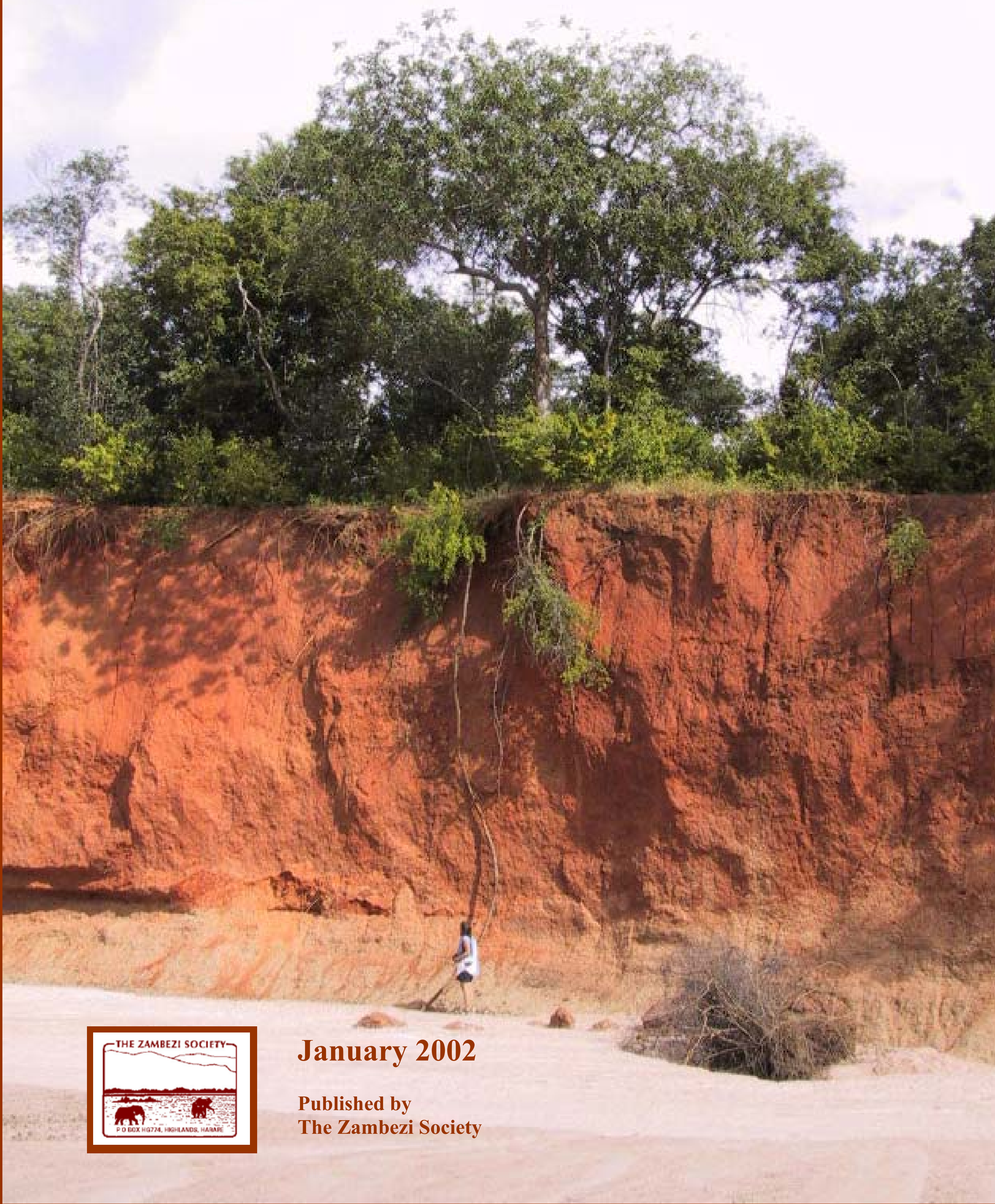
STRUCTURE AND CONDITION OF ZAMBEZI VALLEY DRY FORESTS AND THICKETS



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by

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The Zambezi Society is a non-governmental membership agency devoted to the conservation of biodiversity and wilderness and the sustainable use of natural resources in the Zambezi Basin

THE ZAMBEZI SOCIETY

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FOREWORD

This report has a series of complex relationships with other work carried out by The Zambezi Society. Firstly, it forms an important part of the research carried out by the Society in connection with the management of elephants and their habitats in the Guruve and Muzarabani districts of Zimbabwe, and the Magoe district of Mozambique. It therefore has implications, not only for natural resource management in these districts, but also for the transboundary management of these resources. Secondly, it relates closely to the work being carried out by the Society and the Biodiversity Foundation for Africa on the identification of community-based mechanisms for the conservation of biodiversity in settled lands. Thirdly, it represents a critically important contribution to the Zambezi Basin Initiative for Biodiversity Conservation (ZBI), a collaboration between the Society, the Biodiversity Foundation for Africa, and Fauna & Flora International. The ZBI is founded on the acquisition and dissemination of good biodiversity information for incorporation into developmental and other planning initiatives. The Zambezi Valley dry forests and thickets are of regional biodiversity importance; this project was implemented within the ZBI transboundary pilot area and will, we trust, have major and positive implications for the conservation of these valuable forest and thicket types. We thank the Royal Netherlands Government for its support, not only for this project, but for the overall suite of elephant research projects in the area, of which it forms a vital component

DICK PITMAN
Director,
The Zambezi Society

PROJECT PARTICIPANTS

The field work in this project was carried out by Richard Hoare, Fay Robertson, Kevin Dunham, Jane Hunt, Ian Riddell and John Kambuzuma. This report was compiled by Richard Hoare, Fay Robertson, Kevin Dunham, Dick Pitman and Sally Wynn.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Patches of dry deciduous lowland forest, botanically classified as *Xylia torreana* dry forest, grow on deep, unconsolidated red sands in the Zambezi Valley. Surveys during the late 1990s identified these habitats as a conservation priority owing to their small areas, probable high biodiversity levels, and threats from both communal farming and elephant browsing.

More recent studies of the elephant population in the Zimbabwe- Mozambique border area confirmed that dry forest patches are important habitats which act as elephant refuges, providing protection from human disturbance and serving as daytime "hideouts" for nocturnal crop-raiding.

The present study aimed to improve knowledge of biodiversity within the dry forests; identify indicators of forest condition; and evaluate conservation issues associated with the forests, including the effects of disturbance by humans and wildlife. A rapid assessment method was used to record vegetation structure, indicators of forest health (condition) and evidence of disturbance by people and wildlife.

A provisional sampling protocol was drawn up to record indicators in four categories: plant species; forest structure; forest condition; and disturbance in the forest. Satellite imagery, existing aerial photography and on-site aerial reconnaissance were employed to identify sampling transects for data collection on the ground.

Thirty-one transects were sampled on foot by a team of experienced naturalists in seven different dry forest sites, half of the transects in communal lands and half in protected areas. Six sites were in Zimbabwe and one in Mozambique, although all were close to the international border, which is no barrier to wildlife movement. Results indicated that these patches consist of thicket/forest mosaics of at least three structural vegetation types:

- Forest,
- Thicket with emergent trees, and
- Thicket.

The data collection protocol has been refined and simplified for use by local conservation authorities in other forest sites.

Disturbance levels by humans within the forests were generally low, but fire and over-exploitation of certain tree species were noted as potential problems for monitoring. Encroachment of farming at the edges of those forest patches where the neighbouring soils are fertile and more suitable for cultivation is the most serious anthropogenic threat, affecting the integrity of the forest - savanna ecotones.

Unfortunately, it was not possible to use a time-series of aerial photographs to test the "structural change hypothesis", which implicates tree removal by elephants in a process of cumulative structural change to dry forests, especially in areas of high elephant density such as the Mana Pools National Park. Other evidence suggests that while elephants have changed and continue to change the structure of this vegetation, it is thicket with emergents, rather than dry forest, that has been lost in Mana Pools..

There is scope for specialist investigation of certain taxa in the forest/thicket patches, particularly of the fungi and perhaps lepidoptera.

Dry deciduous lowland forests are rare and threatened wherever they still occur and their conservation is of global importance because they are poorly represented in protected areas. This study confirmed that the Zambezi valley examples have particular conservation significance in southern Africa.

1:INTRODUCTION

1.1 JUSTIFICATION FOR THE STUDY

Dry deciduous lowland forests are a rare and threatened vegetation type and their conservation is of global importance because they are poorly represented in protected areas (Olsen & Dinerstein 1998).

The Zambezi valley examples are known to be fairly species-rich in plants (Muller & Pope 1982, Timberlake & Cunliffe 1997) and may be important for some bird, small mammal, reptile or invertebrate species, or other fauna which are not common elsewhere. Therefore these sites have particular conservation significance in southern Africa.

The Zambezi Society and a partner organization, the Mid-Zambezi Elephant Project, have been conducting research on elephant distribution and movement in the mid-Zambezi valley since 1997. This has revealed a shared elephant population ranging across areas of communal land and Parks & Wild Life Estate in Zimbabwe, and extending into Magoe District, south of Lake Cabora Bassa, in Mozambique. Studies of radiocollared elephants show that dry forests are well-used parts of this elephant range (Zambezi Society 2000).

Most of the dry forest patches are relatively small, being less than 50 km^2 in area. They are being affected to varying degrees by human activity, wild herbivores - notably elephants - or both. In some discrete dry forest patches that are unaffected by human settlement, elephant browsing may be implicated in a process of cumulative structural change: some dry thickets in the Zimbabwe Parks & Wild Life Estate of the Zambezi valley may once have been dry forests (see definitions below) and elephants may have been responsible for their conversion over many years (Th. Muller pers. comm, Timberlake & Cunliffe 1997). For example, the thickets growing on deep sands in the Mana Pools National Park may once have been dry layered forests. By destroying large trees and creating paths, elephants may have altered the structure of the earlier forest and encouraged the growth of a dense shrub layer of *Combretum* bushes (Muller & Pope 1982, Timberlake & Cunliffe 1997). But to date, no investigations have been carried out on this topic and so the idea remains unsubstantiated.

