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Indigenous Wetland Burning: Conserving Natural and Cultural Resources in Australia's World Heritage-listed Kakadu National Park

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My mother and my father taught me a lot, how to look after this land. Riding around this country on horseback we used to go to many places, burning along the way looking after the land. Times have changed, our country has changed a bit, but I still have good knowledge and it is my time to pass on what I have to my children and grandchildren. My mother and father would say if you look after this country, this country will look after you. Violet Lawson

Introduction

Growing worldwide interest in, and appreciation of, traditional ecological knowledge (TEK) is creating a new approach to contemporary land and sea management (Redford and Mansour 1996; Berkes *et al*. 2000; Huntington 2000; Schmidt and Peterson 2009). Driven by concerns about the failure of western science and management to address ecosystem degradation and species loss, people are looking to the deep ecological understandings and management practices that have guided indigenous use of natural resources for millennia for alternative ways of sustainably managing the earth's natural resources (De Walt 1993; Bart 2006; Berkes and Davidson-Hunt 2006). Equitable partnerships between indigenous and non-indigenous researchers and managers are revealing a way of looking after the world that emphasizes human obligations to natural resource management and promotes holistic thinking about the role and impact of humans in the environment (Ross *et al*. 2009). This new recognition of traditional knowledge, coupled with greater control by indigenous peoples over their land and sea estates, holds great promise for better management of the world's natural resources.

Aboriginal people have occupied northern Australia for at least 40,000 years, and over this period have developed a rich culture of law, ceremony, oral history and detailed ecological knowledge. Despite nearly two centuries of European colonization, large areas of northern Australia remain in Aboriginal ownership or have recently been returned to indigenous management and control (Ross *et al*. 2009). A high priority for Aboriginal people is to record and revitalize their indigenous knowledge and practices to meet stewardship obligations and to ensure they are available for younger generations of Aboriginal land and sea managers. In recent years there has also been increasing recognition by non-indigenous peoples of the value of applying such traditional ecological knowledge and practice to contemporary land management (Burbidge *et al.* 1988; Horstman and Wightman 2001; Walsh and Mitchell 2002).

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This is particularly the case for fire management in the savanna landscapes of northern Australia, where in many areas fire management remains an integral part of Aboriginal life and traditional fire knowledge is still strong (Haynes 1985; Whitehead *et al.* 2003; Hill *et al.* 2004; Fig. 1).

The general principles behind Aboriginal burning in Australia have been well documented (Jones 1969; Nicholson 1981; Bowman 1998), and there are emerging examples in northern Australia where Aboriginal burning practices are being adopted on non-Aboriginal lands to improve environmental management (Russell-Smith *et al.* 2009). However there are few case studies written and informed from an Aboriginal perspective that describe in detail the specific aims and practices of Aboriginal fire management. Effective documentation is important for validating traditional ecological knowledge (Davis and Ruddle 2010), and for enabling Western land managers to appreciate both the depth of ecological understanding held by indigenous people and the complexity and effectiveness of traditional land management practices.

In this paper we provide such a case study, describing Aboriginal fire management of wetlands in the World Heritage-listed Kakadu National Park. In Kakadu, traditional ecological knowledge is being used in powerful combination with Western science to manage and monitor vital cultural and natural resources, leading to a dramatic enhancement of biodiversity and cultural values, and to a deeply enriched tourist experience. We hope this paper will contribute to a greater appreciation of the importance of fire management to Aboriginal people, and a greater understanding of the complexities of managing land with fire.

Aboriginal society is made up of individuals with differing needs, skills, aspirations, lifestyles, and environmental and political influences, so it is wrong to assume that all Aboriginal people manage their lands in the same way. This applies within Kakadu, where fire management is a contentious issue as it is throughout northern Australia. Aboriginal use of fire in Kakadu's wetlands prior to European settlement has been poorly documented, and, like elsewhere across northern Australia, Aboriginal people remain gravely concerned as elders die before their knowledge can be properly recorded. However, it is clear that freshwater wetlands were historically keystone habitats for food and other resources for Aboriginal people in the Kakadu region (Russell-Smith *et al.* 1997), and they continue to be critically important today. There was widespread use of fire to manage these wetlands, including the thinning of dense stands of the native grass *Hymenachne acutigluma* in order to promote a variety of other food resources (Russell-Smith *et al.* 1997).

