, trout cod and freshwater blackfish, compete with them for food and compete with macquarie perch and trout cod for space (Cadwaller 1978; Koehn & O'Connor 1990). Cadwaller (1978) has described the regular release of trout for recreation as the most prevalent form of species pollution in the Murray Darling river system.

Erosion Control

Proposed actions (summarised from Yorta Yorta Clans Group 2001):

- Require the preparation of erosion-control plans for all earth-moving operations. This plan should be prepared for any area exhibiting active surface erosion and slope down-cutting and for any area that has significant forest vegetation cover, whether eroding or not.

- Require all applications for permits to quarry sand to be approved by the Yorta Yorta.

Sand mining

This element of the Yorta Yorta *Plan* was included mainly because of the potential impacts of sand quarrying on archaeological and culturally significant sites (Yorta Yorta Clans Group 2001), but sand mining also has some environmental implications. It can destroy banks of waterways and vegetation (Parson 1991). It can increase turbidity and siltation (Parson 1991). It also creates noise, dust and unsightliness and and can contribute to erosion (LCC 1991). The Land Conservation Council (1985) recommended that to have the least environmental impact on the Barmah forest, sand mining operations should (1) concentrate on the least possible sites, (2) ensure reclamation of old sites before moving onto new ones and (3) be deep and limited in area rather than shallow and wide in area.

Conclusion

The environmental aspects of Yorta Yorta proposed management plan for Barmah-Millewa are in agreement with the scientific literature in most respects. It seems that conservation biologists have spent the last thirty years catching up in knowledge to what the Yorta Yorta already knew. That fact reflects one thing: the landscape was managed and shaped by the Yorta Yorta over thousands of years, so to maintain the landscape in the condition that Europeans found it in, the best possible strategy is to re-employ Yorta Yorta management methods. The Yorta Yorta have adapted their traditional management program to deal with threats to their land that non-indigenous people introduced. In doing so, they have clearly demonstrated that they have the skills to manage their land in a way that would meet their own criteria for good management (ie the conservation of all features of the forest for a sustainable future) and that would satisfy the concerns of conservation biologists (primarily biodiversity conservation).

In the words of Robertson (1998): “The restoration of wetlands ... requires a focus on multiple ecological factors and their interactive effects on the environment.” The Yorta Yorta’s plan has presented such a focus, reflecting their track record as custodians of Yorta Yorta country and their future as joint managers of Barmah-Millewa National Park.

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