Integrating Indigenous Knowledge of Wildland Fire and Western Technology to Conserve Biodiversity in an Australian Desert

N.D. Burrows[1], A.A. Burbidge[2] and P.J. Fuller[2]

[1]*Department of Conservation and Land Management, Locked Bag 104, Bentley Delivery Centre, Bentley, Western Australia, 6983*
[2]*Department of Conservation and Land Management, Western Australian Wildlife Research Centre, P.O. Box 51, Wanneroo, Western Australia, 6946.*

Abstract

The relatively recent exodus of Aboriginal people from parts of the Western Desert region of Australia has coincided with an alarming decline in native mammals and a contraction of some fire sensitive plant communities. Proposed causes of these changes, in what is an otherwise pristine environment, include an altered fire regime resulting from the departure of traditional Aboriginal burning, predation by introduced carnivores and competition with feral herbivores.

Under traditional law and custom, Aboriginal people inherit, exercise and bequeath customary responsibilities to manage their traditional country. Knowledge of the fire regime during an estimated 40 000 years of Aboriginal occupation of these lands and the involvement of Aboriginal communities in contemporary land management are important issues to be addressed if conservation lands are to be managed appropriately. As part of this process, Pintupi Aboriginal people were interviewed to obtain information about their traditional use of fire and to obtain their views on how country could be managed with fire. Of particular interest were the reasons for burning country and the temporal and spatial variation in the size and distribution of burnt patches. This valuable but largely qualitative oral information was supplemented with a quantitative study of fire footprints in a chronological sequence of early black and white aerial photographs and more recent satellite imagery. The study focussed on a remote region of the Western Desert, an area from which Aboriginal people living a traditional lifestyle had most recently departed. The earliest aerial photographs (1953) were taken as part of a military rocket development project over an area that was occupied by Aboriginal people living in a traditional manner at the time of the photography. The photography revealed a landscape mosaic of small burnt patches of vegetation at different stages of post-fire succession. This pattern was consistent with information provided by Pintupi people; that fire was used purposefully, frequently and regularly across the landscape for many reasons but mainly to acquire food. Analysis of satellite imagery since the 1970s, and since the cessation of traditional burning practices, revealed that the fine-grained multi-phased mosaic has been obliterated in recent times and replaced by a simpler mosaic consisting of either vast tracts of long unburnt and senescing vegetation or vast tracts of vegetation burnt by lightning-caused wildfires.

Introduction

The Great Victoria, Gibson, Great Sandy and Little Sandy Deserts (the Western Desert) occupy some 1.6 million km^2 of Western Australia, of which more than 100 000 km^2 is managed for nature conservation. The conservation reserves in the Western Desert are large, remote and relatively undisturbed. A management option for such reserves, therefore, is to do nothing and allow natural processes to continue to shape the biota (benign neglect). However, in spite of the apparent pristine nature of these reserves and the lack of direct European impact, a sudden and alarming decline in native mammals has been reported (Bolton and Latz 1978, Burbidge 1985, Burbidge *et al*. 1988, and Burbidge and McKenzie 1989). Burbidge and Jenkins (1984) reported that about 33 percent of Western Australian desert mammals are extinct or endangered. They noted that this decline had occurred over the last 30 to 50 years. Burbidge and McKenzie (1989) have shown that all declines and extinctions have been restricted to native mammals with a mean adult body weight in the range from 35 grams to 5 500 grams (the critical weight range). Three main hypotheses have been proposed to explain the decline and in some cases, extinction of desert mammals; change in fire regime, predation by feral animals and competition from feral herbivores (Burbidge and Johnson 1983). The notion of a changed fire regime contributing to mammal decline has some support among Western Desert Aborigines. For example, Ngaanyatjarra Aborigines from the Warburton area of Western Australia believe that the *mitika*, or burrowing bettong (*Bettongia lesueur*), had "gone to the sky because the country had not been cleaned up" (de Graaff 1976). "Clean up" is a term often used by Aborigines for burning the vegetation (Jones 1980). Kimber (1983) reported that Pintupi people believed that perhaps a "big bushfire" caused the disappearance of the golden bandicoot (*Isoodon auratus*).

Aborigines first arrived on the Australian continent at least 50 000 - 60 000 years ago and occupied the deserts of the interior by at least 20 000 years ago (Mulvaney 1975, Flood 1983 and Gould 1971). They showed remarkable resilience and resourcefulness to survive in a vast expanse of scattered food and water resources (Tonkinson 1978). They were highly mobile, were able to exploit a variety of resources in different areas at different times and developed a detailed knowledge of the environment.

Recent changes in the fire regime are believed to be a direct consequence of the exodus of Aboriginal people from the desert to European settlements, missions, outstations and other communities (Gould 1971, de Graaf 1976, Latz and Griffin 1978, Kimber 1983, Saxon 1984 and Burbidge 1985). Latz and Griffin (1978) postulated that Aborigines created a stable ecosystem by "burning the country in a mosaic pattern". They believed that mosaic burning reduced the extent and continuity of heavy fuels, and therefore reduced the occurrence of intense wildfires. They also stated that a second effect of mosaic burning was to create a range of 'states' in the vegetation, from early post-fire plant communities to old mature patches and that such diversity of states would host a greater variety of plants and animals. Latz (1995) observed that many of the most important food plants are only abundant in the first few years after fire. He reported that of the twelve plants that are most important to desert Aborigines, five are 'fire weeds'.