Fig. 1 Kakadu Traditional Owner Violet Lawson with a fire stick. (Photo: Randy Larcombe)

The burning of wetlands, with the seasonally shifting land and water interfaces, is a more complex procedure than burning the surrounding savanna woodlands, and the timing and extent of traditional wetland burning continue to be the focus of scientific and community debate. This scientific debate can constrain contemporary Aboriginal burning by raising doubts in the minds of Aboriginal people over whether or not they are doing the 'right thing.'

The knowledge we draw on and present here has been passed down from Minnie and Yorky Billy Alderson, parents to Violet Lawson, and grandparents to Sandra McGregor. Like their ancestors before them, Minnie and Yorky lived all their lives on the country, and had traditional obligations to manage it and to pass on their knowledge to the next generations.

Kakadu Wetlands: Changing Natural and Cultural Landscapes

The extensive Ramsar-listed wetlands associated with the floodplains of Kakadu's major river systems make a leading contribution to the Park's World Heritage biodiversity values (Fig. 2). They also support extremely important economic and cultural resources for Aboriginal people (Fig. 3). The nutrient-rich soils combine with an abundance of water and sunlight to produce an extraordinary proliferation of plant and animal life. This has sustained traditional Aboriginal economies for thousands of years, and Aboriginal people in Kakadu continue to use and manage these resources. The wetlands are also a major focus of Kakadu's tourism industry.

The floodplains comprise a complex mixture of freshwater grasslands, sedgelands and paperbark swamps that are highly dynamic over multiple time scales (Finlayson and Woodroffe 1996). These freshwater habitats have developed from mangrove systems over the past 10,000 years with falling sea levels following the last glaciation, and some are only about 1,500 years old (Clark

Fig. 2 The Magpie goose (*Anseranas semipalmata*) is one of Kakadu's iconic species. A large proportion of Australia's remaining population of this species breeds in Kakadu's wetlands. (Photo: Greg Miles)

and Guppy 1988). The entire history of these ecosystems has therefore been in association with people. They undergo an annual hydrological cycle, with the grass- and sedge-dominated plains covered in floodwaters and connecting the permanent billabongs and swamps during the wet season, and progressively drying out during the dry season to form extensive areas of bare cracking clays (Finlayson and Woodroffe 1996). There is very marked year-to-year variation in herbaceous composition on the floodplains, driven by variation in the timing and duration of wet season rains (Taylor and Dunlop 1985; Finlayson and Woodroffe 1996).

The wetland vegetation, and its fire ecology and management, have undergone significant changes due to European settlement over the past 200 years. For example, the exotic Para grass *Urochloa mutica* was introduced as a wetland pasture grass in the old pastoral properties of Mudginberri and Munmarlary in the north of the Park,

Fig. 3 Kakadu's wetlands provide key resources for Aboriginal people. (Photo: Randy Larcombe)

where it now forms an impenetrable monoculture over extensive areas. Para grass has not only changed fire intensity and behavior within the wetlands, but has broadened the boundaries of wetland fires. This species can survive in areas of lower soil moisture compared with native grasses, thereby creating wicks into adjacent fire-sensitive vegetation types such as monsoon vine thickets and riparian forests. The mining and tourism industries have also had important effects on wetland burning by displacing Aboriginal people from their traditional lands, and by reducing Aboriginal burning because of perceived risk to infrastructure.