The Zambezi Society therefore developed the present project. It was designed to improve knowledge of biodiversity within Zambezi Valley dry forests; identify indicators of forest condition; and evaluate conservation issues associated with the dry forests, including the effects of disturbance by humans and wildlife.

The initiative was made possible through a short-term extension to funding of the Zambezi Society's elephant research project (Zambezi Society & MZEP 2000) by the Royal Netherlands Government.

1.2 DEFINITIONS

After a reconnaissance visit, it was considered important to define this vegetation type and to distinguish between its variations. Dry deciduous forests and dry deciduous thickets both occur on well-defined patches of acidic sandy soil, geologically described as “unconsolidated red sands”. These ancient sand deposits often occur in convex shapes known as “lenses” (Broderick 1990). The vegetation has several height layers, the lower ones usually being dominated by multi-stemmed, early-deciduous shrubs.

Strictly speaking, a forest has a canopy of trees whose crowns interlock at 10 m or higher, with variable lower layers; whereas a thicket has a canopy between 3-7 m tall, formed by the interlocking branches of small trees and multi-stemmed bushes. The presence of emergent trees, over 10 m tall and protruding above the canopy or shrub layer, is often a feature of thickets.

The habitat patches of interest are often termed “dry forest”, but there are really three variations of this vegetation type, with the distinctions being based on these structural differences more than on species composition. The three types are:

- Dry forest (with a distinct canopy over 10 m tall);
- Dry thicket (with some emergent trees over 10 m tall); and
- Dry thicket (without emergent trees).

Confusion between these variations can easily arise because:

- The three variations of dry forest usually occur as a mosaic within any one habitat patch;
- They are separated by "intergrades"; and
- Colloquial terms are often used; for example, both thicket and forest, whether riverine or not, are referred to in the Zambezi valley as "jesse" bush – probably derived from the Shona word for this habitat, Muchese.

1.3 CONSERVATION THREATS

There is a broad division in conservation threat to dry forests in the mid-Zambezi valley of Zimbabwe. The key species involved in this habitat modification are humans and elephants, and the impacts of this modification on other taxa of plants and animals are the most serious conservation concern.

The dry forests grow on sandy, infertile soils, not suitable for cotton or maize. If the forest is cleared, millet may be grown for a few years, using the short-lived fertility derived from nutrients that are released into the soil by the burning of trees and shrubs. Clearing for cultivation is most likely at the edges of dry forests and thickets, especially where the sands give way to more fertile alluvial soils.

The mechanism of dry forest conversion by elephants may have involved the loss of emergent and canopy trees, with a resultant increase in light penetration, an altered microclimate beneath the canopy and, in turn, a change in plant species composition. If a loss of plant diversity occurred, it may have resulted in a reduction in faunal biodiversity; and if the additional light destroyed the litter and humus layers, this would almost certainly have affected saprophytic fungi and soil invertebrates. But while some woody layers may have lost plant biodiversity, the herbaceous layer may show increased biodiversity, possibly of Lepidoptera, especially if the shrub layer was also opened up.

It is likely that if forest conversion has occurred, changes would be more obvious in the Mana Pools National Park and Sapi Safari Area, where elephant densities are fairly high; but less obvious or absent in the Dande Safari Area or Dande Communal Land, where elephant densities are less (Davies 1999). Previous work in Zimbabwe has highlighted substantial density-related effects of elephants on biodiversity in miombo woodlands across National Park-Communal Land boundaries (Cumming et al. 1997).

While excessive human and elephant pressures may be damaging in different ways, it is tentatively accepted in ecological thinking that some natural disturbance - or limited human disturbance - to forests may in fact help to maintain high biodiversity. This has been termed the "intermediate disturbance hypothesis" (Petraitis et al. 1989). Therefore the current levels of disturbance need to be quantified if possible and inferences made about "permissible" limits to disturbance.

1.4 OBJECTIVES OF THE STUDY

The objectives of the study were defined as: -

- To determine whether, in areas of with a high density of elephants, patches that are now dry thickets were previously dry forests, 45 years or so ago.

- To identify the current and future threats to dry thickets and forests and to quantify the extent and magnitude of current disturbances.
- To add to the floral and faunal inventories of dry forests and thickets (although many taxa will need further investigation during future expert surveys).
- To develop a protocol for the rapid assessment of the ecological condition of similar vegetation types elsewhere in the region.
- To present the preliminary findings to relevant local, national and regional authorities in Zimbabwe and Mozambique in order to encourage inter-district and international co-operation in conservation.

1.5 APPROACH ADOPTED

While the collection of biological specimens is quick and easy, species identification often requires specialist skills. But even when such expertise is available, species identification can be very time-consuming.

Therefore, given the short time available for this study, we decided not to attempt to compile species lists, but instead to record a variety of indicators of habitat structural diversity- vertical, horizontal and lifeform - as this is often a good predictor of species diversity (see references in Magurran 1988). We developed a rapid procedure for assessing structural diversity, vegetation type, disturbance and condition. As a result of this study, we have modified the procedure for use in similar thickets and forests elsewhere in the region.

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2. THE STUDY AREA

2.1. RECONNAISSANCE & TIMING

An initial reconnaissance of the mid-Zambezi valley in Zimbabwe was made during February 2001, to check the size and appearance of forest and thicket patches, the species of importance in them, the road access to them, and the ease of movement and visibility on foot in the dense vegetation.

On return from the reconnaissance, a provisional sampling protocol and an accompanying datasheet were prepared. Some subsequent aerial reconnaissance was carried out using The Zambezi Society's light aircraft, and an application was made to the Zimbabwean Department of National Parks to undertake research within the Parks and Wild Life Estate. The co-operation of the provincial authorities in Tete, Mozambique, was also secured in order to facilitate data collection in Magoe district. The data collection survey took place during April 2001. April is the best time of year for botanical surveys in southern Africa: the rainy season, during which access is difficult, has normally ended, but the dry-season leaf fall has not yet begun. All plants are therefore still in leaf, and thus identifiable.

2.2. SURVEY SITES

The study sampled thickets and forests in communal lands and protected areas. Five sites were situated in Communal Lands and two in Protected Areas (Figs 1 & 2), but the distribution of sampling between the two land-uses was virtually equal, with 16 transects in Communal Lands and 15 in Protected Areas. The following are the local names and botanical descriptions (in parentheses as per Timberlake & Cunliffe 1997) of the sites sampled.

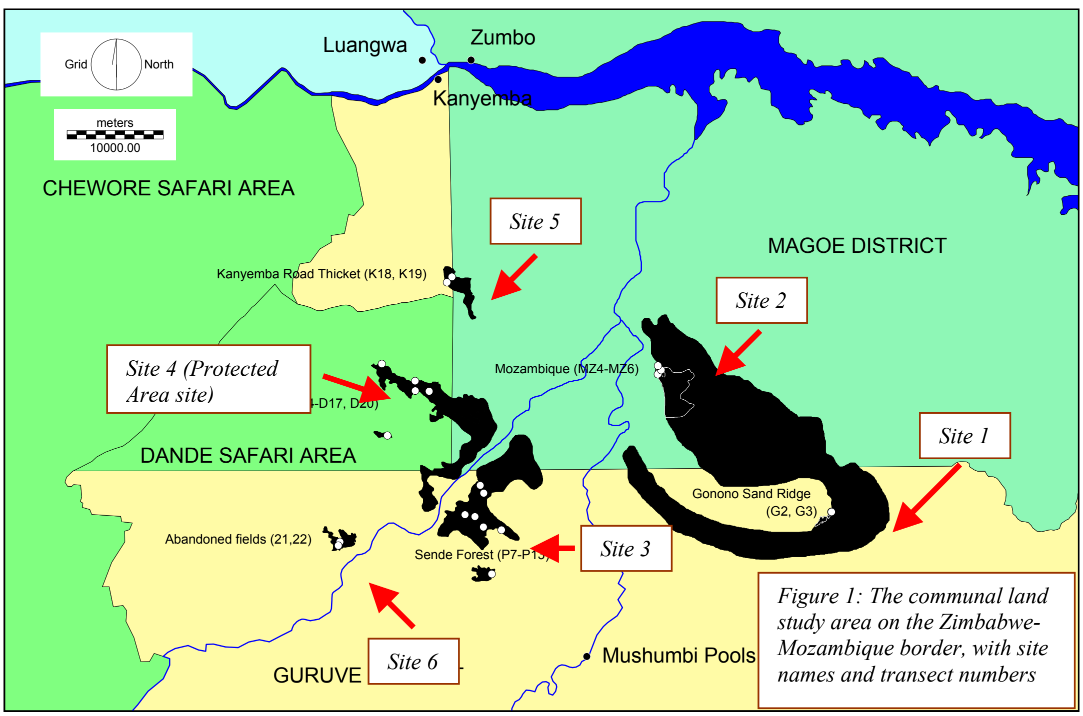

Figure 1: The communal land study area on the Zimbabwe-Mozambique border, with site names and transect numbers

2.2.1. Communal land sites

Site 1: The "Gonono Sand Ridge" (wooded bushland with small patches of *Xylia* dry forest) in the northern part of Dande Communal Land in Zimbabwe (Ward 4, Chiriwo, Guruve District)

Site 2: "Mozambique" the border area of Magoe District, Mozambique, adjacent to the Gonono sand ridge.