The extensive use of fire by desert Aborigines was recorded by early explorers (e.g., Warburton 1875, Giles 1889 and Carnegie 1898) and more recently by anthropologists and ecologists (e.g., Finlayson 1943, Jones 1969, Calaby 1971, Gould 1971, de Graaf 1976, Tonkinson 1978, Kimber 1983, Latz 1995 and Bowman 1998). Kimber (1983) observed that Pintupi used fire in a skilful and controlled manner for many reasons, such as hunting, signalling, to "clean up" the country, for ceremonies, and for fun. He provided a general description of when fires were lit and the range in fire sizes and also made some crude calculations of the proportion of country burnt and the approximate age since the last fire, based on information in the diaries of Davidson, who explored parts of the Tanami Desert in 1900. Latz (1995) noted that, "*the judicious use of fire* (by Aborigines) *was, in the past, the single most important aspect of the desert economy*". Recently Bird *et al*. (in press), working with Martu Aboriginal people of the Great Sandy Desert, have described and quantified the efficiency of burning as a hunting strategy and conclude that mosaic burning increases the efficiency of women hunting for burrowing game but not of men hunting larger, more mobile prey.

There is limited reliable quantitative information about the nature of the past fire regimes. Burrows and Christensen (1990) studied early aerial photographs and recent satellite imagery of a 54 000 ha area west of Lake Mackay (Western Australia) and reported a massive increase in the size of burnt patches in the 1970s and 1980s following the cessation of traditional Aboriginal burning in the area.

Quantitative data on past and present fire regimes are of considerable interest to managers of arid zone nature conservation reserves who aim to maintain and improve the biotic diversity of these rich desert ecosystems. If the decline of native fauna is to be halted and faunal diversity restored, then active management is necessary to control introduced predators such as the fox (*Vulpes vulpes*) and the feral cat (*Felis catus*), to ensure a fire regime similar to that which persisted during traditional Aboriginal usage of the land and, where possible, to re-introduce locally extinct and endangered fauna.

This study aims to document some the ways in which Western Desert Aborigines used fire and to compare their oral evidence with remote sensing data. It also aims to quantify the scale of the fire mosaic created by traditional Aboriginal burning and to provide quantifiable evidence of a changed fire regime since a departure from traditional burning practices. As well as bringing together oral evidence and photographic evidence, we build on the earlier work of Burrows and Christensen (1990). Knowledge of past fire regimes and of traditional burning practices would greatly assist with the formulation of appropriate fire management strategies for desert conservation reserves. We comment on the benefits of not only incorporating Aboriginal knowledge into land management decisions, but of meaningfully involving Aboriginal communities in decision making and on-ground management activities.

Methods

The departure of Aborigines from their desert homelands started with first European contact at the end of the nineteenth century. Amadio and Kimber (1988) present a summary of European exploration and contact with Aborigines of the northern portion of the Western Desert and also describe the movements of Aboriginal people away from their homelands and into European settlements.

To gather information about the traditional use of fire, we decided to focus the study on a region of the Western Desert from which Aborigines had most recently departed from a more-or-less traditional lifestyle. We learnt that a very remote tract of land in Western Australia north of the community of Kiwirrkurra and west of Lake Mackay in Western Australia was the last homeland utilized in a traditional manner by Pintupi people (Richard Kimber, Billy Nolan Tjapinati and Warlimpirringa Tjapaltjarri, pers. comm.). The area lies on the eastern edge of the Great Sandy and Gibson Deserts between longitudes 127º 30' E and 128º 50'E and latitudes 22º 8'S and 22º 50' S (Figure 1). As a result of the arid climate and sandy soils, the vegetation consists mainly of hummock grasses, or spinifex (*Triodia spp*.) and associated small shrubs, herbaceous plants and scattered low trees. The sand plains that cover most of the region are crossed by longitudinal, stable dunes, which trend east-west. Playas are scattered throughout the area, the largest playa being Lake Mackay, which has a total area of about 3 500 square kilometres (Blake 1977).

To the best of our knowledge, the main exodus of Pintupi from this region commenced in the early 1960s, with the last of the bush people coming into Wulungurru (Kintore) and Kiwirrkurra communities in 1985. We interviewed Aborigines from the Kiwirrkurra-Lake Mackay area about their use of fire in the "old days". We compared this oral evidence with the quantitative data on temporal changes in fire size and distribution extracted from aerial photographs and satellite imagery, substantially increasing the size of the area studied by Burrows and Christensen (1990) by more than 240 000 ha; their original study area being about 54 000 ha.

Traditional Aboriginal Use of Fire: Oral Evidence

In 1987, two of the authors (Andrew Burbidge and Phil Fuller) travelled to the remote desert Aboriginal communities of Walungurru and Kiwirrkurra (see Figure 1) to talk to Pintupi people about their traditional use

of fire, especially bush fire. At this time, many people in this area had only recently come in contact with European society and retained a profound knowledge of their traditional lifestyle.