However, the most significant recent changes to Kakadu's wetlands have been due to grazing, trampling and wallowing by the introduced Asian water buffalo *Bubalus bubalis*, especially during their population peak from the 1950s to 1980s (Skeat *et al*. 1996; Petty *et al*. 2007). Buffalo greatly reduced grass biomass and therefore fuel for fires during this period. They also caused extensive salt water intrusion into fresh water swamps by damaging micro-levies separating fresh and salt water. Salt water plays a vital role in maintaining biodiversity in Kakadu wetlands, particularly at the saltwater/freshwater interface, where the sedge *Eleocharis dulcis* and surrounding wild rice *Oryza* spp form preferred nesting and feeding grounds for Kakadu's million or so magpie geese *Anseranus semipalmata*. However, excessive saltwater intrusion through buffalo activity has severely degraded this interface (Skeat *et al*. 1996). Today, rotting stumps surrounding wetlands that border the South Alligator River are reminders of the devastating effects that saltwater has had on *Melaleuca*, *Eucalyptus* and other trees that have been unable to cope with increased salinity. Saltwater intrusion remains a serious conservation threat with the imminent prospect of sea-level rise due to global warming (Bayliss *et al.* 1997).

Buffalo were virtually eliminated from Kakadu during the late 1980s during an intensive effort to eradicate bovine tuberculosis (Skeat *et al.* 1996). This has seen a dramatic recovery in herbaceous biomass on the floodplains (Petty *et al*. 2007), especially of the dominant grass *Hymenachne acutigluma*, which now forms extensive monocultures in the absence of buffalo disturbance. It is now clear that disturbance by buffalo promoted floodplain biodiversity through enhanced habitat heterogeneity, much in the same way as feral livestock promote desert spring diversity in Australia and the USA (Kodric-Brown and Brown 2007; Kodric-Brown *et al*. 2007).

Why Burn Wetlands?

Fire management is a fundamental expression of Aboriginal knowledge of their local ecology and their connection to

their environment. The primary motivation behind Aboriginal wetland burning is to improve availability and access to food resources. The wetlands are important hunting grounds for water fowl, goannas, turtles, and file snakes, and provide a variety of edible water plants. Fire management is integral to the hunting and gathering of these resources. Much like buffalo disturbance, frequent fire prevents the development of a hymenachne monoculture, thereby promoting habitat diversity and providing the full range of food resources for Aboriginal people (Fig. 4). In addition, fire clears the grass to improve access and mobility, and to reduce the risk of snakes and other dangers. Fire also plays particular roles in maintaining populations of favoured prey items, such as almangyi (the long-necked turtle, *Chelodina rugosa*). These turtles hibernate under the mud throughout the dry season, and come out of hiding once the floodplain is inundated following wet season rains. However, if the floodplain remains unburned for several years the turtles will aestivate within the accumulated dead grass, and therefore be susceptible to burning when fire does occur. The turtles also need mud to lay their eggs in.

Fig. 4 Ecological impacts of burning at Yellow Water in Kakadu National Park. **a** A fire line showing how burning (right hand side) has broken the dominance of the grass *Hymenachne acutigluma*, which forms a dense monoculture in the absence of disturbance. **b** Following burning this area supports a great diversity of wildlife; it was previously a monoculture of hymenachne, a patch of which still occurs at the base of the tree at top left. (Photos: Alan Andersen)

Sandra McGregor has a particular memory from her teenage years of the importance of wetland fire management. The Yellow Water area of the South Alligator River has traditionally been a favourite family hunting ground for magpie geese, ducks and almangyi. However, large amounts of grass began accumulating soon after the removal of water buffalo in the 1980s, reducing waterfowl populations and making it difficult to hunt for turtles. In 1988, a high intensity fire was put through the floodplains to 'clean' the country. Sandra remembers the high flames, huge amounts of smoke in the sky, and the creation of a mini tornado in the heart of the fire. She saw for the first time large paperbark (*Melaleuca* spp.) trees burning down on the floodplain. The following year saw carpets of paperbark seedlings sprouting in the burned area, with native rice and a range of water lilies and sedges emerging during the following wet season. Hunting for geese and ducks returned to the area, and to this day it is very productive for magpie geese, water lilies, lotus seeds and turtles.

