Chapter 8

Discussion and Recommendations of Biological Survey of the Bungle Bungle Area

by
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OVERVIEW OF THE FAUNA

We list a total of 298 vertebrates (149 bird, 81 reptile, 41 mammal, 15 fish and 12 frog species) from the Purnululu National Park, Conservation Reserve and adjacent area. This fauna comprises a mixture of widespread species, species typical of the tropical north (Torresian) and a minority of species characteristic of arid Australia (Eyrean). The affinity of the fauna is with the higher rainfall areas of the Kimberley, rather than with the Great Sandy Desert or Tanami to the near south (and south-east). The mammal fauna in particular bears close resemblance to that of the south-west Kimberley (McKenzie 1981a). The Bungle Bungle fauna is also very similar to the wildlife of medium-rainfall (c 600-1200 mm) areas of northern Australia (e.g. Katherine Gorge, Kakadu Stage III, Pine Creek, Gregory, Keep River, Lower MacArthur), illustrating the relative uniformity of the Torresian fauna across an extensive longitudinal arc (Woinarski *et al.* 1989a). In addition to this broad suite of widespread species, several species found in the Bungle Bungle area have a distribution which is restricted to the Kimberley-Keep region: the gecko *Gehyra* sp.nov., Ningbing Antechinus, Kimberley Mouse, White-quilled Rock-Pigeon, the frogs *Litoria splendida* and *Uperoleia borealis*, the monitor *Varanus kingorum* and the skinks *Ctenotus militaris*, *Ctenotus tantillus*, *Lerista borealis* and *Lerista greeri*.

Species are distributed very unevenly within the Bungle Bungle area. Torresian species occur mostly in the relatively tall and dense riparian vegetation of the main water courses and in the more sheltered gorges. These areas represent the local southern (inland) limit for many such species (e.g. Bar-breasted Honeyeater, Pale Field-Rat, Large-footed Mouse-eared Bat, Common Koel, Olive Python). Rocky ranges with spinifex - e.g. Osmand Range, Bungle Bungle massif, Turner area - have a very different fauna including some notable species whose range is otherwise largely confined to the arid centre: Desert Mouse and the skink *Egernia slateri*. Other rock-dwelling species include the Common Rock-Rat, Rock Ringtail Possum, Short-eared Rock Wallaby, White-quilled Rock-Pigeon, Variegated Fairy-wren, Sandstone Shrike-thrush, Copland's Rock Frog, the monitors *Varanus glauerti*, *Varanus kingorum* and *Varanus acanthurus* and the skink *Cryptoblepharus megastictus*. Another distinctive group of species occurs on the black-soil plains of the Ord River basin: these include the Northern Nailtail Wallaby, Rufous-throated Honeyeater, Rufous Songlark, Golden-headed Cisticola, Australian Bustard and Singing Bushlark. The extensive sandplains surrounding the massif characteristically contain Sand Goanna, Delicate Mouse, Western Chestnut Mouse, Stripe-faced Dunnart and the skink *Lerista greeri*. Yellow-throated Miners, Northern Rosellas and Pied Butcherbirds are abundant where these sandplains carry taller woodlands.

OVERVIEW OF THE FLORA

We list 619 vascular plant species from the Bungle Bungle area, an increase of 244 species from that previously known. Based on a regional comparison relating species tallies to survey area, this number is marginally higher than expected, especially so given the relatively low rainfall of the Bungle Bungle area. The flora is closely related to that reported for the Gregory National Park of north-western Northern Territory, although we have not compared it directly with other surveyed sites in the Kimberley.

The number of weed species recorded from the Bungle Bungle area is relatively low (17 species, or 2.8 per cent of the flora), though several of these species now present serious problems. The abundance of weeds is highest on lowland and river frontage areas. Additional species are likely to colonize in association with increased visitor numbers and ongoing land degradation.

We list 35 notable species, including several probable new species, new records for Western Australia, new records for the Kimberley and species at the limits of their known range.

Based on floristic records from the 150 quadrats, we classify the vegetation of the Bungle Bungle area into 17 floristic groups. These groups are mostly closely related to the vegetation communities described by Forbes and Kenneally (1986).

The Osmand Plateau and Osmand Range have not been adequately surveyed for plants, and there has been insufficient collecting during the wet season.

DEGRADATION, AND THE STATUS OF THE FAUNA

By far the greatest problem that the wildlife of the Bungle Bungle area has faced historically is the degradation of the environment caused by overgrazing by domestic and feral stock. Ongoing degradation through the continued presence of feral donkeys and cattle, and the residual consequences of former overgrazing will be the major management concern affecting wildlife of the area for the next few decades.

Over the last century, high densities of cattle and feral stock (especially during periods of below average rainfall: Robinson 1971) have led to changes in the composition of native grasslands, reduction or extermination of some plant species, loss of vegetative cover, change in run-off and water-holding capacity of the soil, extensive and very severe erosion, siltation of waterholes and destruction of waterside vegetation, especially reedbeds and dense stands of *Pandanus* (e.g. Robinson 1971; Forbes and Kenneally 1986; Colreavy *et al.* 1989; Coombs *et al.* 1989). With the development of grazing leases, the diaspora of Aboriginal custodians has been accompanied by a change in traditional fire regimes. Elsewhere in Australia, these environmental modifications have been associated with substantial losses of mammals (e.g. Frith 1973; Kitchener 1978; Burbidge and McKenzie 1989; Morton 1990).

There were no fauna collections of consequence from the east Kimberley before this century. Lacking historical information on the wildlife of the Bungle Bungle area, it is now difficult to describe how this environmental degradation has affected the wildlife. Two bird species, Purple-crowned Fairy-wren and White-browed Robin, have probably disappeared from the pandanus fringes of the upper Ord River (as elsewhere: Smith and Johnstone 1977; Rowley 1988). Based on information from Aboriginal custodians, it is probable that several medium-sized mammals have also disappeared or declined substantially - Bilby, Northern Quoll, and possibly Spectacled Hare-wallaby, Golden Bandicoot and Northern Brown Bandicoot. The large macropods - Agile Wallaby and Common Wallaroo - also may have become rarer. There is no evidence to describe historic changes in status for reptile, frog, fish or small mammal species.