The interviews were conducted with the aid of a Pintupi linguist, John Heffernan. We experienced some difficulty obtaining interviews because of two local events that coincided with our visit. Many people had left the community to attend a sports meeting at Yuendumu, a community across the Western Australian border in the Northern Territory. Of much greater significance was the initiation ceremony being conducted at Kiwirrkurra, involving many of the knowledgeable old people with whom we wished to talk. We were not permitted to move about the area freely during the ceremony, which continued for several days. Eventually, we managed to conduct nine interviews, as well as talk about the local mammals. We displayed the skins (obtained from the Western Australian Museum) of a number of mammals now locally or totally extinct. This proved a popular draw card with Aborigines and was a useful means of initiating more interviews and obtaining additional information about the animals and about fire.

Fire size and distribution: Photographic evidence

We expanded on an earlier study by Burrows and Christensen (1990) who used early (1953) aerial photography and satellite imagery to map fire footprints and to quantify the size and spatial distribution of burnt patches. They examined imagery that covered an area of some 54,000 ha west of Lake Mackay (Figure 1). This region was chosen for study because it was known to be one of the last areas in which traditional Aboriginal burning was practiced. While the exodus of Pintupi from a traditional lifestyle to European-style settlements probably began in the early 1960s, the last people to lead a traditional lifestyle without European influence, emerged from this part of the Great Sandy Desert in 1985. As part of a military rocket research project by the Australian and British governments (the Blue Streak Rocket Project) the flight path of the rockets was mapped from low level (1:50 000) black and white aerial photography flown by the Royal Australian Air Force in July 1953. This coincidence of events provided a unique opportunity to investigate traditional Aboriginal burning practices, combining first hand Aboriginal knowledge and aerial photography. We substantially extended the original study by Burrows and Christensen (1990) by selecting a second sample area of about 80 km x 30 km (240 000 ha) some 80 km south-west of their original site.

We mapped fire footprints that were clearly visible on the 1:50 000 scale 1953 aerial photography and on a chronological sequence of Landsat satellite imagery (80 m and 25 m pixel) (see Tables 1 and 2 below). We used a similar method of mapping and digitising fire footprints to Burrows and Christensen (1990). If the fire boundary was not readily discernible, then the fire footprint was not mapped. Therefore, only relatively recent fires (probably <5 years old) were mapped. Older fire footprints were visible, but boundaries became diffuse as the vegetation recovered. The 1981 Landsat imagery was difficult to interpret because several large and often overlapping fires had burned almost the entire scene in the previous 10 years. This made it difficult to distinguish individual fire boundaries

Results

Oral evidence of the traditional use of fire

Not surprisingly, fire was an integral part of traditional Aboriginal life. The following is a summary of fire related Pintupi words and meanings (see Burbidge *et al.* (1988) for orthography):

waru is universally and commonly used for fire, firewood, and heat.
kunparatji is close relationship speech for *waru*.
kurrkalpi, *malarra*, and *kinparitji* are words for cooking fire.
tjangi is a firestick used for setting fire.
puyu is smoke.
kunarurru is a signalling fire in the distance (also a distant smoke plume or haze).
tili is flame.

tilirninpa is to make fire. Both men and women were able to make fire, although the implements used were different. Men used a *mirru* (spear thrower made from a hard wood such as mulga, *Acacia anuera*) on a piece of soft wood, often a *kurtitji* (a shield made from *Erythrina vespertilio* wood.) The verb for this is *patjipunginpa*. Women used a fire drill. Both sexes commonly carried fire sticks.
nyaru is the word most commonly used to describe the practice of burning off country. *Lunta* and *yarrpara* are synonyms. *Nyaruninpa* is the verb.

Pintupi people often referred to "cleaning up country" with fire. We did not fully understand what was meant by this but took it to mean a combination of clearing the ground to facilitate access on foot and for regenerating food plants. At times during the interviews, we found it difficult to distinguish between information about fires lit for hunting and those lit to "clean up country". Fires were often lit to achieve a number of purposes. On a field trip into the Lake Mackay area, our Pintupi guides would regularly ask us to stop the vehicle so that they could "clean up country" by setting fire to it. They found long unburnt and senescing spinifex aesthetically displeasing and where clearly agitated by it. They claimed that firing made country "healthy".

We were told that everyone can light fires to hunt or "clean up", even the children. We were frequently given long lists of animal species that were hunted using fire. Of the larger mammals, such as bandicoots and wallabies, all were hunted this way except those that inhabited burrows. Many reptiles were also hunted this way. *Kipara*, or Australian bustard (*Ardeotis australis*) is a prized food item and we were told that the best way to catch *kipara* was to light a bush fire; *kipara* would see the smoke and fly in and land on the recently burnt ground to feed on insects and lizards exposed or killed by the fire.

Our Pintupi informants told us that the size of hunting and plant regeneration fires varied. Some fires went out soon after they were lit, and so were very small, and other fires burnt for long distances. When we asked about how far fires travelled, we were usually told that it depended on the wind and the amount of fuel.

Some quotes from our interview reports in relation to fire size are:
Question: "How large did the fires get in the old days?"
Answer (informant A): "You could follow a fire for up to a few days. Some were big and some were small. Fires would sometimes go out at night. Sometimes they would go on for several days".
Answer (informant B): "You would follow a fire, camp overnight and follow it again the next day."
Answer (informant C): "Sometimes they could get quite large; could go for five nights."