Preparing the Floodplain Margins

Floodplain burning occurs at the end of the dry season, starting in September or October. Fire conditions are at their most extreme at this time of the year, so it is important that the floodplain margins have already been burnt earlier in the year, to prevent fires from escaping into the surrounding savanna woodlands. Such protective burning begins early in the dry season, when the grassy fuels are still moist and fire intensities therefore low (Fig. 5). Burning continues from the edges of the surrounding woodland down to the floodplain as the water dries up over the ensuing months. Such continuous burning creates a mosaic of burned and unburned patches. Often follow-up burns will be conducted coinciding with the different curing times of grasses and herbs or when animals have young to nurse. This creates another fire mosaic of patches burned at different times of the year.

The Aboriginal calendar in the Kakadu region has six seasons, each with its own biological (e.g., flowers, fruits, insect calls) as well as climatic indicators such as temperature and wind direction (Braithwaite and Estbergs 1988). Burning of the woodlands surrounding the floodplains starts in *Bangerreng*,[1] the time of the 'knock'em

[1] This and the following italicized words describing seasons are Gundjeihmi, the most commonly used Aboriginal language in the region.

Fig. 5 Woodlands surrounding the wetlands are burnt by low intensity fire early in the dry season, to prevent fire escaping when the wetlands are burnt under more extreme fire conditions late in the dry season. (Photo: Peter Christophersen)

down winds' from mid-March to early April. *Bangerreng* fires are very patchy and move very slowly, allowing insects and other slow moving creatures to get out of harm's way. Grasses and herbs quickly re-sprout following these fires, as the soil is still moist. Along with the unburned patches, this regrowth provides food and shelter for insects, lizards, nesting birds and small mammals when follow-up fires occur later on.

Yegge (April–June) fires are still relatively slow burning and of low intensity, with the weather becoming cooler and less humid. In this season the water levels begin to drop, and burning continues in the woodland down to the moist boundaries of the creeks, as Aboriginal people start to fish along the freshwater creek systems. Such fires go out early in the afternoon. During this period, water lilies (*Nelumbo nucifera* and *Nymphaea* spp.) and aquatic yams are also collected, as are yams in adjacent vine thickets. Such 'yam jungles' are sometimes burned to 'clean up' the ground, but not severely or frequently enough to kill trees.

Wurrgeng (June–August) is an important time to burn to protect fringes of pandanus (*Pandanus spiralis*) and paperbark woodlands, yam jungles, and also creeks and springs that flow into the floodplains. These are critical habitats for animals to shelter from predators and the heat later in the dry season (*gunumeleng*); by this time the grasses have regrown because of persistent soil moisture. This is why it is important to conduct *wurrgeng* burning, to protect these special areas from high intensity *gunumeleng* fires. It is also important to prevent the creek lines from becoming conduits for *gunumeleng* floodplain fires entering the woodlands.

Wurrgeng fires also remove the very flammable bark from the trunks of paperbark trees that grow along the floodplain, making them more resilient to higher intensity fire. Burning early on floodplain edges also benefits other plants such as palms, herbs and fruit-bearing species that insects and birds rely on in the later seasons. This is especially important for the flowering species that sustain native bees (*Trigona* sp.), which produce the popular 'sugar bag' (wild honey).

Most woodland grasses and herbs have been cured by *wurrgeng*, so fires burn longer and travel further. The hunting of magpie geese, whistle duck and black duck begins during this period.

Fire on Water: Burning the Floodplains

Gurrung (August–October) is the time when burning of the floodplains themselves begins, and floodplain hunting intensifies, particularly for long-necked turtles, magpie geese, ducks, goannas and pigs. Native honey is also collected as burning continues through the paperbark stands bordering the wetlands.

