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CRITICAL DATA REQUIREMENTS FOR THE MANAGEMENT OF FIRE ON NATURE CONSERVATION LANDS IN SOUTH WESTERN AUSTRALIA

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SUMMARY

Fire is one of the most widely used techniques for the broadscale management of conservation reserves in a fire prone environment. Management decisions concerning fire on nature conservation lands should be based on a sound knowledge of the natural resources of the area and the processes that sustain those resources. Administrative, legal and cultural factors will also have important influences on the way fire is managed in a reserve. In this paper we propose a set of critical data requirements which should be considered for the management of nature conservation lands in south Western Australia. We concentrate on biological data needs and discuss with examples how these data are collected, presented and stored. A framework is thus derived that is applicable to all reserves but has the flexibility to cater for the management requirements of specific reserves. Strategies for management in the absence of critical data are also examined.

INTRODUCTION

Over 728 000 hectares or 30% of publicly managed land in the forest regions of the south west of Western Australia lie in conservation or proposed conservation reserves. These reserves include four categories of land (viz Nature reserve, National Park, State Park and Forest Park) and range in size from a few hectares to the proposed Shannon-D'Entrecasteaux National Park of over 171 000 hectares. Extensive areas outside the forested regions of the south west are also contained in conservation reserves.

Fire remains the most widely used tool in the management of such reserves (Underwood and Christensen 1981, Burrows *et al.* 1987). Policies and objectives for the management of fire have evolved rapidly in recent years in response to changed land use objectives, improved information and increased public awareness of environmental issues (McCaw and Burrows in press, Good 1981). Fire management decisions in conservation reserves should be based on a firm understanding of the role of fire in the ecosystem. However managers may have little or no data on which to base decisions, and have only limited resources and time for collection and analysis of data. Faced with this situation there is a clear need to separate the data which are critical to decisions from that which are not essential, even though they may be of considerable interest.

In this paper we attempt to define the critical data set necessary for making sound decisions about the management of fire in nature conservation lands, focussing on examples from south Western Australia. Because certain management activities will and should take place even in the absence of a critical data set, we also address the question of management in the absence of such data.

OBJECTIVES OF MANAGEMENT

Specific fire management objectives should correspond directly to the broader objectives of management identified for each reserve. Broad objectives will normally be formulated on the basis of the exising knowledge of a reserve; at the same time these objectives will also influence the nature of the data required for fire management planning. For example, if the objective of management for a particular reserve is to maintain known populations of a rare plant species, knowledge of the response of this species to fire becomes critical for fire management. A clear statement of the broad objectives of management is therefore necessary as a preliminary for defining a critical data set for any reserve. Underwood (this book) suggests a framework for setting and evaluating management objectives for nature conservation lands.

DATA REQUIREMENTS

Planning for fire management on nature conservation lands must address 3 key questions:

- What are the current regimes of fire in the reserve (and, in the absence of intervention, will these continue unchanged into the future)?
- How does the biota respond to these regimes (particularly in comparison with historical fire regimes)?
- How does fire interact with reserve neighbours and visitors?

Critical data can be considered as the data necessary to answer these questions at a level of detail appropriate to a particular reserve at a given time. Time and scale will be important in decisions about what are critical data for a given reserve.

1. Fire regimes

The frequency, intensity and seasonality of fire together characterise a fire regime (Gill 1975). The range of fire regimes within a reserve will be determined by 2 primary factors. These are:

1. the opportunity for fire spread, which is dependent on fuel characteristics and climatic conditions,
2. the risk (Luke and McArthur 1978) or probability of fire ignition.

To adequately define the opportunity for fire spread, fuel and weather information should be integrated in the form of a fire behaviour model. Such a model should also be capable of accounting for topographic influences on fire behaviour. For planning purposes fire behaviour models should provide unbiased predictions over a wide range of circumstances, although a high level of accuracy may not be required. This contrasts with the use of models developed for prescribed burning purposes where accurate results are desirable over the specific range of conditions where the model is most regularly applied.

Fire behaviour models used in Australia for grasslands (McArthur 1977, Condon 1979) and eucalypt forests (McArthur 1967, Sneeuwjagt and Peet 1985) predict fire behaviour according to basic weather and fuel quantity inputs. Being empirically derived, predictions of fire behaviour from these models are most reliable when fuel conditions are similar to those for which the model was developed. The fire spread model developed by Rothermel (1972) has potential for application in a wide range of fuels but requires detailed information about fuel characteristcs: considerable field calibration of this model will probably still be required in most circumstances (Catchpole 1987).