Aborigines mentioned a recent fire that went from Kiwirrkurra to Jupiter Well (about 130 km). Another recent fire went from Kiwirrkurra to Walungurru (about 180 km). We were also told of a recent fire that went from Walungurru to Mount Liebig (180 km). These fires and were considered by the Aborigines as very large and unusual.

An informant from near Tjukala said that in the old days fires often went only a short distance and they would often have to light them again.

Question: "What would people look for when deciding to light up?"
Answer: "When the spinifex gets dense. Sometimes you would light up small grass areas, often you would have to light these areas several times; it would depend on the wind and rain."

"People would come back to burnt areas after rain and about one year later to gather food and to track goannas" (*Varanus spp*.).

One informant commented: "We would burn areas and hunt while the fire was burning; then we would move on and return to these areas later to collect food from plants that had regenerated and to hunt animals that had moved in to feed on those plants".

Question: "Which animals can you find in burnt country sometime after fire?"
Answer: "You could burn up country, go away, visit family and relatives, come back after rain when animals would be there. Kids would burn up country to catch lizards. Fires would make it easier to track animals. People would walk and keep up with the fire front so they could hit *kuka* on the head as they came out". "*Kuka"* is literally meat, but in this context, it refers to food animals.

People could also tell whether an area needed burning by the amount of growth and by density of animal tracks. If, for example, they saw a lot of *mala* (rufous hare-wallaby) or goanna tracks they would burn so they could follow the tracks and find the burrows. *Mala* would move into sandhill areas to eat fresh plants after fire and rain. *Mala* were hunted with fire and were chased several hundred metres.

When questioned on their use of fire today, the Aborigines responded with: "No need to go hunting with fire any more because there is no longer any *kuka* there".

Question: "How often were hunting fires lit? Every day?"
Answer: "*Yuwa*" (Yes).

When it was suggested to one group of Aborigines that the mammals might have disappeared because the people were no longer out in the bush lighting fires we received the reply: "That would be right; no longer any green shoots".

We were also told that fires were often lit for communication. For example the women would light a fire to let the men know that they had collected food. Fire was also used to communicate between groups. A party entering another group's land would light fires to let them know that they were coming.

Pintupi people have a good understanding of the relationship between fire and the germination of many important food plants. We were frequently given long lists of plants that regenerate following fire and rain. *Ukiri* is generic for new growth and *mirrka* is a collective word for all the non-meat bush foods.

We were told that lightning could start fires any time during the hotter months. One informant described the start of the lightning season as the time when goannas come out of their burrows. Lightning fires were more common on the hills but also occurred on the plains. Some people told us that lightning fires were not under their control so they did not have much to do with them. Others, however, said that lightning fires were also used for hunting. Our impression was that no good fire should be ignored if it was suitable for hunting.

Pintupi people (and other Western Desert Aborigines) regret the passing of medium sized mammals (Burbidge *et al*. 1988) and want them returned to their country. During this series of interviews, Aborigines made it clear they were worried that all the animals had "finished" in their country. They would be pleased to see the animals back because they (Aborigines) "had been eating white fellows meat for so long that they had become weak". They wanted to eat their own *kuka* (meat from native mammals) so they would be strong again. After explaining to several older Ngaanyatjarra men that we wanted to reintroduce some of the mammals that were once common, they were overjoyed, but warned that country had to be burnt first to provide food for the animals.

Photographic evidence

The 1953 black and white aerial photography of the 241 210 ha study area revealed a mosaic of numerous small, recently burnt patches (Figure 2) with about 22% of the area having been burnt recently (< 10 years prior to the photography). A fire palimpsest was evident and appeared to be similar to the contemporary mosaic suggesting that the 1953 photography was not a temporal outlier. Seventy five per cent of the burnt patches were less than 32 ha and 50% were less than 5 ha (Table 1and Figure 3). Of the recently burnt area, about 20% was burnt by fires < 100 ha, and 36% by fires > 1 000 ha; the largest fire being about 6 000 ha (Figure 4). While it was not possible to determine the ignition source of all fires, the shape of many of the

burnt patches on the 1953 photography was consistent with having been lit by a person dragging a firestick. Since 1953, the number of burnt patches has decreased dramatically from 846 to a low of 4 in 1981, and the size of the burnt patches has increased markedly (Table 1). Habitat boundary, which is the total fire perimeter within the study site and is a measure of the boundary between vegetation of different ages since fire, decreased from 3 888 km in 1953 to 392 km in 2000 (Table 1). This indicates a substantial reduction in the diversity of fire ages or states of post-fire succession within the landscape. These findings are consistent with those of Burrows and Christensen (1990) (Table 2) who studied an area some 80 km north-east of our site.

The pattern of burnt patches evident on the 1953 photography was relatively uniform across the study, although there were patches of very concentrated burning (Figure 2). A useful measure of the size and distribution of burnt and unburnt patches is the ratio of variance to mean patch size (Peilou 1977). A random distribution produces a ratio of near 1. A uniform or over dispersed distribution results in a ratio greater than 1 while a clumped or contiguous distribution yields a value much less than 1. In 1953, the patchiness ratio of both burnt and unburnt areas was 0.62 to 0.72 respectively, indicating a near random distribution of patches (Burrows and Christensen 1990). They reported that mean length of continuous burnt vegetation had increased from 467 m in 1953 to 2 570 m in 1986 and the variance ratio had reduced to 0.43, indicating a clumped distribution of patch size and a significant increase in mosaic grain size.