Dense stands of hymenachne form three distinct layers that are differentially flammable, so that multiple fires are required to burn them (Fig. 6). First, there is a basal mat of accumulated mulch that varies in thickness with time since the last burn. This mulch layer is the last to burn, and tends to smoulder. The second layer consists of the relatively dry bases of the living grass, and is highly flammable; it is the first layer to be burned. The third layer consists of the upper, green leaves which fall to the ground when their bases are burned and, after two or three days of curing, are ready for follow-up burning. By September/October,

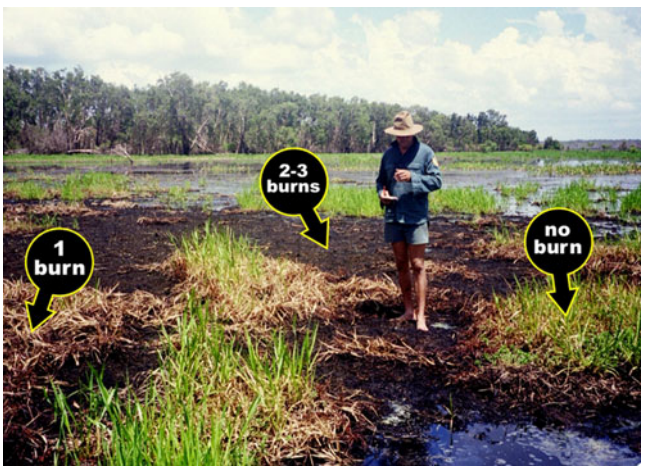

Fig. 6 Wetlands are burnt multiple times over several weeks to thin out dense stands of hymenachne. The first fire just burns the dry bases of the grass, causing the green leaves to fall over and die. Subsequent fires burn this and the root bases, preventing it from regenerating. (Photo: Peter Christophersen)

mapilil winds coming in from the north help fuel floodplain fires as they are started in the late afternoons and keep them burning into the night and sometimes all through the next day. The fires spread back and forth across the floodplains, burning up to four or five times over the same area depending on the thickness of the basal mat.

Floodplain burning finishes in the hotter months of *Gunumeleng* (October/December). During this time, there are often short bursts of strong winds late in the morning or early in the afternoon, which help carry fires through light fuel loads and across moist land. These fires can travel across water, burning the emergent grasses, and may continue for days, before becoming extinguished by pre-monsoon storms. If left unburnt for several years, large mats of hymenachne can form floating islands, which nevertheless can be burned under suitable conditions. *Gunumeleng* is still a good time to find long-necked turtles that are aestivating in the dry mud, and most of the last floodplain fires are lit when people are hunting for them.

Documenting Burning Impacts

Changes in the landscape pattern and composition of vegetation resulting from fire have been measured at Boggy Plain on the South Alligator River. This was done using high-resolution, satellite remote sensing, in conjunction with ground-truthing of vegetation cover using airboat surveys, as well as helicopter surveys for mapping fire-scar boundaries. Survey data were spatially referenced to enable their location to be identified on geo-registered satellite imagery. These analyses have documented dramatic change in vegetation composition and structure following burning, with a large reduction in cover of previously dominant hymenachne, and increases in cover of other wetland vegetation types (Fig. 7).

Water birds have been identified as key indicators of the benefits of wetland burning because of their high values for biodiversity conservation, traditional resource use, and tourism. Water bird monitoring at Yellow Water demonstrates the dramatic impact of burning, with abundance and richness many times higher at recently burned compared with long-unburned sites (Fig. 8). Bird populations decline over subsequent years as hymenachne expands, indicating the need for ongoing fire management.