Fuel characteristics may be strongly influenced by the nature of the vegetation and the time since previous fire; maps of vegetation type and fire history are therefore critical. Additional information necessary for fire behaviour prediction that can be related to vegetation maps includes the impact of canopy height and density on wind strength, potential for crown fires and long distance spotting, and the necessity for mop-up of burning woody debris or peat following fire. Depending on the size and complexity of the data base involved this information may in some cases be readily handled by map overlays, or may require computer based geographic information systems (Kessel *et al.* 1984).

Adequate fire behaviour guides are not currently available for a number of fuel types widespread throughout Western Australia, and even with a commitment to ongoing research this situation will persist for some time to come. However accumulated local experience and careful analysis of past fires may still provide an adequate basis for action in the absence of more sophisticated data.

With even a basic understanding of fire behaviour, historical weather records can be used to define patterns of potential fire spread within the major fuel types in a reserve. Daily records of maximum temperature, minimum relative humidity and wind speed and direction during morning and afternoon are an appropriate starting point as they are available for most settlements and also form the basic inputs to several of the fire behaviour model widely used in Australia. Preliminary analysis of this type could aim to define periods with

- little or no potential for fire spread
- potential for fires of low to moderate intensity
- potential for large fires of high intensity.

This form of analysis may be developed to a high level of sophistication incorporating computer based information systems (Kessell *et al.* 1984) given sufficient time, resources and an established need. Reserves which generate a high level of interest from the community tend to pose complex issues for management and therefore require comprehensive data on which to base decisions. In south Western Australia there is an increasing level of public debate about the management of fire in conservation lands especially in the forested areas.

The second major factor determining fire regimes is the risk, or probability of fire ignition. In the forested areas of south western Australia prescribed fire is used extensively for a range of purposes including fuel reduction, management of fauna habitat (Christensen 1980), and manipulation of the forest understorey to disfavour *Phytophthora cinnamomi*, the causal agent of jarrah dieback (Shea *et al.* 1979). Human activity is also responsible for about 93% of unplanned fires, with lightning accounting for the remaining 7% (Underwood and Christensen 1981). Careful analysis of historical records of unplanned fires is important in quantifying the level of risk: for useful analysis such records should describe

- the cause of the fire (eg lightning, arson, escapes from campfires, industrial operations or prescribed burning),
- geographic patterns of fire occurrence,
- seasonality of fire ignition.

An understanding of these factors may suggest ways in which the frequency of unplanned fires could be reduced through enforcement of regulations, public education or alteration of activities which entail a high risk of fire.

Where land use patterns are changing rapidly, historical fire regimes may not necessarily provide a good indication of future fire regimes. For example escapes from high intensity agricultural clearing fires have been a major cause of summer and autumn fires in reserves of native vegetation throughout south western Australia in the last 50 years. However clearing fires are now infrequent in areas where alienation of the land is complete. Burrows *et al.* (1987) reported that the area of Dryandra forest burnt by wildfires declined markedly after 1960, corresponding with the completion of land clearing in the district. Historical changes in fire regimes are important in determining appropriate or perceived necessary regimes in the future. We will return to this question in dealing with the interactions of fire and people.

2. Response of the biota to fire

The response of the biota to fire regimes is a crucial element in making decisions about the use of fire. Although there have been many studies of the effects of a single fire, few studies have been published on the response of the biota to fire regimes. Studies of the effects of a single fire, while important, are not in themselves an adequate basis for determining the regimes of fire appropriate to a reserve. This section examines the critical data requirements for flora and fauna, both at the species and the community level while recognising the paucity of information currently available in both these areas.

The pattern of the biota is associated closely with the edaphic and climatic pattern of the reserve. An understanding of this pattern is a critical first step in an understanding of the biota of the reserve.

2.1 *Landform, soils and climate*

Landform, soils and climate exert a powerful influence on the distribution of plant and animal communities. An understanding of the relationships of communities to climatic and edaphic factors enables the definition of similar sites and establishes their extent and distribution within and between reserves. Site specific survey work can thus be extended beyond initial survey sites.