Relationships between the present degradation levels and the distribution and abundance of animal species show complex patterns (Table 22). These relationships are confounded by underlying patterns in the distribution of animals: the open forests and riparian areas of plains and valleys generally support higher diversities of birds, reptiles and frogs than do the low very open woodlands of the rocky ranges. They also have been subjected to much more grazing pressure and consequent degradation, and hence positive associations between degradation and animal species diversity might be expected at this level. Indeed, the more degraded habitats do have more bird species, but notably support fewer native mammal species than do less degraded habitats. Small mammals are also less abundant in the degraded land units. There were no significant correlations across land systems between mean degradation score and the diversities of reptiles, frogs or plants.

Within any given habitat, there is little relationship between the distribution of animal species and the current level of degradation (Table 23), and correlations are not consistent across different habitats. For most of the habitats considered there is a weak tendency for bird species diversity to be higher in the more degraded quadrats, though this is significant only for the Wickham land system. This significant correlation is probably owing to the heterogeneity of the Wickham system, with riparian areas supporting more bird species and also having more grazing pressure than upland parts of the Wickham system. In contrast, native mammals show the opposite trend for Wickham, possibly because of the relatively high diversity of rock-dwelling mammals in upland areas. Native mammals were positively associated with degradation for the floristic group *Eucalyptus brevifolia* low open woodland-*Acacia retivenia-Triodia intermedia*, although the meaningfulness of this correlation is limited by the very low range of degradation scores for quadrats in this habitat.

Many individual bird species occurred more abundantly in degraded quadrats of particular habitats (Table 24). These were mostly granivorous species (e.g. Diamond Dove, Peaceful Dove, Crested Pigeon, Zebra Finch). Only two reptile and one mammal species showed such significant positive associations with disturbance in any habitat. In contrast, more reptile and mammal species, but fewer bird species, were significantly rarer in degraded quadrats for particular habitats. Illustrative of the lack of generality in these patterns, several species showed significant positive correlations with degradation in one habitat but significant negative correlations in another habitat (e.g. Pied Butcherbird, Spinifex Pigeon, Northern Nailtail Wallaby, Crested Pigeon).

The most notable feature of these relationships with disturbance is the lack of clear pattern between existing levels of degradation and the current distribution for most species and for most vertebrate groups. This may be owing to a number of possible causes:

i) those species which were most sensitive to degradation have already been eliminated;

ii) current levels of degradation have very little impact on the distribution of animals;

iii) species may have already responded to the erosion-control procedures implemented in the last decade;

iv) in line with our contractural brief, we did not sample extremely degraded areas, and the range of degradation that we did examine may have been below a threshold where the distribution of animal species was affected.

To an extent, these alternatives may be examined by careful monitoring of experimental restoration and untreated plots. Large-scale restoration work would provide a critical opportunity for examining how native animal species are affected by environmental degradation, and show to what extent land restoration can contribute to the recovery of the indigineous animal community.

The removal of feral stock and the rehabilitation of degraded land is the critical management requirement for ensuring the conservation significance of Purnululu National Park, Conservation Reserve and adjacent land. The banks of the Ord River, the levee plains of Antrim lowlands between Osmand Range and Osmand Creek, and plains on Osmand Valley Station (notably an area about 2-3 km south of Mt. Parker) have suffered massive erosion and loss of vegetation cover (de Salis 1982; personal observation). The Western Australian Department of Agriculture has conducted seasonal shoots of feral stock in the Bungle Bungle area in collaboration with the Department of Conservation and Land Management (CALM). Elimination of feral donkeys is extremely expensive (Choquenot 1988), because of their very high reproductive rates and attainable densities and their ability to subsist on low quality food resources (Freeland and Choquenot 1990). These factors also determine a very rapid recovery following incomplete extermination. This problem requires the goodwill and close co-operation of station managers, CALM and the Department of Agriculture.

Feral pigs also have a high potential for profoundly affecting environmental quality. Pigs currently occur at low density along the Osmand Creek system, and have been reported further south towards the Ord River, within the National Park. These are apparently recent colonizers from escaped Turkey Creek stock (Novelly[12] personal communication). The elimination of feral pigs when they are at high density is an extremely difficult management problem (Hone 1983; Bayliss and Yeomans 1989), and determined efforts to eliminate the current low population would be cost-effective in the long term.

Feral cats occur extensively, but apparently at low densities in the Bungle Bungle area, and feed on native small mammals, reptiles and ground-nesting birds. Their control is presently incorporated into the management duties of ranger staff, though may require more systematic concentration to be effective.

The elimination of feral stock may take many years, or even prove impossible (e.g. Ridpath and Waithman 1988; Bayliss and Yeomans 1989). In the meantime, methods aimed at controlling their damage should be implemented. De Salis (1982) lists the most vulnerable land systems as Antrim lowlands, Elder lower slopes, Headley lower slopes and cracking clays and Nelson frontage, cuestas, cuesta backslopes, upper and lower slopes and low rises. The vegetation being most degraded is that fringing the river systems, soaks, gorges and springs. Most notably, the pandanus thickets along sections of the Ord River have been extremely degraded by cattle trampling, erosion and the spread of exotic plants (e.g. *Cenchrus* spp., *Parkinsonia*). The riverside vegetation on the southern and south-eastern border of the Park (along the Ord River) should be protected from cattle by adequate fencing. This exclusion would also serve to protect vulnerable areas of the Elder lower slopes and Nelson frontage, low rises and cuesta land systems. We note that the present alignment of an electric fence to exclude cattle lies well to the north of the Ord River, thereby offering no protection to these land systems and vegetation. In terms of the conservation of natural values, this fence is currently in the wrong place. To achieve this aim it should be aligned along the southern bank of the Ord River. Alternatively, along the north bank of the Ord River substantial areas of riparian vegetation still in reasonable condition should be fenced off to exclude feral stock.