Representing Traditional Ecological Knowledge Through Bayesian Belief Networks

The spoken understanding of wetland health passed down through generations of traditional owners is detailed and complex, and is difficult to communicate to people who do not have this oral and experiential tradition. We have used Bayesian Belief Network (BBN) modeling for representing traditional ecological knowledge and conveying it to a general audience through a

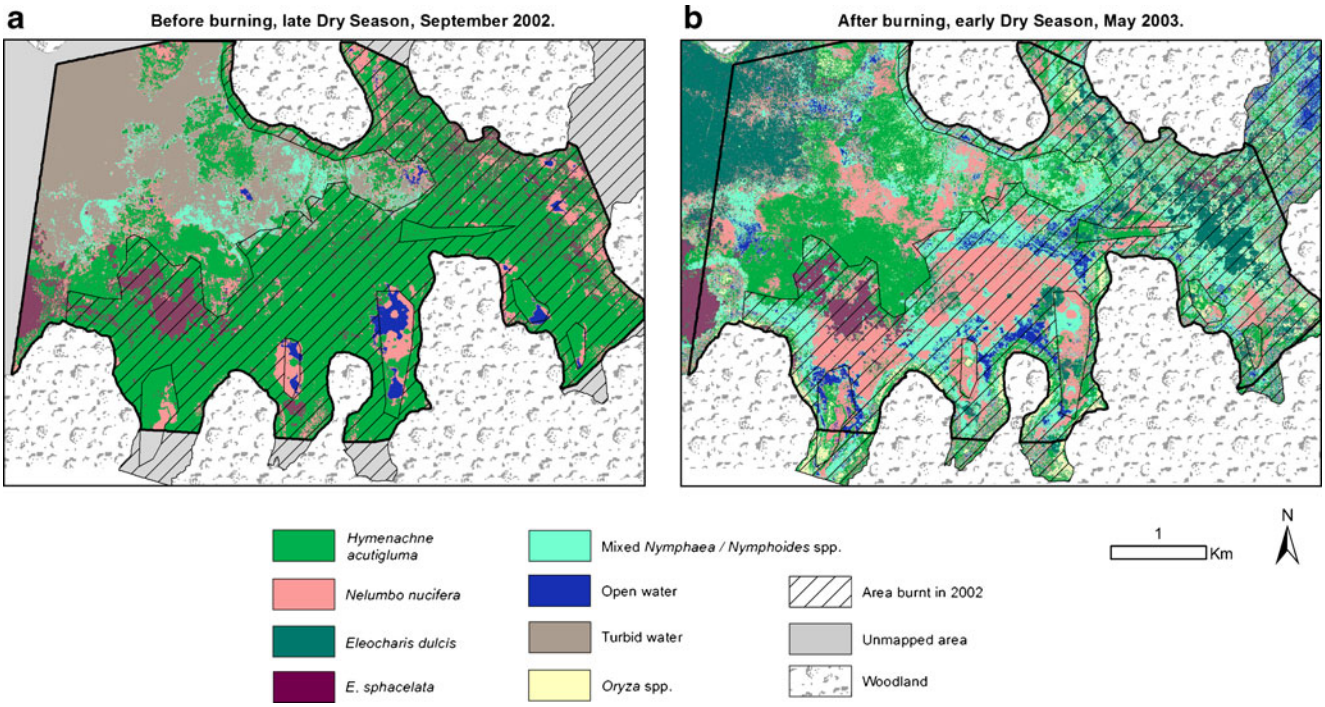

Fig. 7 Remotely-sensed vegetation maps of Boggy Plain immediately before and six months after the first fires (hatched area)