Maps of landforms based on geomorphological characteristics have proved valuable in studies of land use, (McArthur and Clifton 1975), plant community patterns (Cresswell and Bridgewater 1985, Wardell-Johnson *et al.* in press) and as a basis for stratifying samples for survey purposes (Burrows *et al.* 1987, Wardell-Johnson *et al.* in press). Landform and soils information should be available in map form for ease of use in the field but can also be incorporated into computer based information systems.

Scale is an important factor in assessing the usefulness of landform soils maps. A first step for the breakdown of landform soils units should be within a broad region e.g. Churchward and McArthur (1978) and Churchward *et al.* (in press). Such studies enable the portrayal of broad scale patterning in the region and the assessment of the adequacy of the reserve system. However to be valuable in reserve management important reserves within a region should be mapped at finer resolution. Landform soils mapping at 1:25 000 (Churchward pers. comm.) is proving valuable in management for the conservation of Tammar wallabies (*Macropus eugenii*) in the Perup RFPA (Fig. 1). They have enabled the prediction of the potential extent of thicket development within the reserve.

FIG 1 HERE

The availability of computer based climatic data retrieval and prediction systems (e.g. BIOCLIM, Busby 1985) has enabled the prediction of rare fauna distributions, potential pest distributors, the biogeography of Australian Elapid Snakes (Longmore 1986) and the definition of site productivity classes in karri regrowth forest (Inions pers comm). The use of such schemes encourages the efficient use of survey and research time and speeds up the mapping of distributions of species and communities - an essential element in the management using fire of the biota of the reserves.

2.2 *Flora*

2.2.1 *Vegetation communities*

The definition and delineation of vegetation communities and their correlation with landform/soils maps is an important step in land use planning (Havel 1981). Managers of public land need an objective, explicit basis for distinguishing the vegetation communities within their jurisdiction so that they can assess the effects of various disturbances on patterns of plant species composition and richness. Classification schemes should be mathematically robust, interpretable in the field and have a defined area of coverage. They should also have the facility for the allocation of independent sites to the classification. Classification schemes must be able to be related to conveniently mapped characteristics if they are to be effective in reserve management. Programmes can be added to site type models to enable the provision of additional information about specific site types, for example, lists of species, vulnerable species, fuel accumulation rates, dieback sensitivity and erodability. This then enables the more effective use of all relevant data including that which may not be critical to management.

2.2.2 *Flora vulnerable to disturbance*

Vulnerable species are defined as those species whose populations can be reduced or eliminated by inappropriate management regimes or disturbance events. These species may have low ecological tolerances (Austin and Belbin 1982) or life history strategies (Raunkiaer 1934, Gill 1981) that are dependent on particular disturbance regimes. Species that are susceptible to dieback caused by pythiaceous fungi, wherever they occur, should be considered vulnerable.

The identification and mapping of vulnerable species is necessary if we are to be successful in managing for the continued maintenance of their populations at a local level. Because of the high rate of endemism (Hopper 1979) many of the species in the south-west are likely to be vulnerable. Such species may be rare or restricted and where vulnerable, are often at the edge of their ecological range. For the purposes of fire management planning the distributions of these species and their life history strategies need to be determined so that operations can be modified accordingly. Two sub species of *Banksia seminuda* illustrate that rarity in itself is not the major consideration in the conservation of vulnerable species.

Banksia seminuda subspecies seminuda is a long lived fire sensitive banksia confined to gullies and river valleys in the south west (Taylor and Hopper 1987) where stands of the species add greatly to the visual quality of the valleys. The species is readily killed by fire suggesting that though it may be relatively common at present, a failure to account for its presence in fire management may lead to a range loss of the species. *Banksia seminuda* subspecies remanans (Hopper in press) is also a long lived fire sensitive banksia but of very restricted occurrence around granite outcrops in the Walpole area (Plate 1). Failure to account for the presence of this subspecies in fire management has the potential to lead eventually to the extinction of the subspecies. Gill and McMahon (1986) have suggested that the age to maturity and age to produce sufficient seed to ensure the re-establishment of the stand following fire is important for the conservation of species sharing this life history strategy.