It was difficult to identify any areas of long unburnt vegetation; areas not mapped as recently burnt showed evidence of having been burnt, but because the fire boundaries were diffuse, they were not mapped. By 1973, about a decade after Aborigines began to leave the land, the small-grained mosaic of burnt patches evident on the 1953 photography had begun to be erased and to be replaced by a large-grained mosaic of tracts of recently burnt country and tracts long unburnt (> 10 years since fire). The largest fires were observed on the 1981 satellite imagery; four large fires had burned almost 90% of the 240 210 study area in the last 10 years (Table 1).

Figures 2, 3 and 4 here (Fig 2a: map of 1953 fire footprint, Fig 2b: map of 1988 footprint, Fig.3: size class frequency distribution, Fig. 4: proportion of area burnt)
Tables 1 & 2 here

Discussion

Fire size

Oral evidence gained from interviews is consistent with the 1953 photographic evidence. During Aboriginal occupation of country, fire was used widely, frequently and for many reasons, inducing a fine-grained mosaic of burnt patches across the landscape and reducing the opportunity for very large and intense wildfires to develop. The number and size class distribution of the of burnt patches further supports the oral evidence that burning was done routinely throughout the year. The relatively small size of the burnt patches could only be achieved by either only burning under marginal weather conditions (light winds, moist fuels) so that fires did not develop, or by burning country frequently, thereby reducing the quantity and continuity of flammable fuel. Both factors probably contributed to controlling fire size, but given that Pintupi burnt all year round, it is probably the latter, frequent burning, that has mostly influenced the small grain size of the patch-burn mosaic. Kimber (1983) suggested that Aborigines had a good deal of control over fire, using wind, humidity and natural fire barriers such as claypans and sand dunes to control the size and intensity of fires. From our interviews with Pintupis, it was clear that they had a sound empirical understanding of the role of weather and fuel conditions in influencing fire behaviour.

Many generations of Aborigines frequently burning country as they moved through the landscape would have resulted in discontinuous, patchy fuels, ranging from recently burnt to occasional long-unburnt patches. However, when the human ignition source was removed from the desert, fuels accumulated over large,

continuous tracts of land in a relatively short time. Today, lightning strikes can result in massive and intense wildfires, particularly during the hot and windy summer months. These fires can burn unchecked for days and sometimes weeks.

Fire frequency

Following our discussions with Aboriginal informants, we were left with the impression that the vegetation was burnt as frequently as it would carry fire. Rainfall history largely determines the rate of post-fire vegetation (fuel) development (Griffin and Allan 1985) and our observations suggest that the minimum interval between fires based on sufficient fuel accumulation is 7- 10 years. Although it is only a snapshot in time, the 1953 photography of recent fires and the fire palimpsest supports this conclusion. There was evidence of only small areas of long unburnt vegetation within the study area. We cannot be confident of the spatial extent of this conclusion. If there were areas not frequented by Aborigines, then it is likely that these areas remained unburnt for longer periods.

Time of year of fires

Our Pintupi informants told us they burnt all year round (every day). Kimber (1983) believed that most burning by Aborigines was done in August to October and immediately prior to rains in December to February. Occasionally, large fires caused either by Aborigines or by lightning, burnt during the hot, dry, windy summer months. In the area studied here, it would not have been possible for a fire to become larger than about 10 000 ha in 1953 because the fuels were discontinuous as a result of frequent broadscale patch-burning and natural fire barriers. Kimber suggests that the time of year for burning is not as important to Aboriginal people as the opportunity to burn, which was certainly the impression we gained from our interviews. de Graaf (1976) observed that Aboriginal fires in the desert were lit all year round and not seasonally. Both de Graaf (1976) and Kimber (1983) reported that Aborigines did not burn certain areas of the desert because they did not visit these places for religious reasons, or feared that fire would destroy sacred objects. The season of burning was, however, very important in the monsoon forest regions of the Northern Territory (Jones 1980 and Haynes 1985) and to Wadjuk Aborigines in the south-west of Western Australia (Hallam 1975). Today the main ignition source in the remote deserts is lightning. Thunderstorms are common over the summer months and large, lightning-caused wildfires have been reported (e.g., Griffin *et al*. 1983).

Conclusion

Western Desert Aborigines used fire skilfully and for a myriad of purposes, probably for thousands of years. Oral evidence provided by Pintupi Aborigines and quantitative evidence obtained from early black and white aerial photographs is consistent and supports the hypothesis that the fire regime changed significantly and quickly in parts of the Western Desert following the departure of Aboriginal people and the cessation of traditional burning. The size and intensity of fires has increased dramatically over the last 47 years. Today, in the absence of regular burning by Aborigines, fuels have accumulated over vast areas and when lightning (or people) ignites these fuels and under hot, dry, windy summer conditions, large and intense wildfires sweep across the desert. There is at least limited scientific evidence to suggest that this has contributed to the decline in some native mammal species. This change may have further predisposed mammals to predation by introduced predators. It is reasonable to accept the importance of temporal and spatial diversity within a landscape on resource levels and habitat opportunities (Latz and Griffin 1978, Pielou 1977). Saxon (1984) stated, "*When large areas of a single landscape type are subjected to large uniform disturbances, they threaten the survival of wildlife species which depend on irregular boundaries of natural fire patterns to provide a fine grained mosaic of resources*". Bolton and Latz (1978) have shown that a range of post-fire successional stages is important habitat for the western hare-wallaby (*Lagorchestes hirsutus*). Burbidge and Pearson (1989) explain the lack of rufous hare-wallabies in the Great Sandy Desert as being due to the lack of frequency of small-scale burns and to predation by foxes.