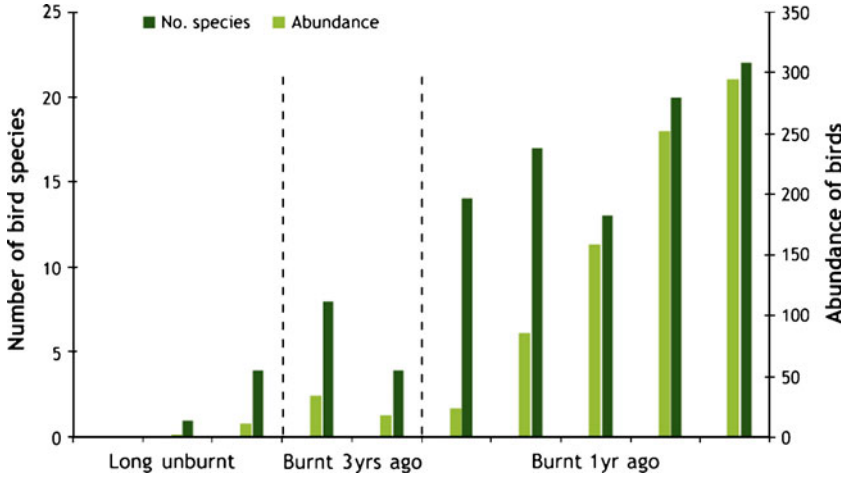

Fig. 8 Abundance and richness of water birds at floodplain sites representing different burning treatments at Yellow Water. Data are visual counts within 1 ha. plots

computer-based expert system. A BBN approach is ideally suited to this task because it allows the input of traditional understanding as informed opinion (in contrast to the quantitative data required to develop conventional process-based ecological models), and provides an intuitive means of exploring system dynamics. Non-quantifiable concepts of wetland health relating to sound and smell can also be incorporated, and terminology familiar to indigenous people used (e.g., 'big mobs' as a measure of magpie goose abundance).

The first step in our BBN modeling was to familiarize the indigenous experts with the general concept of computer modeling and expert systems. Expert knowledge was then used to build and propagate the model, which involved identifying the key ecosystem components and drivers, and assigning probabilities linking drivers to particular ecological states. In contrast to conventional ecosystem models, people were considered central to the maintenance of ecosystem health. The BBN was tested to assess its robustness, and its outcomes were then validated by other traditional owners and elders. Finally, the BBN was used to develop a highly visual and interactive, web-based expert system as an educational tool (Fig. 9).

Discussion

From an Aboriginal perspective, effective burning for cultural and natural resource management requires a finely tuned, expert use of fire that is based on deep experiential knowledge, honed over generations of intimate living with the landscape. This knowledge and practical experience is increasingly difficult to maintain as Aboriginal people experience severe social dislocation as a result of engagement with the mainstream economy. However, although Aboriginal culture (like any other culture) will continue to adapt and change, the underpinning Aboriginal law that provides inherent obligations to care for the land remains unaltered. Violet's family does not want to return to a wholly traditional lifestyle, but they still retain strong aspirations for maintaining traditional land management practices. The traditional knowledge required to do this is still strong, passed on to Violet's children and on again to their children.

The re-application of traditional fire management to Kakadu wetlands dramatically enhances biodiversity as well as the importance of these wetlands in the cultural values of the local Aboriginal people. The enhanced biodiversity values are being documented through science-based monitoring that involves both ground-based surveys and remote sensing. The particular burning practices we have described are highly context-specific, and we do not suggest that they can be widely generalised to other environments (see Agrawal 2002 for a critique of generalizing traditional ecological knowledge). However, we suggest that by integrating indigenous and Western knowledge systems to achieve positive outcomes for both traditional resource use and the conservation of biodiversity (Moller *et al*. 2004), this specific burning program serves as an internationally significant model for the use of fire in the joint management of indigenous lands elsewhere.

A critical ingredient for success has been that Aboriginal people continue to exercise considerable control over burning, and have not had their knowledge and practices subverted by Park management. Aboriginal people want to have control of their knowledge, to have the opportunity to put it into practice, and to be able to pass it on to their next generation. Many Aboriginal people throughout northern Australia have the skill and knowledge to carry out landscape burning, but often lack the guidance, encouragement and resources to put this knowledge into practice. The challenge is to empower such skill and knowledge for the benefit of all.