Rehabilitation of badly degraded land along the Ord River valley has been attempted by the Department of Agriculture, and monitored in a series of experimental plots (de Salis 1982; Colreavy *et al.* 1989). Although some success has been claimed (e.g. Anon. 1986), Coombs *et al.* (1989) note that the Ord River Regeneration Reserve has shown little evidence of successful regeneration. There appears to have been no treatment of the badly degraded areas of the northern section of the Conservation Reserve, Osmand Valley Station or the southern part of Texas Downs Station (personal observation).

Our survey was not designed to enquire into rehabilitation, but we note with disquiet the use of exotic pioneer species (*Aerva* and *Cenchrus*) for soil stabilization. In incidental observations we noted little colonization by native plant species of areas sown with these exotic species. Although our data provide no usable evidence on the suitability to native animals of exotic pastures *vis-a-vis* regeneration by native grasses, it would be parsimonious to presume that most native granivorous animal species are better adapted to exploiting seeds of native species than those of introduced species.

[12] Paul Novelly - Western Australian Department of Agriculture, Kununurra

The use of, or at least experimentation with, native pioneer grasses should be regarded as mandatory for restoration within a National Park. In this context, we note that Robinson (1971) doubted the wisdom of using introduced strong perennial grasses (e.g. *Cenchrus*) for rehabilitation, suggesting instead the natives *Enneapogon* and *Eragrostis falcata* for restoration work in the Hardman Basin. We recommend much more extensive experimentation using native plant species for the rehabilitation of all degraded areas in the National Park, Conservation Reserve and adjacent areas. Although rehabilitation measures must be taken urgently, experimentation into rehabilitation should be considered also over a long enough period to incorporate the influence of burning regime and over many years of rainfall variability. Experimentation should involve a considered design which includes the range of susceptible land units, topography, vegetation, visitor use, fire regimes and present erosional condition. If conducted properly, experimentation in the Bungle Bungle area could be used as a springboard for the restoration of the very extensive degradation across the Kimberley and north-west Northern Territory.

The rehabilitation procedure used to date, and any variations used in the future, provide an excellent opportunity to experimentally test the factors involved in the effects of degradation (and recovery with rehabilitation) for native animal species. Such monitoring should be integral to the vegetation rehabilitation trials and practices. We note, however, that over the long-term some reintroductions of medium-sized mammals may be desirable.

In attempting to restore an intact natural environment to this conservation area, the control of exotic weed species will pose a formidable problem. The woody weeds *Calotropis procera* and *Parkinsonia aculeata* have aggressively colonized degraded flats and riparian areas, and these, in particular, require continued urgent management attention. Although the diversity of exotic plants in the Bungle Bungle area is generally low, this invasion by exotic plant species is very variable, ranging from less than 0.5 per cent of the plant species in quadrats for the Buchanan frontage, Buchanan sandplains and Elder upland units, to 7.1 per cent in Nelson lower slopes, 7.3 per cent in Nelson low rises, 11.6 per cent in Antrim lowlands and a disquieting 13.6 per cent in Nelson frontage. With the continued presence of feral stock and an increase in tourist numbers, additional weed species may be expected to colonize the Bungle Bungle area.

CONSERVATION SIGNIFICANCE

Few species of the Bungle Bungle fauna are recognized as rare or endangered on a national scale. The most notable species that we recorded were Grey Falcon, Desert Mouse, the skinks *Egernia slateri* and *Lerista* sp.nov. and the gecko *Gehyra* sp.nov.

Although generally rare, the Grey Falcon has a very wide range across semi-arid Australia and may be at least partly nomadic (Blakers *et al.* 1984). It would be desirable to monitor their numbers and residential status in the Park area.

The Desert Mouse has an unusual distribution in central Australia without any apparent environmental determinants (S.Morton[13] personal communication), and is regarded as rare and declining (Strahan 1988). The Bungle Bungle population represents the most northerly and high rainfall area known to be occupied by this species. It appears to be reasonably widespread and abundant in the Bungle Bungle area, especially in relatively old spinifex on gravel or rock substrates. Further trapping in such habitat would define more precisely their distribution and abundance, and could determine suitable fire regimes to be implemented for their conservation.

The presence of *Egernia slateri* on the Bungle Bungle massif represents a very disjunct population of a species whose range is otherwise restricted to central Australia. Again, fire regimes which would be most suitable for this species have not been defined, and further trapping would be desirable in order to determine its precise distribution and abundance.

The distribution of an undescribed *Lerista* is not yet sufficiently known to determine the significance of Bungle Bungle National Park for its conservation, though it is possible that the Bungle Bungle area may comprise its total range.

The new species of *Gehyra* is thought to occur also in Keep River National Park and around Kununurra (M.King personal communication). Within the Bungle Bungle area, this species is abundant in caves, crevices and exfoliating rocks.

The greatest frustration of this survey was in the very limited information gathered on medium-sized mammals. We remain unsure of the continued presence within the Park area of the Bilby, Spectacled Hare-wallaby and Northern Quoll, and we gathered no evidence for Northern Brushtail Possum, Golden Bandicoot or Northern Brown Bandicoot, all of which may have been expected. These species are of considerable conservation significance because of their widespread decline in recent times (McKenzie 1981a; Burbidge and McKenzie 1989). Further attempts to detect these species (possibly using low-flying helicopter survey in sandy areas: Burbidge and Pearson 1989) are warranted. If located, populations may require protection from grazing and the local implementation of suitable burning regimes.