It is somewhat ironic that modern mammal extinctions in the Australian deserts may due, in part, to the changed fire regime that resulted from the departure of Aborigines and cessation of traditional Aboriginal burning. Although contentious, some authors (e.g., Tindale 1959, Merrilees 1968, Jones 1968 and Flannery 1994) have suggested that extensive burning by Aborigines contributed to the extinction of the Pleistocene mega-fauna. Today, it is likely that the large, intense wildfires that occur throughout the deserts are placing extreme stress on some plant and animal communities (Griffin 1981, Latz 1995). These intense fires are damaging vast areas of fire-sensitive vegetation such as marble gum (*Eucalyptus gongylocarpa*), desert oak *(Allocasuarina decaisneana*), and mulga (*Acacia anuera*) (Start 1986). There is sufficient evidence of the disadvantages of the current wildfire regime on the conservation status of desert reserves to warrant the development and implementation of managed fire regimes that mimic those in place during Aboriginal occupation of the land.

Limited resources available to conservation and land management agencies and the remoteness of many of the desert nature conservation reserves in Western Australia means that fire is not actively managed. There are many Aboriginal communities located in the Western Desert and given the knowledge and skills possessed by older people particularly, and the overwhelming desire by many Aboriginal people to care for country, a wonderful opportunity exists for co-management of these lands. The challenge for conservation and land management agencies is to develop processes that enable Aboriginal people to participate in land management in a meaningful and mutually beneficial manner. Hill (2003) presented a useful framework and mechanisms (bridging tools) to facilitate this. Her framework recognises an Indigenous "toolbox" founded on traditional knowledge and customary law and a non-Indigenous toolbox founded on science, legislation and policy. She identifies processes such as joint management, native land title and planning as the "bridging tools".

Fire management on desert nature conservation lands provides an opportunity for conservation agencies to facilitate and resource the reintroduction of traditional burning. In addition to conservation benefits, co-management provides an opportunity for Aboriginal people in remote communities to participate in an economic activity on their own terms, while at the same time, ensuring that important connections with country and traditional knowledge and skills are maintained.

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Captions for Figures

Figure 1: Location of the Pintupi burning study area in the Western Desert.

Figure 2a. Map of burnt country discernible on 1953 aerial photography of a 241 210 ha area south-west of Lake Mackay in the Western Desert. Pintupi Aborigines who occupied the desert at the time of photography lit most fires.

Figure 2b: Map of burnt country discernable on 1988 Landsat imagery of the area described above in Figure 2a. Lightning probably caused most fires.

Figure 3. Frequency distribution of the size (ha) of burnt patches evident on 1953 black-and-white aerial photography of a 241 210 ha area of the Western Desert.

Figure 4: Proportion of the total area burnt (from 1953 photography) by burnt patch size classes.

FIGURE 1:

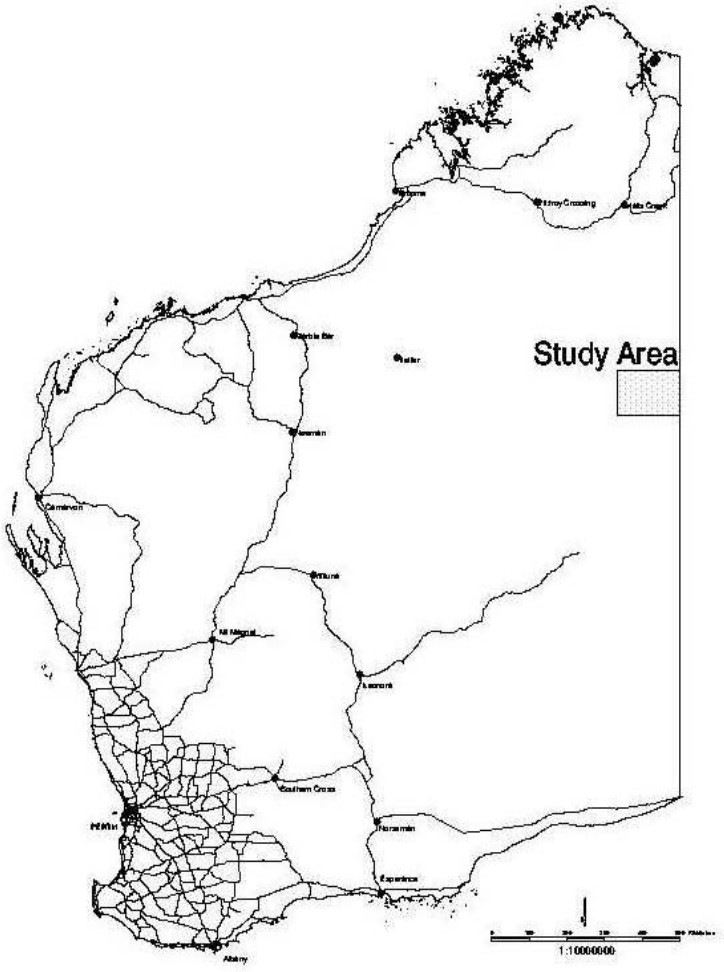

FIGURE 2a:

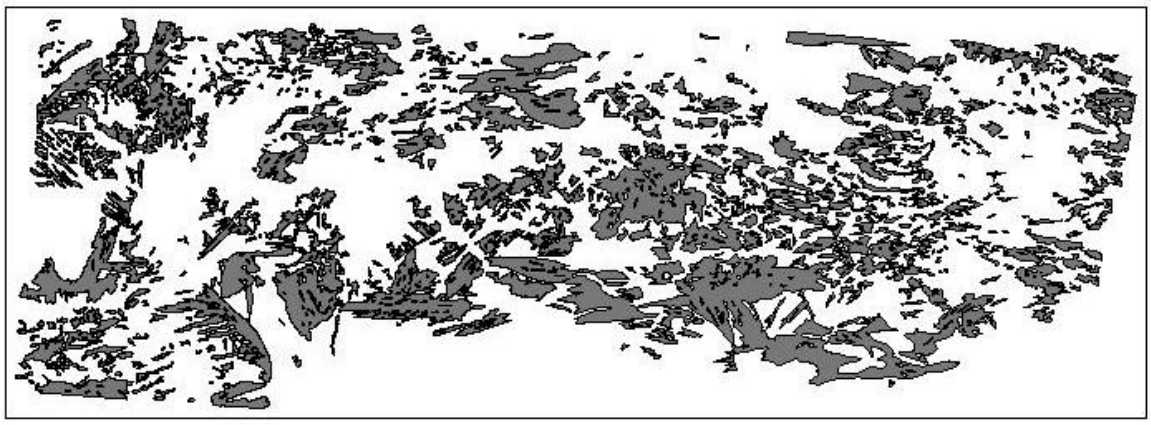

FIGURE 2b:

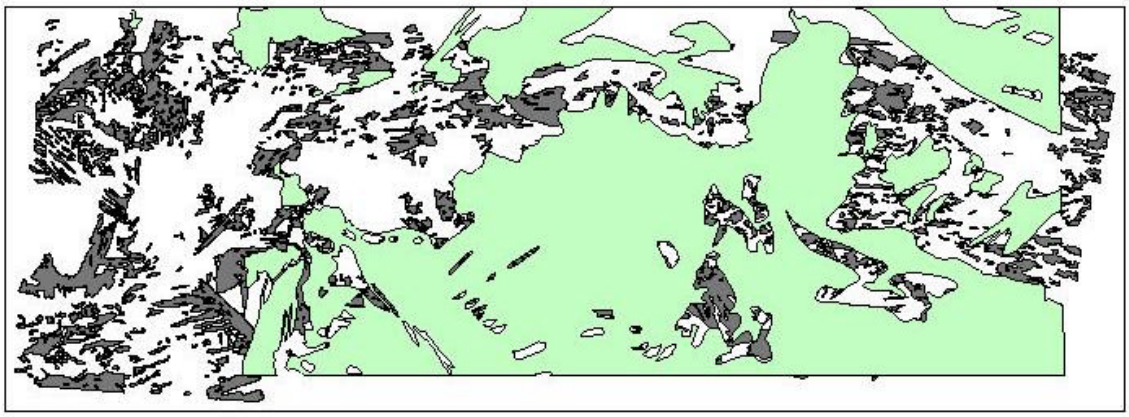

FIGURE 3:

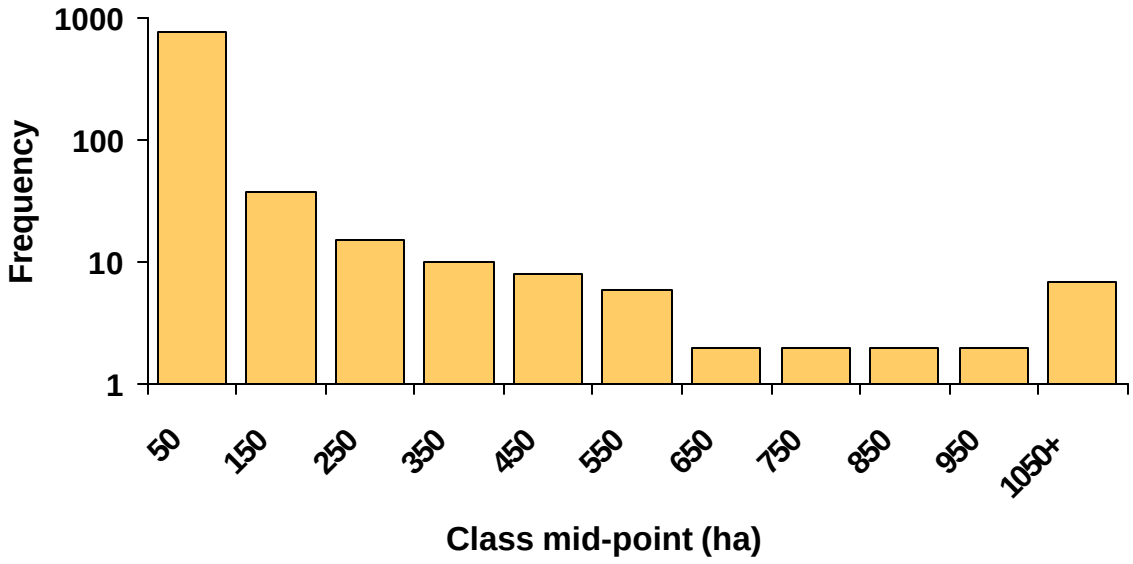
1000
100
10
1
Frequency
50
150
250
350
450
550
650
750
850
950
1050+
Class mid-point (ha)