PLATE 1 HERE

2.2.3 *Keystone muturalists*

Plant taxa that fruit, flower or seed outside community peaks in production or that provide other specific habitat requirements may be extraordinarily important in maintaining sedentary vertebrate populations. These have been designated "Keystone muturalists" (Leighton and Leighton 1983 after Gilbert 1980) based on the key role played by (eg) species of strangling Ficus in providing the continuous availability of fruit for many frugivorous species in a lowland tropical rainforest in Borneo. This concept should be transferred to other ecosystems to ensure that those species most limiting to vulnerable fauna are delineated and their requirements determined. In a situation of limited resources, those species most critical to the maintenance of a diverse or vulnerable fauna should be targeted first for research and management effort. The identification of these species requires a knowledge of interactions within a system and of species responses following disturbance.

Gastrolobium bilobum may be termed a "keystone muturalist" in the PRFPA where it forms thickets suitable as habitat for the tammar wallaby (Christensen 1980). Specific management operations are there necessary to ensure that the habitat of the tammar remains suitable for their continued presence in the situation of coexistance with introduced predators such as the fox. In this example, maintaining the distribution of suitable habitat requires burning prescriptions to produce intense fires under controlled conditions. Some species of *Proteaceae*, *Myrtaceae* and *Epacridaceae* may be termed keystone muturalists and are also vulnerable to disturbance. Many flower at a time of otherwise limiting food resources in the community. Many are also susceptible to dieback disease or inappropriate fire regimes. Such species are priority targets for research and management.

2.3 *Fauna*

The fauna is usually decisive in the choice and management of any conservation reserve. However detailed information on the distribution and abundance of all species is expensive to collect and is generally little used in practice, except for that relating to rare, endangered or vulnerable species. Fauna surveys are of benefit when the abundance of fauna is related to the distribution of defined habitats. This approach allows the development of a data base from which the occurrence of species can be predicted in similar habitats in other areas. Thus quantitative data on the distribution of fauna and corresponding information on the habitat enables a comparison of indices of animal abundance (density) from one locality to another. The ability to use information collected under one specific set of circumstances to predict animal abundance elsewhere is necessary.

The two sorts of information currently most requested and, when available, most readily applied by reserve managers are;

a. the identity location and extent of fauna rich areas.

b. the identity, location and extent of the preferred habitats and requirements of species that are either vulnerable to habitat perturbation or are rare and endangered.

2.3.1 *Wildlife Priority Areas*

The term wildlife priority areas (WPA) is coined for a locality either rich in fauna or supporting vulnerable, rare or endangered species. The logical basis for fauna management is a classification and an outline of the distribution of communities. This should be considered at two scales. In the broad sense the most valuable areas are already known from the presence of particular species. At this scale; the designation of WPA's can define the most valuable areas for reservation in the face of conflicting interests and few resources (e.g. Urquhart 1987).

WPA's should also be considered at the scale of the most sensitive or valuable areas within a reserve. The priority is to ensure that WPA's can be predicted and that these areas be mapped. Braithwaite (1983) found 63% of the individuals of seven arboreal mammal species were found in 9% of a forest area studied in NSW. This pattern was related to nutrient distribution. Nutrient rich areas could be mapped from vegetation types. If the agents governing the pattern of distribution are known, further areas can be determined, suitable sites artifically created and translocation programmes carried out.

2.3.2 *Fauna vulnerable to disturbance*

Some species of fauna require special consideration in respect to perturbation for conservation of populations at a regional level. Vulnerable species are defined with respect to their habitat requirements as those species that are;

(a) dependent on habitat components that can be eliminated or diminished by disturbance events or

(b) dependent on particular successional stages triggered by disturbance events.

Vulnerable species tend to have low population densities (constitutionally rare), be specialists of patchily distributed habitat or successional states, or have low dispersal ability. Species may be vulnerable at their range periphery and resilient near their range centre.

Vulnerablity can be exascerbated by;

(a) fragmentation of habitat

(b) the introduction of, or failure to control, pests and diseases

(c) inappropriate management regimes or activities.

Lists of species considered as vulnerable and therefore requiring specific consideration in management should be completed for each reserve. An accurate knowledge of the current distribution of vulnerable species, assessment of the factors influencing their vulnerablity and thus guidelines for their management are necessary for the effective management of fire on conservation lands. The factors governing the distribution of species must be understood if conservation programmes are to be effective as distributions change with time (Bowers 1986, Rosenweig and Abramsky 1985). A knowledge of the spatial variation in density of vulnerable species is necessary because species are usually more vulnerable to environmental perturbations at the edge of their ranges (Hengeveld and Haeck 1981, Hengeveld and Haeck 1982, Kavanagh and Kellman 1986).