[13] S. Morton - CSIRO Wildlife and Ecology, Alice Springs

For all the native terrestrial vertebrates recorded from the Bungle Bungle area, we examined for presence in the other National Parks and Conservation Reserves throughout north-western Australia (using published surveys and file notes from Hamersley, Ruddall River, Point Coulomb, Windjana Gorge, Prince Regent , Drysdale River, Parry Lagoons, Hidden Valley, Keep River, Berry Springs, Holmes Jungle, Litchfield, Gregory, Howard Springs, Mary River, Fogg Dam, Douglas Hot Springs, Butterfly Gorge, Umbrawara Gorge, Coburg, Kakadu, Katherine Gorge, Katherine Low Level, Cutta Cutta Caves, Mataranka Pool, Connells Lagoon, Lawn Hill, and Camooweal Caves). For nine species, the Bungle Bungle area is the only conservation area in which they have been recorded in north-western Australia. Nine other species have been recorded from the Bungle Bungle area and only one other of these reserves (Table 25). It is for the conservation of these 18 species that Purnululu National Park may be critically important. This should be qualified by the presence of at least some of these species in conservation reserves outside north-western Australia, and the incompleteness of many species lists from reserves in north-western Australia.

HUMAN IMPACT

Direct human impact was not considered specially in this survey. This impact falls into three classes:

i) hunting by custodians,
ii) intensive pressure on particular areas by tourists, and
iii) a very large number of scenic low-level flights over the Bungle Bungle area.

At present, most hunting by outstation residents is for feral stock. If feral stock are eliminated or reduced to very low density, the demand for fresh meat may be transferred to the larger macropods and, possibly, Bustard. There has been no research on the consequences of traditional hunting with modern weapons in any area of northern Australia. The expanding number of cases of traditional owners or custodians living within National Parks (e.g. Kakadu, Gurig, Nitmiluk) may be expected to result in some conflict in Park conservation aims. It would be desirable to monitor density, removal rates and reproductive status of macropods if these become a major food item of custodians. Common Wallaroos enjoy a better conservation status (in terms of abundance and representation in National Parks) than do Northern Nailtail Wallabies, and any hunting should be restricted mainly to them. We note that custodians have expressed concern about the perceived low numbers of macropods in the Park area, and in response to this they are not currently hunting these species.

Tourists may make some impact on localized areas of high use, by frightening away shy species, possibly interfering with nests and picking or trampling rare plant species (especially in the sheltered gorges). Such impact is likely to be very minor and restricted. Access tracks and tourist infrastructure (e.g. airstrip) may lead to erosion, spread of weeds and occasional roadkills of small vertebrates, but again impacts on wildlife would be limited and localized. Camp fires are currently prohibited throughout the Park. This policy is probably justified at designated campgrounds, as the availability of timber is limited. The few studies elsewhere in Australia (e.g. Rolls 1989; Laidlaw and Wilson 1989) suggest that the rapid depletion of standing and fallen timber around sites of intensive camping is associated with a local decline in the animal species using this resource. The provision of timber from outside the Park is probably no solution because of expense and the possibility of introducing unwanted species to the Park area. Where camping is to be permitted beyond designated intensive-use campsites (e.g. for overnight bushwalks) there is no compelling biological reason (other than possible escape to wildfire) for prohibition of campfires.

Intensive camping is currently restricted to two sites, and the area open to visitors is also tightly controlled. In general, the conservation value of most sites that we visited would not be jeapordized by well-controlled tourist use. Qualifying this, there are areas which we consider unsuitable for intensive use by tourists. These include the relatively lush gorges and springs of the Osmand Valley (Winnama, Bream and Wulwuldji) which contain unusual vegetation which may be vulnerable to trampling if visited by excessive numbers of tourists (Forbes and Kenneally 1986); the larger pools of the Ord River and Osmand Creek (e.g. Blue Holes, Island Yard) which provide critical foci for many wildlife species in the late dry season, such that human disturbance then would be undesirable; and the plateau of the massif whose isolation and difficult access has allowed the persistence of several species more characteristic of central Australia. Additionally, most caves in the Bungle Bungle area are inaccessible or nearly so, but for the few which can be reached by tourists, some controls may be required in order to ensure that disturbance of their bats is minimized.

Domestic cats and dogs (owned either by tourists or custodians) should continue to be prohibited from the National Park and Conservation Reserve, because if these wander or become feral they may place high predation pressure on native species.

There is no information available on the effects of low-flying aircraft on native animals. We would presume that most animals of the Bungle Bungles are now habituated to this disturbance.

Any consideration for more tourist development and infrastructure in the Park should be preceded by an environmental impact assessment including examination for the presence of the notable species we document in this report.

VALUE OF CONSERVATION RESERVE AND POSSIBLE EXTENSIONS

We sampled five sites in the National Park, two sites in the Conservation Reserve, one site on the border of the two zones and two sites on adjacent pastoral leases, Texas Downs and Osmand Valley (Table 2). The two sites on pastoral leases averaged more native animal species (105) than those on the Conservation Reserve (98 species) or the National Park (91 species).

Twelve animal species were found at the pastoral lease sites but are not known from the National Park or Conservation Reserve: Bar-breasted Honeyeater, Eastern Water Rat, Northern Mastiff-bat, Beccari's Mastiff-bat, Black Whip Snake, Olive Python, Carpet Snake, Brown Tree Snake, the gecko *Crenadactylus ocellatus*, the skink *Eulamprus isolepis* and the snake *Vermicella roperi*. A further five species were recorded at our pastoral lease sites but at no other of our intensive survey sites (although we recorded them incidentally, or they are known from other sources, within the National Park and/or Conservation Reserve): Pacific Baza, Grey Butcherbird, Short-tailed Mouse, Pale Field-Rat and the monitor *Varanus glauerti*.

Extension of the National Park to include Osmand Valley Station and the southern part of Texas Downs would therefore increase the number of terrestrial vertebrate species known from the National Park and Conservation Reserve by between 4 and 5 per cent, including many Torresian species at the local southern limit of their range. It would also place in a reserve one species (*Crenadactylus ocellatus*) known from no other conservation reserve or National Park in north-western Australia. It would greatly increase the representation of the distinctive Wickham land system of hard sandstone ranges, deeply-incised gorges and lush riparian vegetation. Management by CALM of these areas would increase the protection of the dense riparian vegetation flanking Osmand Creek, its tributaries (e.g. Mt. John Creek), springs and gorges. We did not survey the small areas of Mabel Downs and Sophie Downs suggested for possible expansion of the National Park.