Site 3: The "Sende Forest": (dry layered forest), Dande Communal Land, on the south bank of the Angwa River (Ward 2, Chisunga, Guruve District).

Site 5: The "Kanyemba Road Thicket": (wooded bushland with occasional patches of *Xylia* dry forest [although we found no dry forest here]) between the Dande Safari Area and Kanyemba (Ward 1, Chapoto, Guruve District).

Site 6: "Abandoned fields": (thicket with emergents) small thicket patches, situated on the Kanyemba road between the Dande Safari Area and the Angwa River (Ward 2, Chisunga, Guruve District).

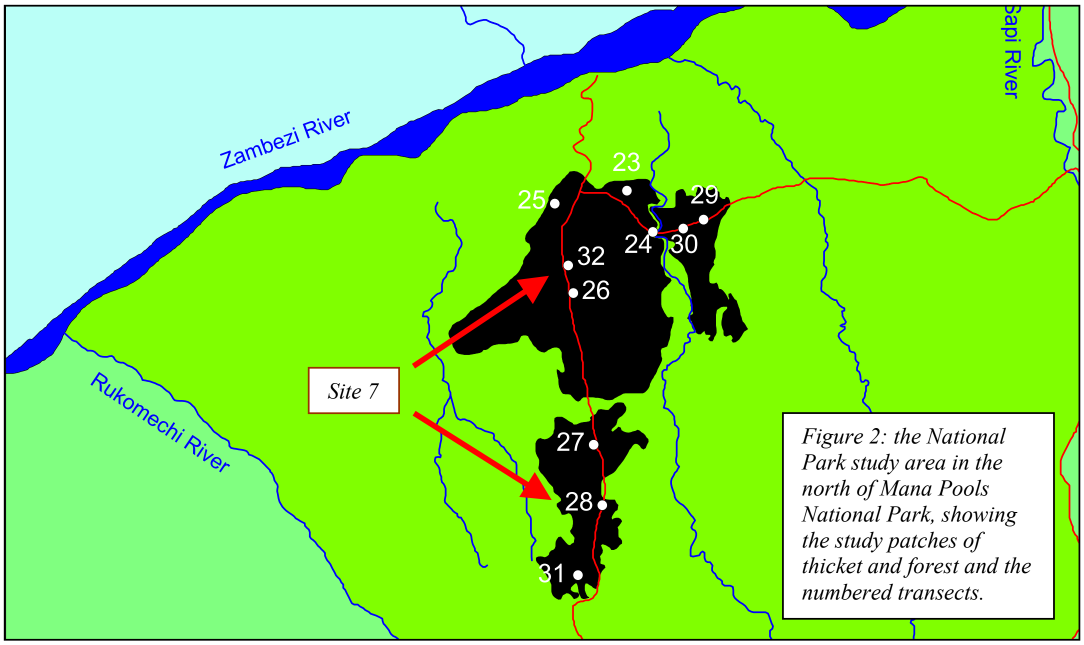

Figure 2: the National Park study area in the north of Mana Pools National Park, showing the study patches of thicket and forest and the numbered transects.

2.2.2. Protected area sites

Site 4: The "Dande Forest": (*Xylia/Pterocarpus lucens* forest fringed by *Combretum* thicket), on the north bank of the Angwa River in the Dande Safari Area, Guruve District (almost contiguous with the Sende Forest).

Site 7: The "Mana Pools Thickets": situated near the main central access road in the Mana Pools National Park (NP), around the park airfield and on either side of the Chiruwe River to the south-east of Nyamepi camp.

2.2.3. Comparability of sites

Valid comparisons between National Park and Communal Land sites are dependent on soil properties and rainfall being similar at the two sites. Accordingly, soil surveys (Anderson 1987, Bennet et al. 1985), geological information (Broderick 1990) and rainfall records (Department of Meteorological Services) were consulted. Although the patches of deep unconsolidated sands on which this vegetation grows may have slightly different geological origins in the Mana Pools National Park and the Dande Communal Land, the soil properties are sufficiently similar to make comparisons valid (T. Broderick pers. comm.). All the *Xylia* dry forests and thickets grow in areas that have fine- to medium-grained, reddish, loamy sand topsoils, overlying reddish, unusually acid (pH about 4), sandy loam subsoils.

The study sites are situated on an east-west axis of about 150km. The prevailing winds are easterly and much of the seasonal rainfall comes from the east. The Chewore Hills are situated between the Communal Land and National Park sites, but examination of the available records (1963-1993) revealed that mean annual rainfall at Kanyemba (690 mm) was similar to that at Mana Pools (739 mm).

3. MATERIALS & METHODS

3.1. SATELLITE IMAGERY

LANDSAT colour imagery (Landsat TM; scale 1:400 000; May 1998; bands 4, 5, 3, RBG) covering the east of the study area was available. Dry forest patches are clearly visible on this image, which provides a good indication of the abundance and cross-border distribution of this vegetation type.

In addition, commercially-available panchromatic composite images from SPOT scenes dated 1992 were purchased from the Surveyor-General's office for the entire study area. These are georeferenced to the mapping grids used in Zimbabwe (both latitude & longitude and UTM) and have a convenient 1:100 000 scale, at which the heavily-vegetated dry forest patches show readily in dark shades. Dry forest patches on the SPOT images (Zimbabwe) and LANDSAT images (Mozambique) were electronically scanned. These new images were georeferenced and patch areas measured in km^2 after digitising the patch boundaries with the computer program CARTALINX.

3.2. AERIAL PHOTOGRAPHS

Since the 1950s, the Zimbabwean Surveyor General's Department has taken a series of panchromatic, vertical air photographs of Zimbabwe at intervals of 5 to 10 years. If structural types of vegetation could be distinguished on the earliest photographs, it would be possible to test the hypothesis that the present Mana thicket was dry forest during the 1950s, when elephant densities were relatively low. Photographs of the dry forest patches were purchased from the Surveyor-General's office, or borrowed from the research section at the Mana Pools National Park. The photographs consulted were taken during 1954, 1973 and 1981, but unfortunately these varied in both coverage and scale (details in Appendix A). The photographs were examined with a stereoscope (Wild ST4 with 3x and 8x magnifying oculars with individual focus) to determine canopy cover and the relative densities of emergent trees in different years.

3.3. AERIAL RECONNAISSANCE AND MEASUREMENTS

Reconnaissance flights were conducted over the forest patches prior to entering them on the ground. Possible sample transects, selected from satellite images and aerial photographs, were inspected from the air. The botanist and the pilot selected locations for several transects within each patch, in such a way that while each transect remained within a single structural type, the range of structural types within a patch was covered by different transects. Within these limitations, transects were always located in positions that were easily accessible by road. After a number of transects had been completed at one site, the straight-line distance from the starting point of each transect to the edge of the nearest human settlement was measured using a Garmin 92 Global Positioning System (GPS) receiver mounted in the aircraft.

Table 1. Summary of sample site characteristics

Site name	Site number (Figs. 1 & 2)	Land use type *	Patch areas (km^2)	Number of transects	Distance to human settlement (range, in km)
Gonono Forest	1	CL	0.8 **	2	4.5 – 4.7
Mozambique	2	CL	12.5	3	0.4 – 0.8
Sende	3	CL	2.5; 23.4	7	0.2 – 4.2
Dande	4	PA	0.7; 21.1	5	9.6 – 13.4
Kanyemba Road	5	CL	6.4	2	8.7 – 9.4
Old Fields	6	CL	3.8	2	0.9 – 1.2
Mana Pools	7	PA	14.1; 24.3; 65.3	10	>50
TOTALS:	**7**			**31**	

* CL = Communal Land; PA = Protected Area

** Gonono Sand Ridge consists mainly of bushland, but with two smaller areas of dry forest (G2 and G3 on Figure 1).

3.4. DATA COLLECTION

In the provisional sampling protocol, assessment was based on four categories of data (Table 2).

Table 2. Data categories in dry forest assessment

Category	Number of indicators	Details
Indicator plant species	30	Table 3
Indicators of structural diversity	11	Table 4
Indicators of forest disturbance	10	Table 5
Indicators of forest condition	6	Table 6

Earlier work (Guy 1977, Muller & Pope 1982, Du Toit 1983, Timberlake & Mapaure 1992, Cunliffe 1995, Timberlake & Cunliffe 1997) was used to draw up a list of woody species (Table 3) that were believed to be:

- indicators of either forest or thicket structure; or
- common dominants in the shrub layer, the canopy layer, or as emergent trees; or
- known to be especially vulnerable to disturbance by elephants, fire, or people; or
- rare or endemic.

Some species qualified as indicators on more than one count. Species included in Table 3 were utilised for the evaluations of structural diversity, forest disturbance and forest condition in Tables 4, 5 and 6.