2.3.3 *The role of monitoring*

Monitoring programmes may be necessary to detect populations changes. However, such programmes tend to be of little scientific or practical value unless accompanied by corresponding environmental information that allows the process responsible for population changes to be identified. Similarly the monitoring must have an explicit hypothesis to be successful in determining whether criteria are being met. It follows that the organism appropriate to the hypothesis should be identified and monitored.

Monitoring of particular species will be of advantage if a relationshp exists between the abundance of several species at any time. Thus low numbers in one species may suggest reason for concern in others. The spatial variation in density and thus comparative suitability of monitoring sites should be known before the establishment of monitoring programmes.

FIG 2 HERE

Fig. 2 shows trapping results in three years in two reserves known to include populations of the

Woylie (*Bettongia penicillata*), common Brushtail Possum (*Trichosurus vulpecula*) and Southern Brown Bandicoot (*Isoodon obesulus*). Different trapping rates for woylies in the two reserves suggest different sized populations. However population sizes are not static suggesting a need to plan operations designed to manipulate habitat that may be potentially disruptive in the short term. Some species are not as readily trapped as others. If high population densities of easily trapped animals such as the woylie reflect high populations in other species, the role of monitoring can be readily defined.

3. Interactions between fire, reserve users and neighbours

Management of fire is influenced by political and social factors and objectives for reserve management generally reflect societies prevailing attitudes and ideas. The cultural environment therefore has considerable influence on the detail of management practices. Fire regimes are a product of the cultural and biological system and cannot be separated from concepts of fire and human history

(Pyne 1982). Major changes in the attitudes of the community towards fire have taken place in the last 150 years in southwestern Australia (McCaw and Burrows in press); such changes will no doubt continue in the future, probably at an accelerated rate.

Government agencies responsible for management of conservation lands generally must comply with a wide range of legislative requirements. These acts are therefore an essential part of the critical data requirements. For fire management of conservation lands in Western Australia the Conservation and Land Management Act (1984) and the Bushfires Act (1954) are particulary important. The Wildlife Conservation Act (1950) is also significant as it requires that managers must seek specific ministerial approval for operations, including fire, which may result in the taking of plant species gazetted rare under the act.

Many conservation reserves are subject to additional land uses, ranging from passive recreation to open cut mining; illegal activities such as wildlife poaching may also have to be taken into account in some cases. Information about the distribution, extent, nature and timing of these activities is critical, both for determining the risk of ignition posed by these activities, and for determining the degree of hazard to which land users may be exposed during fire. In many instances land use patterns change rapidly according to social, economic and political considerations, and the data base will need to be regularly updated. Data may be collected by a wide variety of techniques including visitor survey, ranger patrols and remote sensing.

All reserves have neighbours, whether they be private landholders, shires, other government agencies or the crown. To be effective fire management must be planned on a regional basis, and for this reason the attitudes and policies of neighbours towards fire may have an important bearing on management of fire in a reserve. Effective liaison and participation with volunteer bushfire brigades, local authorities and public interest groups should be fostered as a means for gauging local opinion. In many cases reserve managers may be able to obtain much useful information about a reserve from local people with long experience in the district.

4. Priority rating system

Many factors limit the capacity of managers to undertake all fire management operations considered desirable and priorities must therefore be assigned to ensure that resources are deployed efficiently. Systematic evaluation of the risk of fire ignition and of the hazards posed by fire to different values provides a logical basis for allocating priorities. Hazard rating systems have been developed for national parks in eastern Australia (Good 1985) and forest areas in Western Australia (N. Burrows, pers. comm.). Once maps of relative hazard can be generated for individual reserves, appropriate steps can be taken to modify or reduce the level of hazard. Areas which should receive priority allocation for reduction of hazard levels include those where life, valuable property assets and significant biological values are involved. Hazard reduction is often considered by some to be synonomous with fuel reduction burning but this need not be the case and a range of options should be evaluated. These options may range from employing an alternative means of fuel modification to relocation of the asset itself away from the perceived hazard.