FIGURE 4:

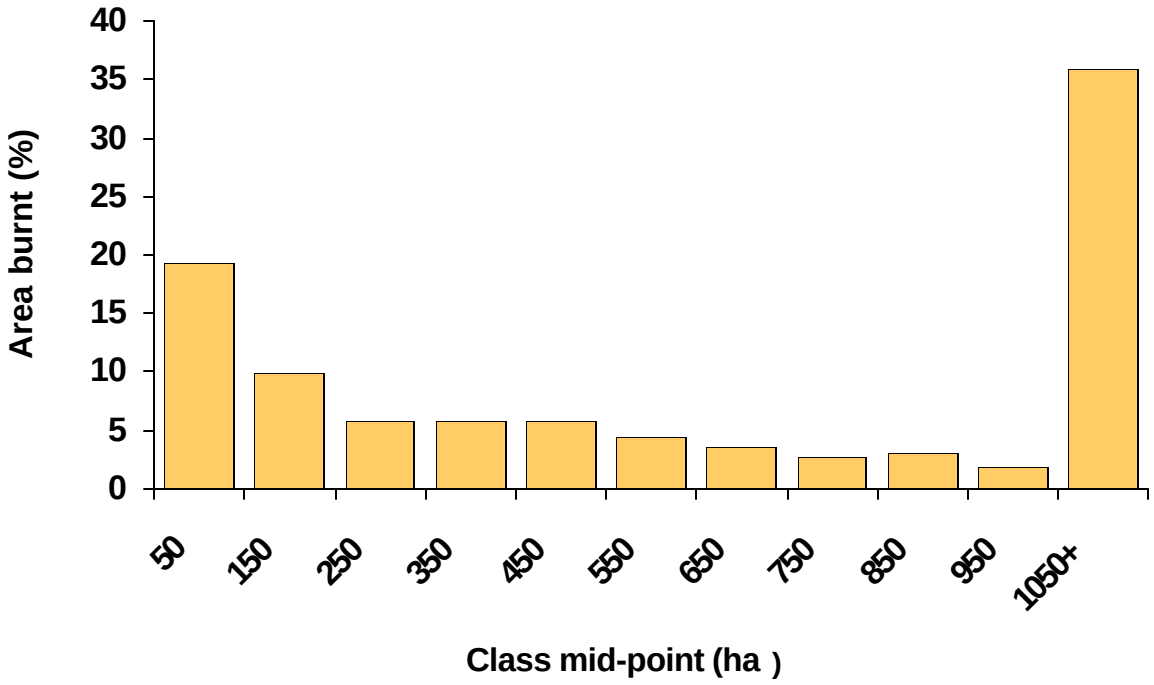
Area burnt (%)
40
35
30
25
20
15
10
5
0
50
150
250
350
450
550
650
750
850
950
1050+
Class mid-point (ha)

Table 1: Area and perimeter statistics for recently burnt patches clearly visible on 1953 aerial photography and 1973, 1981, 1988, 1994 and 2000 Landsat satellite imagery for a 241 210 ha sample area 80 km south-west of Lake Mackay. Burnt patches are estimated to be < 10 years since fire (se = standard error).

Year	Number of recently burnt patches	Total area recently burnt (ha)	Total burnt perimeter (habitat boundary) (km)	Mean burnt patch size (ha)	Range - burnt patch size (ha)	75th percentile (ha)	50th percentile (ha)
1953	846	54 234 (22%)	3 888	64 (se = 10)	0.5 - 6 005	32	5
1973	24	38 014 (16%)	518	1 583 (se = 1 086)	15 - 24 780	236	61
1981	4	210 576 (87%)	1 324	52 644 (se = 26 096)	17 113 - 129 646	-	-
1988	19	94 447 (39%)	814	4 970 (se = 23 080)	1 - 71 346	1 581	390
1994	83	46 589 (19%)	1 053	561 (se = 181)	8 - 11 992	234	91
2000	25	11 121 (4.6%)	392	445 (se = 165)	19 - 3 683	412	78

Table 2: Area and perimeter statistics for recently burnt patches clearly visible on 1953, 1973 and 1977 aerial photography and 1986 Landsat imagery for a 53 483 ha sample area west of Lake Mackay. Burnt patches are estimated to be <10 years since fire (source: Burrows and Christensen 1990).

Year	Number of recently burnt patches	Total area recently burnt (ha)	Total burnt perimeter (habitat boundary) (km)	Mean burnt patch size (ha)	Maximum burnt patch size (ha)	Median burnt patch size (ha)	Mode burnt patch size (ha)
1953	372	12 643 (24%)	1 198	34	1 744	6	2
1973	27	22 800 (43%)	412	845	13 534	197	5
1977	3	31 752 (59%)	293	10 584	30 618	-	-
1986	1	32 184 (60%)	272	-	32 184	-	-