Table 3. Zambezi dry forest assessment: list of woody plant species and justification for their use as indicators

Forest Layer	Indicator Species	Justification
Tree	*Pterocarpus lucens*	Forest canopy tree Vegetation type indicator Fire vulnerability Elephant vulnerability (debarking)
	Adansonia digitata	May support many other lifeforms Elephant vulnerability
	Schinziophyton rautanenii	Forest canopy tree
	*Entandrophragma caudatum**	Forest canopy tree
	Pteleopsis species	Forest canopy tree Vegetation type indicator Elephant vulnerability (debarking)
	Balanites maughamii	Indicator of complex vertical structure Preferred browse species Elephant dispersed
	*Afzelia quanzensis**	Timber tree
	Berchemia discolor	Common emergent Possible indicator of destroyed forest
	Acacia nigrescens	Elephant vulnerability (debarking)
	*Boscia mossambicensis**	Elephant vulnerability (debarking)
	*Diospyros quiloensis**	Abundant emergent Timber tree
	Commiphora karibensis	Indicator of simple vertical structure Reportedly felled by elephants
	Other *Commiphora* spp.	Reportedly felled by elephants
	Kirkia acuminata	Common emergent tree
	Xeroderris stuhlmannii	Common emergent tree

Table 3 Cont'd

Forest layer	Indicator species	Justification
Tree	*Xylia torreana*	Dominant tree Vegetation type indicator
	*Strychnos decussata**	Common emergent tree Elephant vulnerability (debarking)
	Schrebera trichoclada	Common emergent tree Indicator of simple vertical structure
	Combretum collinum	Elephant vulnerability (felling)
Climbing shrub	*Strophanthus kombe*	Vegetation type indicator
Liane	*Combretum kirkii*	Indicator of complex vertical structure Zambezi endemic
Shrub	*Monodora junodii*	Indicator of complex vertical structure
	Acacia ataxacantha	Vegetation type indicator
	Cleistochlamys kirkii	Abundant shrub Possible indicator of destroyed forest
	Meiostemon tetrandrus	Dominant shrub Vegetation type indicator Elephant browse
	Neoholstia tenuifolia	Indicator of complex vertical structure
	*Croton scheffleri**	Dominant shrub Vegetation type indicator Not browsed by elephant
	Combretum celastroides	Dominant shrub Vegetation type indicator Elephant browse
	Combretum eleagnoides	Dominant shrub Vegetation type indicator Elephant browse
	*Citropsis daweana**	Vegetation type indicator
	*Dalbergia martinii**	Vegetation type indicator
	Fagara/Zanthoxylum sp.	Indicator of complex vertical structure
	Zanthoxylum lepriurii	Indicator of complex vertical structure
	Xylotheca tettensis	Indicator of complex vertical structure Rare in Zimbabwe
	Karomia tettensis	Indicator of impoverished thicket
	Acacia eriocarpa	Indicative of bushland cf. thicket
	*Combretum apiculatum***	Vegetation type indicator
	*Baphia massaiensis***	Vegetation type indicator

Vegetation type indicator = characteristic species of *Xylia torreana* dry forest and thicket.
* Species included as a result of this work, but not included in the initial list
** Species omitted from final list of indicators as uncommon or uninformative

Table 4. Zambezi dry forest assessment: indicators of structural diversity

Forest layer	Indicator	Indication of:	Measurement scale
All	Woody layers*	Vertical structural diversity	Number of layers
Tree	Density of emergent (taller than 10 m) trees	Life form diversity	Number**
Tree	Tree cover	Diversity	% cover, estimated using crown: gap ratio
Shrub	Shrub cover	Diversity	% cover, estimated using crown: gap ratio

Table 4 Cont'd

Forest layer	Indicator	Indication of:	Measurement scale
Lianes	Other lianes (lianes other than *Combretum kirkii*)	Life form diversity	Number**
Epiphytes	Orchids, figs, ferns, mosses	Life form diversity	Number, by life form**
Tree	Standing dead trees	Substrate diversity	Number**
	Tree stumps	Substrate diversity	Number**
Ground	Logs	Substrate diversity, Absence of fire	Number**
Ground	Broad-leaved grass species	Horizontal diversity Low light penetration	% cover score, using Walker's scale ***
Ground	Narrow-leaved grass species	Horizontal diversity High light penetration High fire hazard	% cover score using Walker's scale ***
Ground	Forb cover	Horizontal diversity Low light penetration	% cover score using Walker's scale ***
Ground	Termite mounds*	Horizontal diversity	Number**

* included as a result of this work, but not measured initially
** Number is converted to density per standard transect (1000 paces x 20 metres)
*** Walker's scale (Walker 1976): **0** = none; **1** = 1-10%; **2** = 11-25%; **3** = 26-50%; **4** = 51-75%; **5** = 76-90%; **6** = 91-99%; **7** = 100%

Table 5. Zambezi dry forest assessment: disturbance indicators

Forest Layer	Indicator	Indication of:	Measurement Scale
Tree/ shrub	Elephant browsing of trees & shrubs	Elephant use	Number of plants affected, by species**
All	Alien species of woody plant	Human disturbance Stress	Presence, by species
Tree/ shrub	Wood chopping	Human use	Number of plants affected, by species**
Tree/ shrub	Stem debarking by elephant	Elephant use	Number of plants affected, by species**
Tree/ shrub	Stem debarking by people	Human use	Number of plants affected, by species**
Ground	Felled tree	Recent mortality of trees Causes of mortality	Number of plants affected, by species when identifiable**
Ground	Fire sign	Fire presence Human use	Presence/absence
Ground	Domestic animal dung*	Use by domestic livestock	Number of dung piles**
	Poaching sign	Human use	Number of instances**
Ground	Elephant path	Use by elephants	Number of paths crossed**
Ground	Elephant dung	Use by elephants	Number of dung piles**

* Included as a result of this work, but not measured initially

**Number is converted to density per standard transect (1000 paces x 20 metres)

Table 6. Zambezi dry forest assessment: condition indicators

Forest Layer	Indicator	Indication of:	Measurement Scale
Tree	Tree "stag-headedness"	Stress	Number of plants affected, by species*
Tree/ Shrub	*Xylia* atypical multistem development	Stress	Number of multi-stemmed plants among the first twenty *Xylia* plants encountered
Ground	Seedling establishment	Regeneration	Semi-quantitative, absent, few (1-10) or many (>10) by species
Ground	Litter cover	Loss of canopy protection Substrate diversity	Cover scores using Walker's scale**
Ground	Large mammal sign	Species diversity	Number of signs, by species*
All	Forest birds	Species diversity	Qualitative, all species seen or heard

* Number is converted to density per standard transect (1000 paces x 20 metres)
** Walker's scale (Walker 1976): **0** = none; **1** = 1-10%; **2** = 11-25%; **3** = 26-50%; **4** = 51-75%; **5** = 76-90%; **6** = 91-99%; **7** = 100%

3.5. GROUND SAMPLING

The ground team consisted of six people: a local guide, four data collectors and a recorder. The guide led the team in single file, moving through the forest at a slow walk, seldom following any established paths and heading roughly in a wide semicircle. If a transect was to start near the road access, a position about 30m into the forest was considered far enough to be free of the direct effects of the road. Some transects involved initial positioning by walking for up to half an hour from the road. The length of most transects was 1000 paces, each pace being noted on a manual tally counter. Transect start and end points were noted using a GPS and transect length recorded in metres from the GPS; the mean length of 1000 paces was 645 m. However, GPS was not used as the primary method of recording transect lengths for two reasons. Firstly, it was thought that satellite reception was likely to be erratic under forest canopies; secondly, as one of the project objectives is to develop methodologies that can be used by local monitors, the testing and use of the manual tally counter for measuring transect length was felt to be more technologically appropriate.

The width of the transect in which observations were recorded was an estimated 10m either side of the transect line; periodically, team members checked that their estimates of 10m agreed with each other. The time spent walking each transect was about 1-1.5 hours; with positioning delays, usually only two or three transects could be completed in one day. A total of 32 transects was undertaken in seven different forest patches (Figs 1 & 2) over a period of 13 days (the initial transect was used to test the methods and its results were not included in the analysis).

Data collection was divided amongst team members according to their specialist skills, and individual observations along transects were called out for recording on a customised datasheet (a modified version of which is given in Appendix B). Birds were recorded separately by a ornithologist using both sightings and calls. Taped bird calls were used at intervals to attract certain expected species with cryptic habits.

At the end of each transect, scores for indicators involving estimation of proportions (e.g. aerial cover of shrubs and trees, ground cover of litter) were agreed by consensus among team members, using "Walker's scale" of percentage categories (Walker 1976).

3.6. DATA ANALYSIS

All data were entered into a computer spreadsheet (Microsoft Excel 2000), giving a matrix of values for 31 transects by 57 indicators (Tables 3-6). Present and absent were recorded as 1 and 0 respectively.

Results were standardised for those indicators that were counted along transects, and the number counted per 1000 paces used as a density index. For these indicators, sampling was, in effect, in a belt transect and the approximate area of the belt transects can be calculated as the product of the mean estimated length of 1000 paces (645 m) and the estimated transect width (20 m), namely 1.29 ha.

3.6.1 Indicator plant species
A TWINSPAN classification was used to investigate whether the indicator species of plant that we had chosen were a useful guide to structural complexity and species diversity. The presences or absences of the indicator species in the 31 sampled plots were displayed in an objectively-derived two-way table that grouped like species with like, and like plots with like. Indicator species that occurred in just one or two plots were excluded from the analysis.

3.6.2 Structural diversity
The botanist classified the transects into structural types based on a combination of White's (1983) and Timberlake, Nobanda & Mapaure's (1993) definitions. The bracketed abbreviations are those used throughout this document for these structural types:

Bushland (B): an open stand of bushes, having a shrub canopy of 3-7m in height, often with occasional emergent trees and a canopy cover of 20-80 %. The only transect with a bushland structure was an old field abandoned two years previously.

Thicket (T): a dense stand of woody plants 3-7m high with a cover of 80-100 %, such that visibility is limited and human passage difficult.

Thicket with emergents (TE): as for thicket, but with numerous emergent trees protruding 2-3m above the thicket.

Intermediate between thicket with emergents and forest (TE/F).

Dry Forest (F): a closed, often multi-storeyed stand of trees with an interlaced upper canopy at least 10m tall, composed of species many of which are leafless during the dry part of the year.

Structural diversity was investigated further using an ordination based on a principal components analysis of the following structural features along all 31 transects: tree cover (%); shrub cover (%); density of emergents (number of emergents per 1000 paces); narrow-leaved grass cover (Walker's scale); broad-leaved grass cover (Walker's scale); aerial cover of all species in the family Euphorbiaceae in the shrub layer (Walker's scale); and aerial cover of all *Combretum* species in the shrub layer (Walker's scale). Values for the structural features were standardised and centred before analysis to make the different scales comparable.