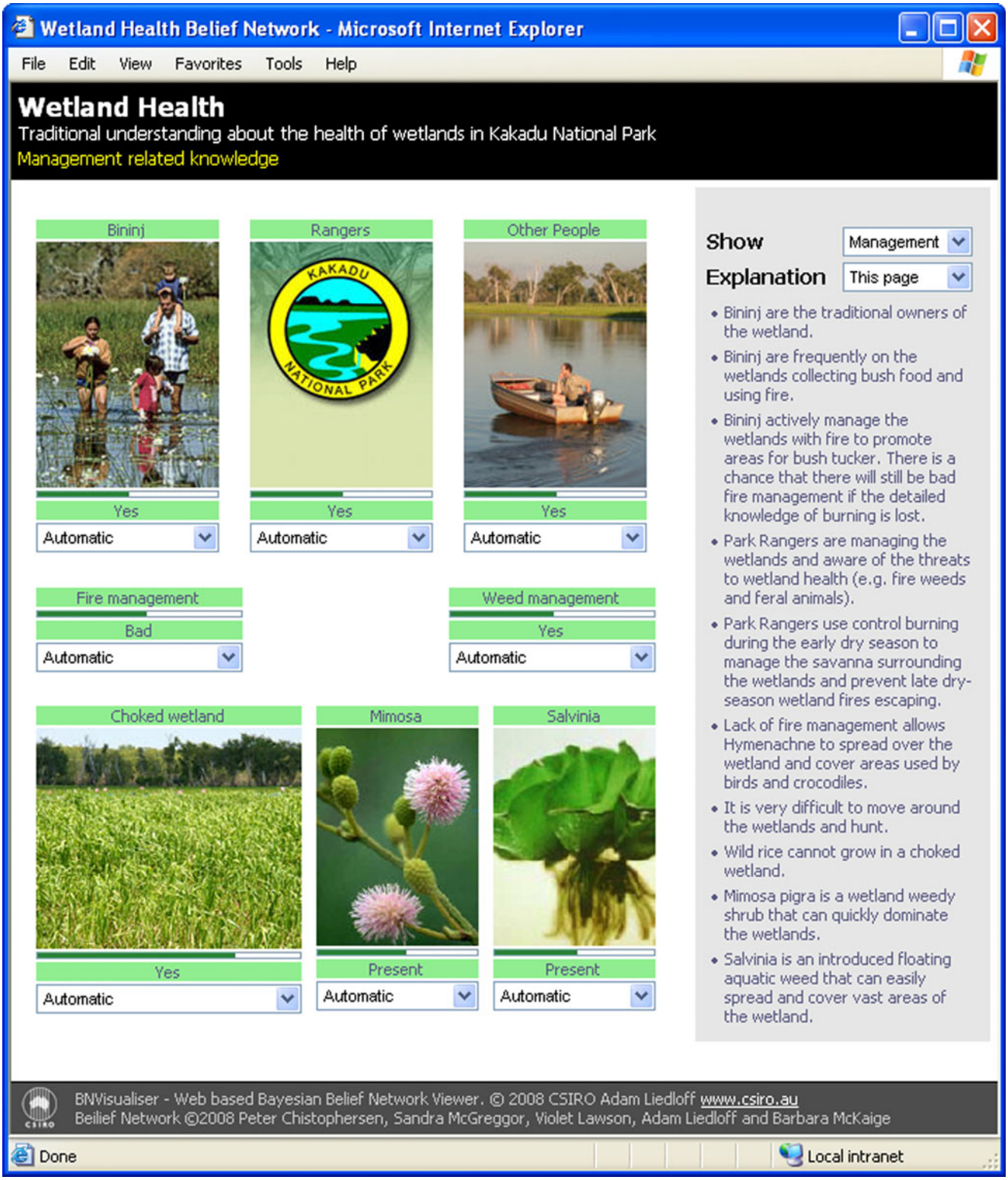

Fig. 9 Visual representation of the traditional ecological knowledge captured by a Bayesian Belief Network, where management results in controlled numbers of weeds and an open wetland suitable for water birds and the collection of bush foods

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