5. Management in the absence of data

The provision of the minimum data set suggested here for the effective management of conservation reserves may take many years to compile even for a single reserve. To the extent that this is an interim paper on the critical requirements of data for conservation reserves so too must all management plans be considered as interim. Management will continue, even in the absence of critical data and interim plans are therefore of considerable importance. Necessary management operations can continue even while we know little of the biological pattern and processes of the reserve. To this end management should be conservative in its approach and employ the following directions;

(1) oppose disruptive activities in the reserve (e.g. mining, damaging recreational use, activities encouraging weed or pest invasion).

(2) heal the scars of disruptive activities (e.g. attend to pest problems, rehabilitate gravel pits, close poorly sited access tracks, ensure good fencing between neighbours with different land use policies, ensure demarkation).

(3) take action to prevent the entire area of any single vegetation type being burnt at the one time.

(4) liaise with neighbours, encourage a feeling of sensitivity and their interest in the reserve.

(5) encourage the gathering and dissemination of a critical data set for the reserve.

(6) ensure that there is sound justification for every management operation and that the effectiveness of all operations are documented and monitored.

(7) be prepared to move with the times and update management plans as information comes to light.

(8) adopt a strategy of experimental management (Gill 1986, Hopkins and Saunders 1987) where variations of current operations are tried and monitored.

(9) Avoid undertaking large scale operations pre-emptive of a management plan (e.g. major new roadworks on secondary roads, broadscale burning of sensitive areas) until public input on such operations has been obtained.

(10) Ensure a thorough public involvement in the management plan process. Local people often have critical data and ideas about the management of reserves for which they have taken a special interest or to which they are neighbours.

CONCLUSION

The minimum data requirements in the management of fire on conservation lands is a broader topic than is usually addressed in the compilation and field implementation of fire management plans. Too frequently fire management plans do not adequately account for important factors of the cultural and biological environment because of a lack of data and instead are dominated by considerations of hazard or the influence of specific groups concentrating on single issues. Critical data needs increase with time and public interest. It is therefore essential to define those aspects of the biological, physical and cultural environment that must be researched first to ensure that management concentrates on key issues and is able to become more sophisticated as the needs increase. In the absence of critical data requirements conservative management strategies should be adopted that enable more effective management to be readily applied as reliable data comes to hand. Our goal of fire management should be to accommodate the requirements for protection with those of the biological and cultural environment according to sound ecological principles.

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Captions to Figures and Plate

Fig. 1 Scale in landform soils mapping: An area of the Perup RFPA mapped at 1:250 000 and 1:25 000. *Gastrolobium bilobum* (heartleaf) has the potential to form thickets on subunits defined at the finer scale enabling the prediction of potential thicket extent.

Fig. 2 Trapping results using box traps in three years in the Perup RFPA and Dryandra State Forest.

Plate 1 A stand of *Banksia seminuda* subspecies remenans killed by fire in the Walpole-Nornalup National Park. Abundant seedlings have replaced the old stand.

Fig 1

Landform Units at a 1:250 000 Scale After
Landform Units of the Darling System

Dwellingup; Gently undulating landscape with duricrust on ridges; sands and gravels in shallow depressions. Dw

Coolakin; Valleys of the eastern part of the plateau; sandy and gravelly duplex soils on the slopes; narrow valley floors; some rock outcrops. Ck

Catterick; Valleys of the south-eastern part of the plateau; yellow duplex soils and red earths on slopes; narrow alluvial terrace. Cc