Eight species were recorded at sites in the Conservation Reserve but at no other sites: Richard's Pipit, Square-tailed Kite, Red-capped Robin, Olive Whip Snake, Dusky Horseshoe Bat, *Litoria rothi*, *Oedura rhombifer* and *Varanus kingorum*. Relative to the National Park, the Conservation Reserve includes much more of the Wickham, Dockrell and Antrim uplands land systems, and their inclusion clearly would add to the representativeness of the Park.

FIRE REGIMES

Both in the tropical north (e.g. Braithwaite and Estbergs 1985; Press 1987; Braithwaite 1987; Noske 1988; Woinarski 1990) and arid and semi-arid areas (e.g. Bolton and Latz 1978; Suijdendorp 1981; Kimber 1982; Burbidge 1985; Caughley 1985; Woinarski 1989) fire regime is an important determinant of vegetation pattern, and consequently of the distribution and abundance of animal species. By manipulating fire periods, intensities and size, the habitat suitability can be controlled for particular target species, and ecological diversity can be maximized.

Our survey was not aimed at defining suitable fire regimes, but some information was collected incidentally. Most notably, our records for the Desert Mouse were mostly from relatively old and dense spinifex, and this species may be favoured by reasonably long (10-20 years) intervals between fires. In many other areas of Australia, a range of animal species has been shown to be particularly associated with old spinifex (e.g. Mather 1979; Coventry and Dixon 1984; Noske 1988).

In contrast, in the tropical north, annual burning early in the dry season is favoured by many species of bird (Woinarski 1990) and some reptiles (Braithwaite 1987). In this environment, mammals, other reptiles and bird show a great array of preferred fire regimes, including some species which prefer long periods without fire (e.g. Kerle 1985; Braithwaite 1987).

In seeking some compromise to these various ecological demands, managers of national parks in the northern part of Australia have implemented a system of mosaic burning (Press 1987, 1988), consciously mimicking the broad pattern traditionally produced by Aborigines (Lewis 1985; Hallam 1985). Carefully considered (and long-term) experimental manipulation of fire regimes, and the detailed monitoring and chronicling of fire history (using LANDSAT) have been critical elements in the development and continuation of this strategy. Ecological monitoring of this management system is also recognized as essential to providing feedback into its sucess and failures.

The arid area has a conspicuously different climate and vegetation to the tropical north, with consequent marked differences in fire behaviour and vegetation responses. But as with the tropical north, in arid areas controlled mosaic burning has been identified as critical for some mammals (e.g. Bolton and Latz 1978; Pearson 1989), and recent changes in fire regime have been implicated in the decline of many mammals (e.g. Burbidge *et al.* 1988).

The Bungle Bungle area lies between the tropical and arid zones and includes elements of the climate, plants and animals of both in a complicated mix. Accordingly, it is unrealistic to extrapolate to the Bungle Bungle area the fire effects and preferred burning regimes from either tropical or arid examples. In the absence of fire response data from the south-east Kimberley, the most prudent management plan for the immediate future would be to ensure the availability of as wide a range of successional ages of vegetation as possible, through the carefully considered implementation of mosaic burning.

To identify the optimal design of an imposed fire regime for the Bungle Bungle area, it is crucial that experimental areas be established and be subjected to a variety of fire treatments. Vegetation and animal responses to these regimes should be monitored over a period of at least ten years. Further research into the relationships between fire regime and the distribution of animal species in the Bungle Bungle area is also desirable, especially for notable species.

As a further aid toward the establishment of a fire policy for the Bungle Bungle area, it is important to determine the fire regime traditionally used by Aborigines of the area, and to document, if possible, the reasons why such burning practices were used. In Kakadu National Park, Aborigines living within the Park are intimately associated with the management fires.

It should be implicit that the management of the Park requires the careful collection of fire history maps (preferably using LANDSAT imagery), and that the development and implementation of a fire regime for the Park area requires such sustained and accurate mapping. Over the last few years, the foundation for such a fire history map has been established for the Bungle Bungle area (Done[14] personal communication).

INTERPRETATION

Tourists to the Bungle Bungle area are drawn by the beauty and unusual nature of the massif. In contrast, most of the rich fauna is inconspicuous and/or uncommon. This is so especially for mammals and reptiles, and many visitors may be disappointed at failing to encounter wildlife in this remote natural area. Sensible interpretation will at least inform such visitors of what animals do occur, may give them ideas of where and when to look for particular species, and help them identify those that they may see. Such well-informed tourists may contribute records of additional species and/or locations of particular notable species, useful in the ongoing description and management of the Park's fauna.

[14] C. Done -Department of Conservation and Land Management, Kununurra, W.A.

REGIONAL PERSPECTIVE

Throughout this report we have focused on the Bungle Bungle area as defined in the Introduction (National Park, Conservation Reserve and immediate surrounds). Conservation of the south-east Kimberley will not be served solely by the simple reservation of this defined area. For example, not all plants and animals of the south-east Kimberley occur within the Purnululu National Park. But also, the condition of land in the region surrounding the Bungle Bungle area may influence the viability of populations within the National Park. This is most evident for nomadic species (such as the Masked Wood-swallow, Grey Falcon, Rufous-throated Honeyeater and Cockatiel) which depend on tracking seasonally shifting areas of resource abundance. No matter how well managed the National Park area is, such species will decline in it if the surrounding area is degraded. A conservation strategy for pastoral land in the Kimberley region is required.

INFORMATION SYSTEM

The management of a large and popular National Park with considerable conservation significance is a formidable task, made even more difficult by the requirements to develop and monitor extensive rehabilitation and burning strategies. The careful planning and integration of much information which must form the framework for this management would be greatly aided by the use of some form of geographic information system (GIS). We have consciously tried to present our data in a form which is amenable to inclusion in such a system. The use of some form of GIS is implicit in many of the recommendations that we now offer.