-o-o-o-o-o

4. RESULTS

4.1. PLANT SPECIES INDICATORS

(See Table 7, page 14). Tree and shrub species may be classed according to whether they are most likely to be found in transects:

- In the Dande Safari Area, Sende and Mozambique (which fall on the left-hand side of the first vertical division of the table; or
- On the Gonono sand ridge, in old fields in the Dande Communal Area and in Mana Pools NP, on the right-hand side of this division; or
- Evenly distributed between the two groups.

On each side of the first major division, some species are more likely to occur in forest, in thickets with emergent trees, or in thickets. The following species groups were identified:

- ***Group A:*** Species usually present in the forests and thickets with emergents of the Dande Safari Area and Sende. Group A includes *Balanites maughamii, Monodora junodii, Neoholstia tenuifolia* and *Xylotheca tettensis,* the Zambezi endemic *Combretum kirkii*, and an as yet unnamed *Fagara* species. These species are seldom found in the Mana Pools National Park, or in thicket elsewhere.

  Species in group A are the most useful potential indicators of structural complexity and species diversity.

- ***Group B:*** *Berchemia discolor* and *Cleistochlamys kirkii,* which are found most frequently in the forests and thickets with emergents of the Dande and Sende. These two species also occur in the Mana thickets, but only in those plots which support many canopy trees.

  Thicket plots which support* Berchemia discolor *and* Cleistochlamys kirkii *may once have been forest (although additional evidence is required to support that hypothesis).

- ***Group C1:*** Species found along almost every transect, including the canopy trees *Xylia torreana, Pterocarpus lucens* and *Pteleopsis* spp., the shrubs *Meiostemon tetrandrus* , *Combretum eleagnoides, Combretum celastroides*, *Acacia ataxacantha* and the scrambling climber *Strophanthus kombe*).

  All transects in which four or more of the species in Group C1 are found might be classed as Zambezi Valley* Xylia torreana *dry forest or thicket.

- ***Group C2:*** Species which may occur in any location, but which are missing from many plots. Group C2 includes *Adansonia digitata, Xeroderris stuhlmannii* and the shrub *Baphia massaiensis*).

  The species in Group C2 are not useful indicators of structure or diversity.

- ***Group D:*** Species which are most likely to occur in Mana Pools NP. These species also occur occasionally in the Dande, Sende, Gonono and Mozambican plots, but generally not in plots that have a dense canopy of tall trees. Group D includes notably *Schrebera trichoclada* and *Commiphora karibensis*.

  Schrebera trichoclada *and* Commiphora karibensis *are indicators that a plot is probably structurally simple, without a forest canopy and with few emergent trees.*

Table 7. Indicator species occurrences in the transects of the Zambezi Valley forests and thickets, as classified and organised by TWINSPAN. Key to vegetation structural classes: F = Forest; TE = Thicket with emergents; TE/F = intergrade between TE and F; T = Thicket; B = Bushland.

* Borderline transects may have been misclassified

Transect no:	G2	MZ 5*	D14	P7	P9	P11	P12	K19	D20	D15	D16	K18	M Z6 *	P8*	P10	P13	D17	G3	MZ 4*	21	22	MN 25	MN 28	MN 27	MN 23	MN 24	MN 29	MN 32	MN 26	MN 30	MN 31	
Vegetation Structure	T	T	F	F	F	TE	F	TE	F	TE/ F	TE	T	T	T	TE	TE	TE	T	T	B	T	TE	T	TE	T	TE	TE/ F	TE	T	T	TE	**Species groups**
Indicator Species																																
Balanites maughamii	1	1	1	1	1	1	-	1	1	1	-	1	-	-	1	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	
Kirkia acuminata	1	1	1	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Fagara species	-	-	1	-	1	1	-	-	1	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Xylotheca tettensis	-	1	1	-	-	1	1	1	1	1	1	1	1	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Monodora junodii	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	**A**
Zanthoxylum lepriurii	-	-	-	1	1	-	1	1	1	1	-	1	-	-	-	1	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	
Neoholstia tenuifolia	1	-	-	1	1	1	1	-	1	-	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	
Combretum kirkii	-	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	
Combretum collinum	-	-	-	-	-	1	1	1	1	1	1	-	-	1	1	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	
Berchemia discolor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	1	1	1	1	-	-	1	**B**
Cleistochlamys kirkii	-	1	1	1	1	1	-	1	1	1	-	1	1	1	1	1	1	-	1	-	-	-	-	-	1	1	1	-	-	-	-	
Pterocarpus lucens	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	-	-	1	**C1**
Adansonia digitata	-	-	1	-	-	1	1	1	1	1	1	1	-	-	1	1	1	-	-	1	1	1	1	-	-	1	-	1	-	-	1	
Baphia massaiensis	-	-	1	-	-	1	1	-	-	1	-	1	-	1	-	1	1	-	-	-	-	-	-	-	-	-	1	1	-	1	1	**C2**
Xeroderris stuhlmannii	1	-	-	-	1	1	1	1	1	-	-	-	1	1	1	1	1	1	-	1	-	1	1	1	-	1	-	1	1	-	-	
Acacia ataxacantha	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	
Combretum eleagnoides	1	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1	
Xylia torreana	1	-	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Pteleopsis spp.	1	1	1	-	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1	**C1**
Combretum celastroides	1	1	1	-	1	1	1	1	1	1	1	1	-	1	1	1	1	-	1	1	1	1	1	1	-	1	1	1	1	1	1	
Meiostemon tetrandrus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Strophanthus kombe	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Commiphora spp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	1	-	-	-	-	1	-	-	-	-	-	-	-	**C2**
Acacia nigrescens	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-	-	-	-	
Commiphora karibensis	1	1	1	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	1	-	1	1	-	-	1	-	-	1	-	-	-	**D**
Schrebera trichoclada	1	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	1	-	-	-	-	1	1	1	1	1	1	1	1	1	1	
Ochna rovumensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	1	1	-	
Number of indicator species per transect	16	16	18	12	17	20	18	18	21	19	14	16	10	16	20	19	21	11	14	9	11	13	11	10	10	14	14	16	10	10	12	

4.2. STRUCTURAL DIVERSITY

We considered two types of structural diversity: vertical structure; and differences in structure between transects within patches. Bushland and thicket have a simple vertical structure, being composed of a herb layer and one shrub layer. Thicket with emergents has an additional upper layer of trees. Forest is the most structurally complex type, having a herb layer, a shrub layer, one or more subcanopy layers and a canopy layer of tall trees.

All the patches of dry forest and thicket that we investigated supported at least two structural types. The Sende and Dande supported the greatest range of structural types in a complex mosaic of thicket, thicket with emergent trees and patches of dry forest.

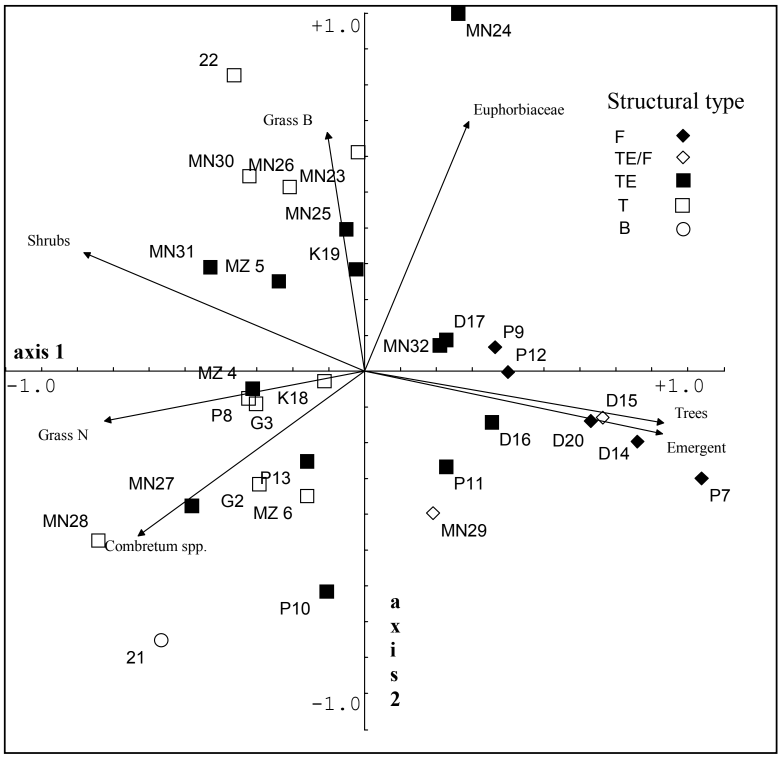

Figure 3. Structural characteristics of the transects in the Zambezi Valley forests and thickets, as derived from a principal components analysis

(See Figure 3, this page). In this biplot display, structural characteristics that are illustrated by arrows pointing in roughly the same direction are closely correlated. If two arrows are at right angles to one another, the characteristics that they represent are not related, and if two arrows point in opposite directions, the characteristics are negatively correlated. Transects lying close together are most similar in their structural characteristics. These structural characteristics are: Trees = tree cover; Emergents = density of emergent trees; Shrubs = shrub cover; Grass N = cover of narrow-leaved grasses; Grass B = cover of broad-leaved grasses; Euphorbiaceae = cover of shrubs in the Euphorbia family; *Combretum* spp. = cover of shrubs belonging to the genus *Combretum*.. Each transect has also been independently classified into a vegetation structural type (F = forest; TE/F = intermediate between forest and thicket with emergents; TE = thicket with emergents; T = thicket; B = bushland).