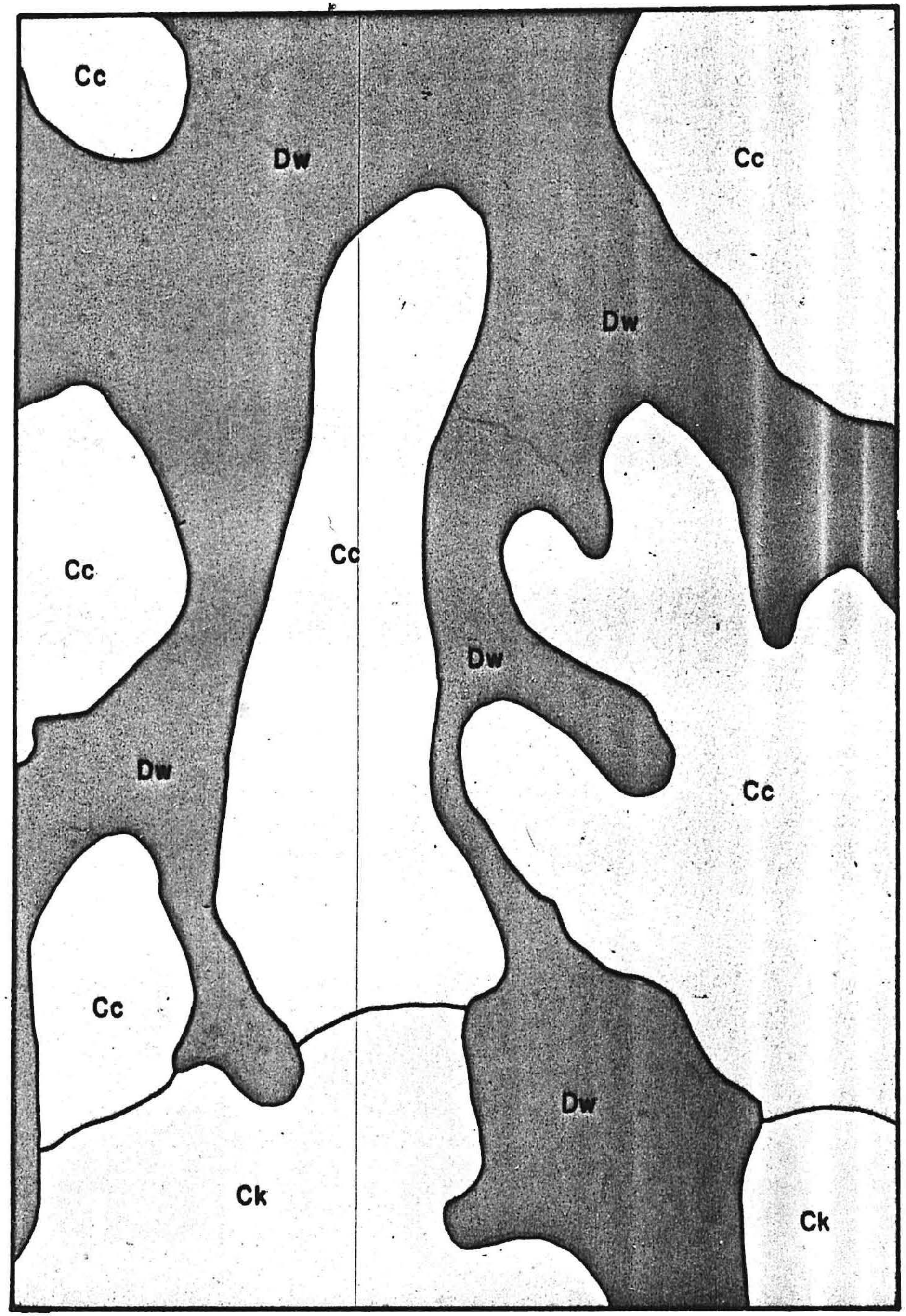
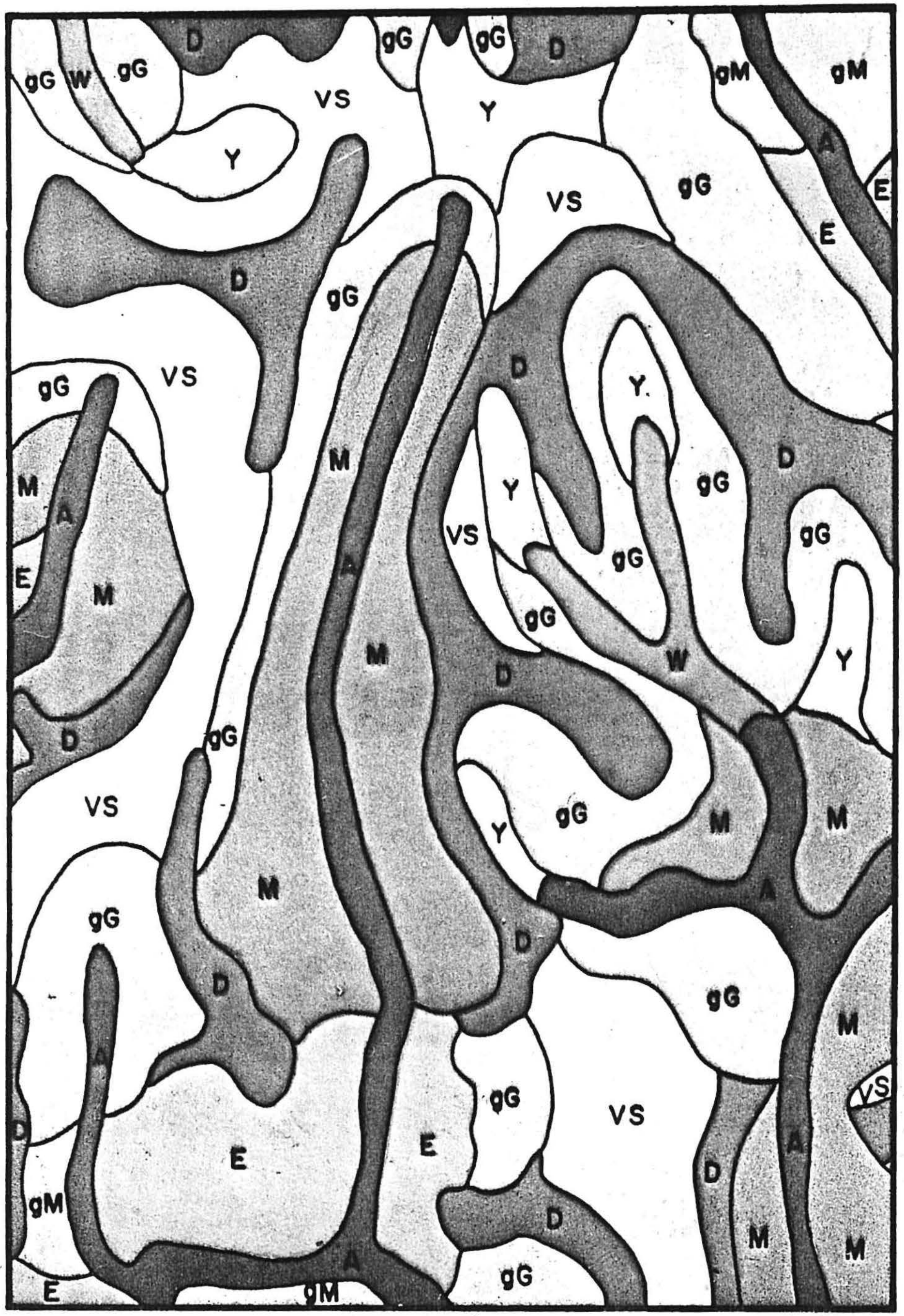