RECOMMENDATIONS

More detailed arguments or comments relating to these recommendations are given in the preceding discussion. We caution that it is hubris to pretend that an initial survey of wildlife and vegetation should provide recommendations for wide-ranging aspects of the management of an area as large and diverse as Purnululu National Park, Conservation Reserve and adjacent pastoral leases.

We assign three levels of priority to these recommendations: urgent, very high and high. We don't attempt to cost any of these proposals, nor comment on their degree of difficulty. In some cases these recommendations complement those identified in the Draft Management Plan (Colreavy *et al.* 1989). Some items in this recommendation list are contingent on or connected with others and form an overall plan for the wise conservation of the Bungle Bungle area's vegetation and wildlife.

A. Synthesis of Management Priorities, Information and Planning

A1. Establish a GIS

A1.1. Introduce a geographic information system for the storage of data on wildlife distribution, vegetation, degradation, fire history, tourist access, Aboriginal sites, and experimental plots. This database would then be used for management planning, prediction and information retrieval.

Priority: Very high.

Justification: Integration and storage of large amounts of information; considered management planning.

B. Land Degradation

B1. Control of feral animals

B1.1. Continue the systematic shooting of feral donkeys and cattle in the National Park, Conservation Reserve and adjacent area, until eradication is achieved (in collaboration with Department of Agriculture/Agriculture Protection Board).

Priority: Urgent.

Justification: Unacceptable levels of land degradation, especially in Osmand Valley Station, the Osmand Valley section of the Conservation Reserve and the banks of the Ord River.

B1.2. Eradicate the population of feral pigs.

Priority: Urgent.

Justification: Threat posed to riparian vegetation if pig numbers increase.

B1.3. Eradicate the small populations of camels and water buffalo.

Priority: High.

Justification: Alien species, damage to control fences.

B1.4. Trap and remove feral cats.

Priority: High.

Justification: Alien species, predation pressure on wildlife.

B1.5. Continue prohibition of domestic dogs and cats.

Priority: High.

Justification: Predation pressure on wildlife.

B1.6. Construct exclosure fences around vulnerable areas, explicitly Wulwuldji Springs, sections of the northern bank of the Ord River (especially where dense *Pandanus* vegetation or reedbeds persist), Winnama Gorge, 'Fowlhouse' and the area around the junction of the Ord River and Osmand Creek.

Priority: Urgent.

Justification: Unacceptably high levels of damage by feral livestock to key conservation areas.

B2. Density of stock on adjacent pastoral leases

B2.1. Scrutinize covenants governing Osmand Valley and Texas Downs pastoral leases. In consultation with leaseholders and the Department of Agriculture, stock levels should be reduced and rehabilitation measures implemented for degraded land.

Priority: Urgent.

Justification: Devaluation of the conservation significance of these areas.

B3. Rehabilitation

B3.1. Accelerate program to rehabilitate badly-degraded areas (e.g. Ord River basin, Osmand Valley in the Conservation Reserve, Osmand Valley Station). Long-term systematic and carefully monitored experimentation, using native species as pioneers, is mandatory. Rehabilitation measures should be well documented such that Purnululu is capable of providing an example for the restoration of degraded lands in the East Kimberley.

Priority: Urgent.

Justification: Loss of conservation value.

B3.2. Methodical monitoring of recovery of animal (especially small mammal and reptile) populations should accompany vegetation rehabilitation trials and also large-scale rehabilitation implementation.

Priority: Very high.

Justification: Ideal opportunity to examine the response of native animals to degradation and vegetation restoration. The recovery of the former animal community should be a primary aim of any land rehabilitation procedure.

B3.3. Consider the collaboration of custodians in the collection and cultivation of native plant species for possible use in restoration.

Priority: High.

Justification: Integrate custodians in the care of the land, use available knowledge and interest.

B4. Remove exotic plants

B4.1. Assess and monitor the current distribution and abundance of exotic plants in the Bungle Bungle area. Particular problem species should be eradicated, especially those which are now in relatively controllable numbers but which have the potential for substantial increase (e.g. *Parkinsonia, Calotropis*). The Antrim lowland and Nelson frontage land systems have the most exotic species.

Priority: Very high.

Justification: Restoring intact natural systems; averting threats for substantial expansion.

B4.2. Continue to look out for additional exotic species, and plan for possible changes in vehicular access should additional species of weeds begin to use the roads of the Bungle Bungle area as colonizing routes.

Priority: High.

Justification: Proactive plan to reduce the threat of rapidly increasing weed species.

C. Wildlife Studies and Monitoring

C1. Notable species

C1.1. Gather information on numbers, distribution and residential status of the Grey Falcon in the Bungle Bungle area.

Priority: High.

Justification: Rare species.

C1.2. Further survey the distribution, habitat requirements and status of the Desert Mouse in the Bungle Bungle area, especially relating to any association with fire regime.

Priority: Very high.

Justification: Rare species, isolated population.

C1.3. Further survey the distribution, habitat requirements and status of the two skinks *Egernia slateri* and *Lerista* sp.nov., especially relating to any association with fire regime. In this area, *Egernia slateri* is currently known only from the plateau of the Bungle Bungle massif. *Lerista* sp.nov. is known only from the sandy floor of Cathedral Gorge.

Priority: Very high.

Justification: Rare species, isolated population, poorly known distribution.

C1.4. Search the dense riparian vegetation (especially *Pandanus*) along the Ord River and Osmand Creek for the Purple-crowned Fairy-wren and White-browed Robin, formerly common in the area but now presumed extinct. If found, populations should be carefully protected. If not found, reintroduction may be desirable if vegetation has recovered sufficiently and can continue to be protected.

Priority: Very high.

Justification: Rare species, restoration of intact natural systems.

C1.5. Continue searches for medium-sized mammals (especially Northern Quoll, Bilby, Spectacled Hare-wallaby, Golden Bandicoot and Northern Brown Bandicoot), preferably in collaboration with custodians. If found, the distribution, habitat requirements, population status and association with fire regime should be defined. Any populations found should be carefully managed.