The cover of trees and the cover of shrubs separated the dry forest transects from the remainder of the transects along the first (horizontal) axis of the ordination. All the transects in the Dande and Sende forests that were classed as forest or forest/thicket with emergents have a high density of emergent trees and a dense cover of trees (right hand side of the diagram). Transects in Mana Pools NP, the old fields, one of the Sende transects and two of the Mozambican transects are characterised by a high cover of shrubs.There is no separation between the transects classified as thickets and those classified as thickets with emergents in this ordination, although such a distinction might have been expected.

The wide range of structural types within the Sende is illustrated by the spread of the Sende transects along the first axis, from dry forest with dense tree cover (P7), to thicket with dense shrub cover and few trees (P8). The Mozambican and Mana patches had a narrower range of tree and shrub cover. From the air, we saw no dry forest in Mana, although we noted groves of dry forest in the Mozambican patch, groves that we were unable to reach within the time available.

The second (vertical) axis illustrated differences in the structure of the shrub and herb layers within both the Mana and the Mozambican patches. These were dominated either by shrubs belonging to the

Euphorbiaceae family, associated with a high cover of broad-leaved grasses (top left-hand side of the diagram); or by *Combretum* species associated with a higher cover of narrow-leaved grasses (bottom left-hand side of the diagram). Broad-leaved grasses can endure lower light levels than narrow-leaved grasses. This association in the thicket transects between the species composition of the shrub layer and the shade tolerance of the grass layer, suggests that in those transects where the shrub layer is dominated by *Combretum* species, more light reaches the ground. The Sende and Dande transects were not dominated by either Euphorbiaceae or *Combretum* spp.: they supported a greater range of shrubby species from several plant families.

Quantitative structural characteristics, as sampled during this survey, separated the dry forest transects from the remainder, but were not satisfactory at distinguishing thicket from thicket with emergents. This was partly due to the mosaic nature of the vegetation, in which the size and density of emergent trees constantly varied along the transect and partly due to difficulties in ensuring that we maintained a consistent definition of an emergent tree. We had used 10 m as the minimum height for an emergent, but found that height difficult to estimate in dense bush.

4.3. STRUCTURAL DIVERSITY INDICATORS

4.3.1. Emergent trees

(See Figure 4, this page). Emergent trees were 10 m high or taller. In areas of forest (parts of Sende and Dande), the crowns of these trees, mainly *Pterocarpus lucens* and *Pteleopis* species, interlock to form a canopy at 10 m or more. Rarely, although not in our transects, we saw forest groves in which *Entandrophragma caudatum* and *Schinziophyton (Ricinodendron) rautanenii* formed the forest canopy. In all forests, there were occasional large specimens of other canopy trees, such as *Berchemia discolor*, *Afzelia quanzensis* and *Xeroderris stuhlmanni.*

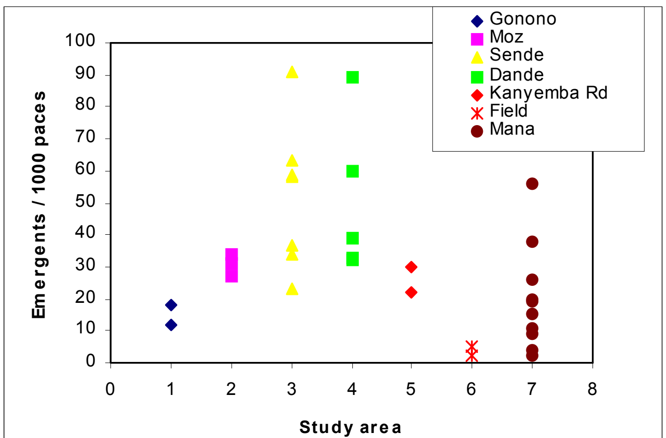

Figure 4: Index of the density of emergent trees

In other patches that were predominantly thicket (Gonono, Mozambique, Kanyemba Road and Mana), emergent trees including *Pterocarpus lucens* and *Pteleopsis* species, as well as trees such as *Diospyros quiloensis, Strychnos decussata* and *Schrebera trichoclada*, protruded above the lower canopy layer, which was about 6 m tall and consisted mainly of *Xylia torreana*.

4.3.2. Lianes

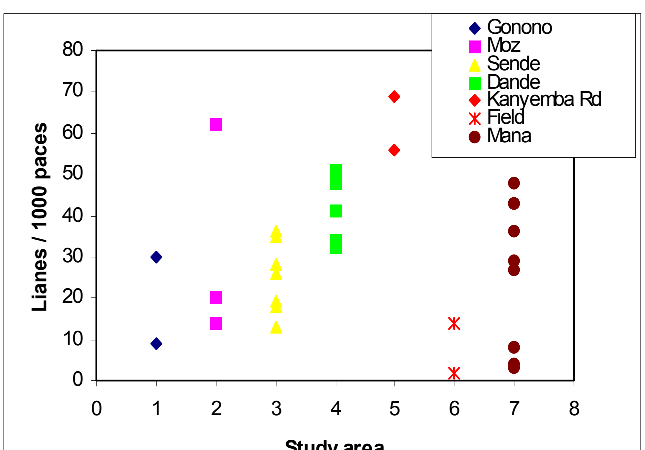

Figure 5. Index of the density of lianes

(See Figure 5, this page). Lianes climb large trees to reach light above the canopy. They contribute to lifeform diversity, especially in forests, and are seldom seen in woodland or savanna. Lianes were common in all patches of forest and thicket, except the old field where large trees had been felled. *Combretum kirkii*, a liane which is a Zambezi endemic, occurred in Mozambique, Sende, Dande and Kanyemba Road.

Strophanthus kombe may be a scandent shrub (i.e. have trailing branches that recline on neighbouring plants), or a true liane with no more than one or two strong stems that twist around tree trunks. *Strophanthus kombe* was common along most transects and we mistakenly counted both lifeforms - scandent shrub and true liane - as lianes. Consequently, the index of liane density along our transects is not a fair reflection of the abundance of the genuine liane lifeform.

4.3.3. Dead trees and logs

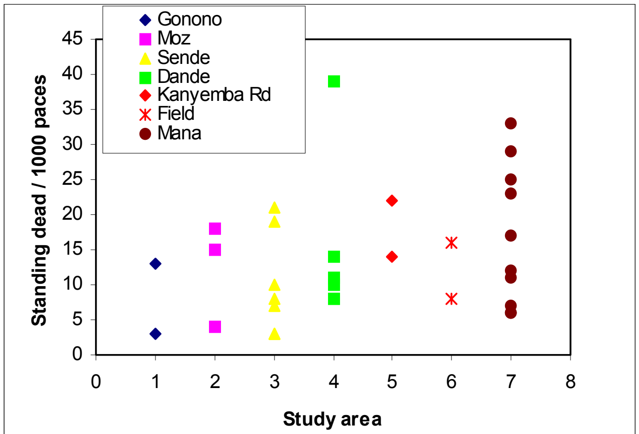

Figure 6. Index of the density of standing dead trees

(See Figure 6, this page). A tree remnant, >1 m tall and >15 cm diameter, was considered a "standing dead" tree. Dead trees may indicate past stressful events which led to mortality, events such as fires, drought, or serious debarking. Both dead trees and logs represent an important substrate for fungi and invertebrate animals. Across all transects, log density was positively correlated with the density of standing dead trees (r = 0.481, n = 31 transects, P < 0.01). This is perhaps not surprising, given that a log is simply a horizontal , and presumably older version, of a dead tree!

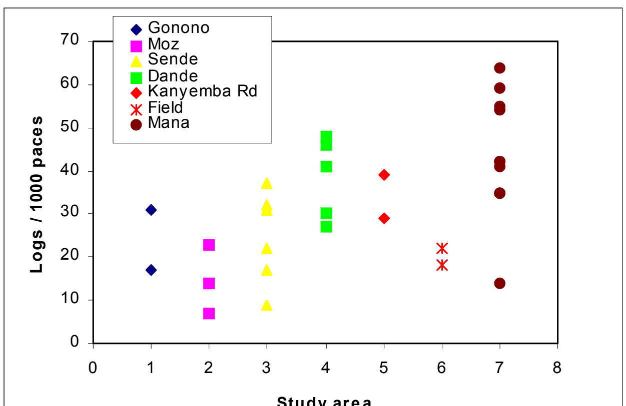

Figure 7. Index of the density of logs

The mean density of logs at Mana was greater than in all other study areas (Figure 7). This could reflect the absence of fire at Mana (see Table 10, page 22), because fires would burn logs. Or it could reflect the high density of elephants at Mana, if elephants there regularly fell trees. Across all transects except those at Mana (where both people and fire were absent), log density was positively correlated with distance to the nearest settlement (Figure 8, r = 0.628, n = 21 transects, P < 0.01).

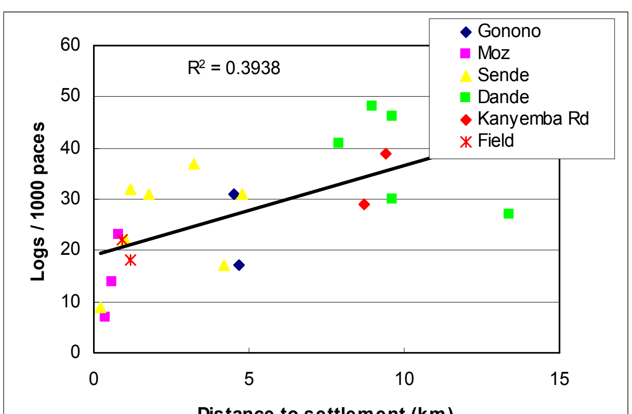

Figure 8. Distance from settlement (all non-Mana transects)

For these same transects, the density of logs and dead trees was greater along transects without fire signs, than where fire signs were present (Table 10). Transects without fire signs were also generally further from settlement than transects with fire signs. It is likely that log density increased with distance from human settlement (Figure 8, this page) because fire frequency declined with this distance.