Fig 1

LANDFORM UNITS AT A 1:25,000 SCALE, WITH LANDFORM CLASSIFICATION TAILORED TO *GASTROLOBIUM BILOBUM*



D	Frequent outcrops of lateritic duricrust. Generally on ridge crest zones often as low broad rises but sometimes as a zone upslope from major breaks of slope.
VS	Broadly concave upland surface. Long very gentle slopes are common. Dominated by coarse or fine gravelly sands. Some pockets of yellow sand. Some unmapped areas of lateritic duricrust.
Y	Deep yellow sand in local hollows and the upper ends of valleys.
WS	Very light grey deep sands near the upper ends of the valleys.
W	Upper minor valley floors. Orange earths, silty sands and some pale brown sands on clay subsoils.
VW	Valley floors down stream from W, mainly pale brown sands on clay subsoils.
gG	Gentle slope with very gravelly surface soils. Trace of lateritic duricrust.
gM	Moderate slopes with gravelly red brown and grey brown sands loams over yellow and brown clays.
M	Moderate slopes with light red brown and grey brown sandy loams over yellow brown and red brown clay subsoils.
E	Moderate to steep slopes. Some exposed country rock, usually granite or dolerite. Light red brown to yellow brown sandy loams over red brown to yellow brown clay subsoils. A narrow zone of alluvium as a valley floor.
A	Brown sandy loam on an alluvial terrace occupying a narrow valley floor.

Fig 2

TRAPPING RESULTS FROM TWO RESERVES SHOWING SIMILAR TRENDS IN NUMBER OF ANIMALS TRAPPED