Priority: Urgent.

Justification: Restoration of intact natural systems, conservation of rare and declining mammal species.

C1.6. Consider the reintroduction of mammal species presumed to have declined or become extinct in this area. If land degradation can be reversed and fire managed sympathetically, such reintroductions may succeed here, especially because of the absence of foxes and rabbits.

Priority: High.

Justification: Restoration of intact natural system; providing sanctuary for species which are threatened across their entire range.

C2. Inventory

C2.1. Continue to update species lists by coordinating observations of tourists and ranger staff.

Priority: High.

Justification: Increased knowledge of natural resources, possible detection of trends in changing abundance.

C2.2. Search in wet season for frogs, snakes and water birds (all possibly under-sampled in this survey).

Priority: High.

Justification: Increased knowledge of natural resources.

D. Vegetation

D1. Additional collecting

D1.1. Survey of plants during the wet season.

Priority: High.

Justification: Almost no collecting has occurred during the wet season, the only period in which many annuals are conspicuous and in which fertile specimens can be collected.

D1.2. Survey vegetation of the Osmand Plateau.

Priority: High.

Justification: Not surveyed in detail by either this survey or by Forbes and Kenneally (1986), and may harbour species of biogeographic interest.

D2. Horticulture

D2.1. Collect seeds to examine suitability of a range of local plant species for propagation for possible use in rehabilitation (see also B3.3). Also, the cultivation of some of the very restricted plants occurring in the sheltered gorges *may* provide some conservation security for these species.

Priority: High.

Justification: Use in restoration and conservation.

E. Fire Regime

E1. Experimental trials

E1.1. Establish long-term, carefully monitored experimental trials to examine the effects of different burning regimes on native plants and animals.

Priority: Urgent.

Justification: Management to increase biological diversity, and to manipulate habitat suitability for particular species.

E2. Traditional burning practice

E2.1. Consult with custodians about their memories of traditional burning regimes, their aims and results.

Priority: High.

Justification: Restoration of natural systems, using available experience and expertise.

E3. Protect long-unburnt patches

E3.1. The Desert Mouse, at least, appears to favour areas with long intervals between fires. A reasonable proportion of such old spinifex country should be adequately protected.

Priority: High.

Justification: Protection of rare species.

E4. Establish a considered fire strategy

E4.1. Based on the above points and on other criteria (e.g. protection of tourists, protection of rehabilitation plots, more general legislation relating to burning), prepare and implement a systematic policy governing fire regime in the Park area. The optimum policy is most likely to be one which uses a mosaic of burning to maintain a wide range of vegetation ages and types.

Priority: Urgent.

Justification: Sound and deliberate management practice, protection of rare species.

E4.2. Maintain a detailed fire history map of the Park and adjacent area, and link this with a GIS (Recommendation A1.1).

Priority: Very high.

Justification: Requirement for considered management, and conservation of rare species.

F. Tourism

F1. Interpretation

F1.1. Provide a digest of some of the information in this report in a form attractive to tourists, such that they can appreciate the wildlife and vegetation values of the Bungle Bungle area.

Priority: High.

Justification: Visitor appreciation of the Park.

F1.2. Establish and coordinate a wildlife database from interested and informed tourists and ranger staff (= C2.1.).

Priority: High.

Justification: Visitor appreciation of the Park, updating and accumulating information on Park resources.

F1.3. Encourage the establishment of nature tours and bush tucker tours, in collaboration with custodians.

Priority: High.

Justification: Visitor appreciation of Park; accumulating information on Park resources; providing commercial opportunities for custodians.

F2. Development of infrastructure

F2.1. Any development involving substantial buildings, clearing of native vegetation or use of waterbodies, should be preceded by environmental assessment, particularly by consideration of the presence of the plant and animal species identified as notable in this report.

Priority: Very high.

Justification: Protection of rare species.

F3. Campfires

F3.1. Campfires should not be permitted at sites of intensive use (e.g. designated camp grounds), as is current policy.

Priority: Very high.

Justification: Local loss of critical resources for some animal species.

F4. General

We can provide little information on other tourist-related management problems, such as increased visitor numbers, better access, low-level scenic flights, camp-fires for dispersed camping and accessibility to additional areas. We note comments on some of these matters in the Discussion.

G. Extensions

G1. Addition of Osmand Valley Station and southern part of Texas Downs

G1.1. We support the incorporation of these areas into Purnululu National Park, although we note that land degradation is continuing (?and accelerating) on these pastoral leases.

Priority: Urgent.

Justification: Outstanding natural values, which largely complement those of the existing National Park.

H. Surrounding Land

H1. Develop a conservation strategy for all lands in the east Kimberley

H1.1. In association with other interested groups (e.g. local councils, pastoralists, Aboriginal organizations, tourist operators, conservationists, and mining companies) develop a conservation strategy for pastoral land, Aboriginal reserves and conservation areas in order to best protect the conservation values of all land in the east Kimberley.

Priority: Very high.

Justification: Conservation reserves alone will not provide sufficient protection for the survival of wildlife and vegetation in this region. Many sites with high conservation value occur in areas where there is currently little protection or appreciation of those values.