4.3.4. *Epiphytes*

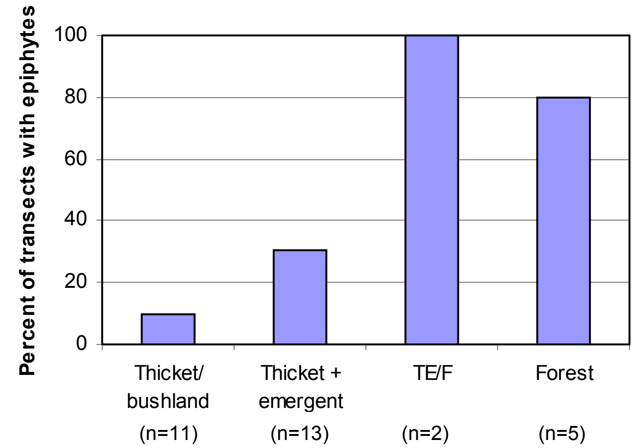

Figure 9: Occurrence of epiphytes relative to vegetation structure

Few epiphytes were seen. Epiphytic figs were recorded along six transects, and orchids along five, while moss was recorded along two transects. Only two transects had more than one type of epiphyte. Epiphytes were found more often along transects through forest and in vegetation intermediate between thicket and forest, than in other structural types (Figure 9, this page).

4.4. INDICATORS OF DISTURBANCE BY ELEPHANTS

4.4.1. Elephant paths and dung

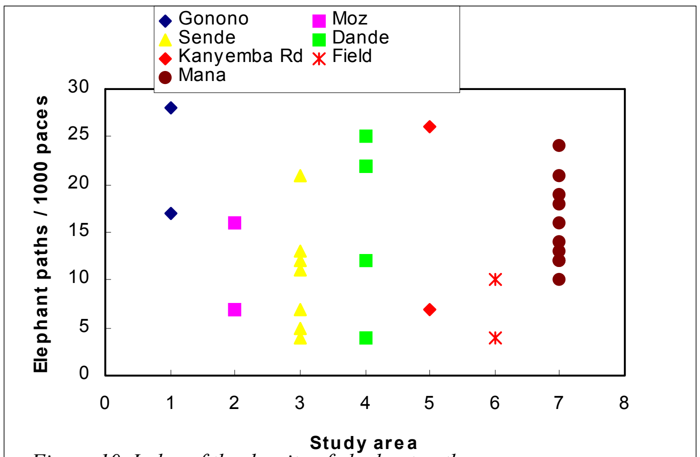

Figure 10. Index of the density of elephant paths

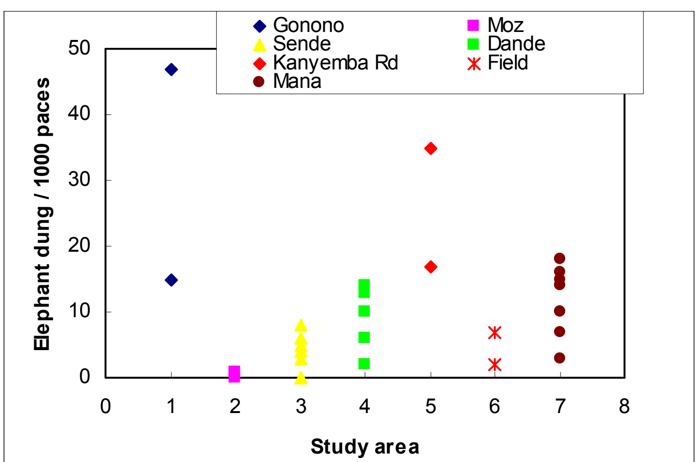

Figure 11. Index of the density of elephant dung

Not surprisingly, the density of elephant dung was positively correlated with the density of elephant paths ($r = 0.677$, $n = 31$ transects, $P < 0.001$). Both dung and the existence of paths clearly created by elephants are crude but reasonable indices of elephant presence in forests and thickets (Figures 10 & 11, this page).

Paths appeared most numerous in patches which elephants might use as refuges for crop-raiding at nearby farms (Gonono and Kanyemba Road), and least numerous close to human habitation (old field), but the density of elephant paths was only weakly correlated with distance from settlement ($r = 0.470$, $n = 21$ non-Mana transects, $P < 0.05$).

4.4.2. Tree debarking by elephants

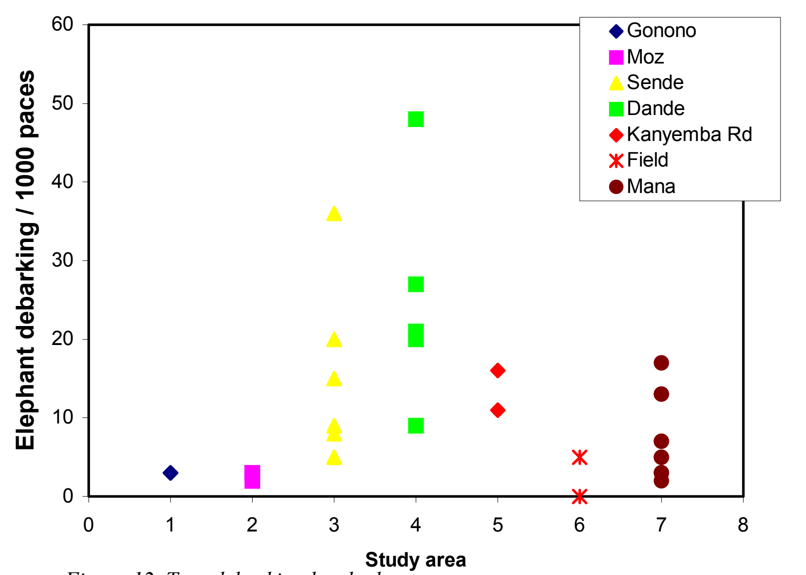

Figure 12. Tree debarking by elephants

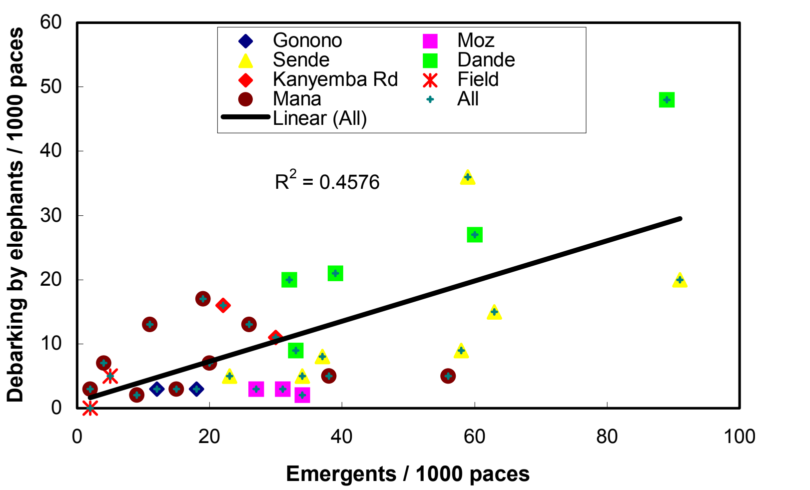

Figure 13. Debarking of trees by elephants in relation to the density of emergents

Debarking was most often seen on large trees, whereas shrubs and smaller trees tended to be browsed. This explains why the density of debarked trees was positively correlated with the density of emergent trees (Figure 13, r = 0.676, n =31 transects, $P < 0.001$).

The densities of debarked and emergent trees were greatest in Sende and Dande, but, for a given density of emergent trees, there was generally less debarking in the Sende forest (in communal land) than in Dande (safari area).

Although 25 species suffered debarking, most debarking was confined to just two tree species; *Pterocarpus lucens* (53.3 % of the 334 debarked trees that we recorded) and *Pteleopsis* spp. (22.2 %). These are common canopy dominants occurring in most thicket and forest patches (Table 7, Page 14) and debarking was widespread. One or more *Pterocarpus lucens* trees was debarked in 85 % of the transects along which *P. lucens* occurred and *Pteleopsis* trees were debarked in 70 % of the transects along which this species occurred. Three other species, *Berchemia discolor, Adansonia digitata* and *Acacia nigrescens*, were debarked in more than 20 % of the transects along which they occurred. *Strychnos decussata* was also commonly debarked. Although *Xylia torreana* trees are widespread and abundant, this species was debarked along only five transects and only eight *Xylia* trees were recorded as debarked.

Physical characteristics of the bark appear to determine how elephants remove it. They usually chip the thin, smooth bark of *Pterocarpus lucens* and *Strychnos decussata*, while the fibrous bark of *Pteleopsis* spp. is pulled off in long strips.

Debarking of the same tree at different times was frequently noted as scars of varying ages across which new bark had begun to develop. Severely debarked trees were often attacked by wood-boring arthropods or fungi, which fed on dead portions of the still-living trees.

4.4.3. Browsing of trees and shrubs by elephants

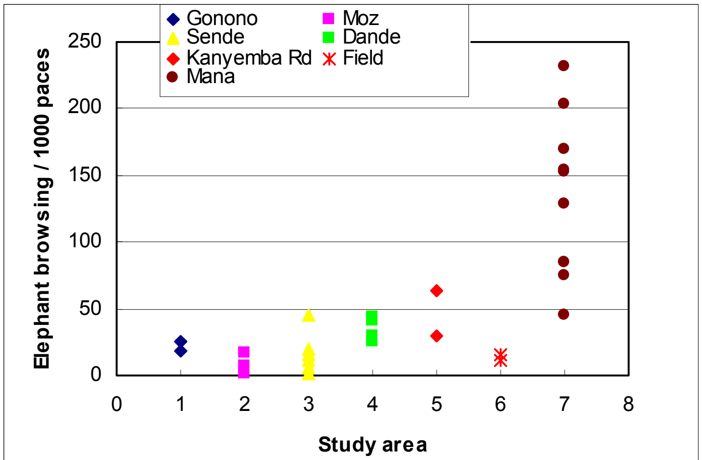

Figure 14. Index of browsing of trees and shrubs by elephants

The low incidence of elephant browsing along most transects suggested that the elephants were not feeding for long periods, but feeding briefly while passing through the thicket/forest patches (Figure 14, this page).