Table 22

Relationships between mean degradation score and number of species of plants and animals across floristic groups. Significance of correlation coefficients : *p<0.05, ** p<0.01

	FLORISTIC GROUP	DEGRADATION	MEAN NO. NATIVE SPP.				
			Plants	*Mammals*	*Birds*	*Reptiles*	*Frogs*
1.	*Livistona - Acacia holosericea - Germania*	0	30.2	3.6	9.6	5.4	1.4
2.	*E. ptychocarpa - Pandanus - Heteropogon*	3.2	29.8	1.6	18.8	4.8	1.0
3.	*E. camaldulensis / Melaleuca - Aerva - Aristida*	8.3	34.3	0.3	26.3	3.5	0.5
4.	*Melaleuca leucadendra - Acacia eriopoda - Aristida*	4.4	35.6	0.4	19.9	3.4	0.3
5.	*Lysiphyllum - Carissa - Heteropogon*	3.2	23.0	2.0	14.4	3.7	0.6
6.	*Lysiphyllum - Acacia holosericea - Cenchrus*	3.6	21.1	0.6	16.6	6.2	0.1
7.	*Acacia farnesiana - Aerva - Aristida*	9.3	22.8	1.0	13.9	2.1	0
8.	*E. collina - Acacia stipuligera - Triodia spicata*	0.1	16.0	1.1	13.1	4.0	0
9.	*E. collina - Acacia tumida - Plectrachne pungens*	0	28.6	1.1	9.7	3.0	0.1
10.	*E. brevifolia - Cassia - Plectrachne pungens*	1.6	35.1	1.6	14.5	3.0	0.3
11.	*Hakea arborescens - Dodonea - Triodia wiseana*	3.0	22.8	2.4	15.2	2.6	0
12.	*E. opaca - Grevillea pyramidalis - Triodia pungens*	2.4	20.3	1.2	11.1	3.6	0.2
13.	*E. brevifolia - Acacia retivenia - Triodia intermedia*	0.8	10.4	2.6	3.6	1.2	0
14.	*E. cliftoniana - Cajanus - Plectrachne pungens*	0	21.0	2.5	7.2	3.0	0
15.	*E. aspera - Acacia eriopoda - Triodia microstachya*	0.3	30.3	2.3	9.3	3.3	4.0
16.	*E. cliftoniana - Acacia spp - Triodia spicata*	0.1	20.4	1.0	6.5	3.1	0.3
17.	*Acacia spp - Triodia spicata*	1.7	14.9	1.0	8.4	4.9	1.0
	Correlation coefficient with degradation:		.27	-.51*	.71 **	-.09	-.21

Table 23

Correlation coefficients between degradation scores and number of animal species, within individual land systems and within individual floristic groups. Significance levels: *p<0.05, **p<0.01

	No. quadrats	*Disturbance range*	*All spp.*	*Birds*	*Native Mammals*	*Reptiles*
LAND SYSTEMS						
Al	21	2-11	.27	.27	.26	-.17
Au	12	0-12	.32	.53	-.54	-.19
Nr	12	1-9	-.04	.09	.58*	-.19
Wk	35	0-6	.65**	.69**	-.55**	.08
FLORISTIC GROUPS						
4	18	2-11	.42	.49	.03	.07
5	12	1-6	.38	.43	-.41	-.05
6	13	1-8	.26	.22	-.44	.27
10	11	0-3	.04	.23	.69*	-.46
12	14	1-5	.07	.04	.23	.11

Table 24

Significant correlations between the abundance of animal species and degradation score, within individual land systems and within individual floristic groups. Number in parentheses after species name is number of quadrats in which recorded for a given land system or floristic group. Significance levels: *p<0.05, **p<0.01

	NO. QUADRATS	DISTURBANCE RANGE	NEGATIVE	POSITIVE
LAND SYSTEM				
Al	21	2-11	-.51* Pied Butcherbird (12)	.53* Spinifex Pigeon (3)
				.42* Diamond Dove (4)
Au	12	0-12		.84** Budgerigar (3)
Nr	12	1-9	-.55* *Ctenotus militaris* (5)	.62* Spinifex Bird (3)
				.62* *Omolepida branchialis* (3)
				.60* Peregrine Falcon (5)
				.59* Zebra Finch (6)
				.58* Northern Nailtail Wallaby (4)
Wk	35	0-6	-.59** Common Rock-rat (21)	.60** Peaceful Dove (19)
			-.45** White-quilled Rock-pigeon (5)	.46** Bar-shouldered Dove (7)
			-.42** *Cryptoblephurus megastictus* (4)	.45** *Heteronotia binoei* (5)
			-.33* Pale Field-rat (7)	.42* Double-barred Finch (17)
				.36* Crested Pigeon (3)
				.35* Long-tailed Finch (5)
FLORISTIC GROUP				
4. *Melaleuca-Acacia-Aristida*				
	18	2-11		.79** Kite (4)
				.68** Torresian Crow (10)
				.57* Australian Magpie-lark (8)
5. *Lysiphyllum-Carissa-Heteropogon*				
	12	1-6	-.57* *Ctenotus inornatus* (4)	.86** Pied Butcherbird (6)
6. *Lysiphyllum-AcaciaCenchrus*				
	13	1-8	-.56* Northern Nailtail Wallaby (3)	.65* Sacred Kingfisher (3)
10. *E. brevifolia-Cassia -Plectrachne*				
	11	0-3	-.69* *Lerista greeri* (3)	.62* Diamond Dove (8)
			-.60* Crested Pigeon (4)	.62* Zebra Finch (4)
12. *E. opaca-Grevillea-Triodia*	14	1-5	-.51* Spinifex Pigeon (5)	.62* Painted Firetail (3)
				.57* Zebra Finch (3)

Table 25

List of native terrestrial vertebrates found in the Bungle Bungle area but known from fewer than two other national parks or conservation reserves in north-western Australia (see text for names of 28 other reserves considered).

SPECIES	OTHER RESERVES	COMMENT
Scotorepens sanborni	-	
Pseudomys desertor	-	
Ctenotus piankai	-	
Ommolepida branchialis	-	
Lerista aericeps	-	
Lerista greeri	-	
Varanus kingorum	-	
Egernia slateri	-	
Lerista sp. nov.	-	
Eremiascincus richardsoni	Hamersley	
Proablepharus reginae	Hamersley	
Pseudonaja modesta	Hamersley	
Diporiphora lalliae	Connell's Lagoon	
Ctenotus militaris	Hidden Valley	
Crenodactylus ocellatus	Geikie Gorge	
Uperoleia borealis	Keep River	
Lerista borealis	Gregory	
Chelodina sp. nov.	Kakadu	