In the Mana Pools National Park, the elephants – which occur at high density - are probably resident in the thickets for much of the year, hence the high incidence of elephant browsing.

In Mozambique, the old fields and most of Sende, there was little sign of elephant browsing.

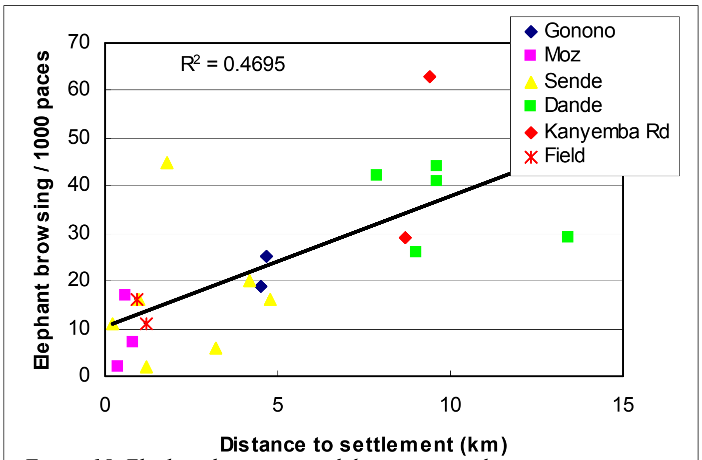

Figure 15. Elephant browsing and distance to settlement

In the eastern Zambezi Valley (that is, all study areas except Mana, the density of trees and shrubs browsed by elephants was positively correlated with distance from human settlement (Figure 15, this page; $r = 0.685$, $n = 21$ transects, $P < 0.01$).

Elephants appear to spend more time feeding in thicket/forest patches that are about 8 km or further from human settlement, than they do in closer ones.

Elephants browsed 61 species of woody plants in the dry forests and thickets. Despite the wide range of species that were eaten, 71.5 % of the instances of browsing in Mana and 50.4 % of the instances of browsing elsewhere involved only four species (Table 8). These four species are all shrubs or small trees that were found along most transects (Table 7).

Table 8. Principal woody species in the diet of elephants feeding in dry forests and thickets

Species	**Percentage of woody diet**	
	Non-Mana (n = 460)	Mana (n = 1329)
Meiostemon tetrandrus	4.3	25.8
Combretum celastroides	2.8	16.7
Combretum eleagnoides	24.6	9.0
Xylia torreana	18.7	20.0
Other species	49.6	28.5

(n = number of browsed plants recorded)

Meiostemon tetrandrus, which was found along all transects, was common in the elephant diet at Mana, although it was seldom browsed elsewhere. This is surprising, because, although no formal measure of the relative abundance of plant species was attempted during this study, it was noted during fieldwork that *M. tetrandrus* was sparse in Mana thickets/forests, but abundant in the Dande Safari Area and the communal lands. *Croton scheffleri* dominated the shrub layer in many of the northerly transects at Mana. This small shrubby member of the Euphorbiaceae, a plant family which often contains toxic substances, was avoided by elephants, which thus may be eating some species at Mana Pools, such as *M. tetrandrus*, that they avoid otherwise.

4.4.4. Felled trees

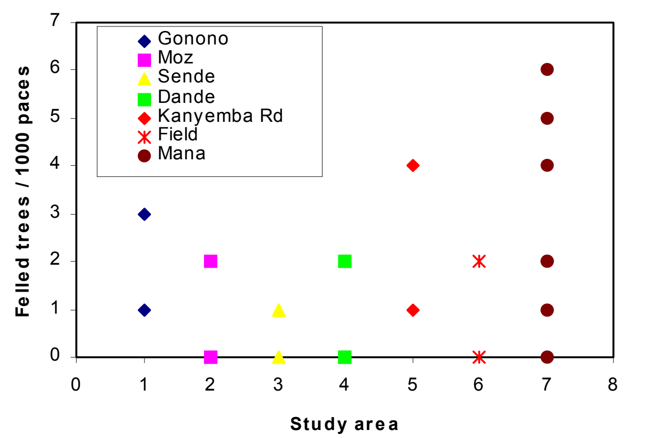

Figure 16. Index of the density of felled trees

Trees were felled by elephants, by people gathering honey, or by the wind. But it was not always possible to determine what caused a tree to fall over. Felled trees were not abundant, but were commoner along transects in Mana Pools NP (mean = 2.3 felled trees per 1000 paces), where elephants are at relatively high density, than elsewhere (mean = 0.9).

Across all transects, the density of felled trees was negatively correlated with the density of emergents ($r = -0.453$, $n = 31$ transects, $P < 0.01$) (see figure 16, this page). In other words, felled trees were abundant where there were few emergent trees. This would suggest that felled trees are not being replaced by recruitment to the emergent layer, but that felling is reducing the density of tall trees, at least in the short-term. Large gaps are created in the forest canopy when trees are felled. Increased light penetration in these gaps changes the species diversity of the forest understorey, by promoting the growth of herbaceous vegetation, particularly narrow-leaved grasses and forbs.

4.5. INDICATORS OF DISTURBANCE BY PEOPLE

4.5.1. Alien invasive plants

No alien invasive woody plants were seen along any of the transects (Table 9), not even the communal land ones, although alien plants such as *Calotropis procera* and *Ricinus communis* were seen elsewhere in the communal areas.

Table 9. Frequency of occurrence of indicators of human disturbance

Indicator of human disturbance	**Frequency of occurrence (percent of transects)**	
	Non-Mana 21 transects	**Mana Pools NP** 10 transects
Alien invasive woody plants	0	0
Signs of wood chopping	48	0
Woody plants debarked by people	14	0
Fire signs	43	0
Signs of animal poaching	5	0

4.5.2. Wood chopping and bark stripping by people

Signs of wood chopping were fairly common in the eastern Zambezi Valley (Table 9), but on most transects where chopping was observed, only one or two shrubs or trees were chopped. Chopping was often associated with honey collection, as collectors chopped the hive entrance holes in order to extract the honey, or even chopped down the entire tree. There was only one instance of chopping for fuelwood.

Bark stripping by people was not widespread (Table 9), nor was it common where it occurred (only 1-5 affected plants).

4.5.3. Fire

The fire signs observed could be divided into two groups: signs of a bush fire that had burnt a major portion of a transect (when counts of fire signs were very subjective); or signs of a fire that had burnt a small, clearly defined area. The latter fires were often associated with honey collection.

Because of the difficulty of quantifying fire signs, analysis in this report is limited to the presence or absence of fire signs. In the eastern Zambezi Valley, transects with fire signs were generally closer to human settlement than transects without fire signs (Table 10).

Table 10. Variation in the density of some structural and disturbance indicators in relation to the presence or absence of signs of fire

Indicator *	**Non-Mana transects with fire signs**		**Non-Mana transects with no fires**		**Mana transects (no fires)**	
	Mean*	**SD**	**Mean***	**SD**	**Mean***	**SD**
Lianes	**20.1**	10.5	**39.7**	18.4	**24.9**	17.7
Emergent trees	**28.1**	17.4	**45.5**	26.4	**20.0**	16.5
Dead standing trees	**9.8**	6.1	**14.8**	9.4	**16.9**	10.0
Logs	**18.3**	8.3	**33.8**	8.4	**44.1**	14.6
Multistemmed trees	**20.3**	16.3	**51.4**	37.7	**139.5**	72.0
Stagheaded trees	**17.4**	18.8	**30.7**	24.4	**66.4**	27.0
Chopping	**9.0**	18.9	**1.3**	3.1	**0.0**	0.0
Debarking by people	**0.6**	1.7	**0.2**	0.4	**0.0**	0.0
Debarking by elephants	**5.3**	4.6	**18.4**	13.5	**7.5**	5.1
Browsing by elephants	**18.0**	10.9	**27.1**	18.7	**132.9**	60.2
Felled trees	**1.1**	1.1	**0.9**	1.2	**2.3**	2.1
Elephant paths	**10.6**	8.0	**15.4**	7.5	**15.9**	4.5
Elephant dung	**9.1**	15.0	**9.5**	9.7	**12.5**	4.9
Distance to settlement (km)	**2.9**	3.1	**5.9**	4.3	**-**	-

*Means given as number per 1000 paces, except for distance to settlement, which is in km

For this analysis, transects were divided into three groups: 9 non-Mana transects with fire signs; 12 non-Mana transects without fire signs; and 10 Mana transects (where there were no fires and which were far from people).

4.5.4. Animal poaching

Definite signs of animal poaching were rare (Table 9) and confined to the finding of the axe-marked skull of one long-dead buffalo.

4.5.5. Grazing

Grazing was not specified as a disturbance during this survey. Signs of cattle were noted along only one transect near an old field (transect 22). Thickets and forests are largely unsuitable for grazing livestock, because the biomass of grass, usually unproductive broad-leaved annuals, is so low. If fire, elephant and or human disturbance kill many trees and shrubs, allowing more light to penetrate, narrow-leaved perennial grasses will invade and there will be more opportunities for grazing. Such grasses are likely to cure early because the soils do not have a high water holding capacity and will not provide grazing during the dry season.

4.6. CONDITION INDICATORS

4.6.1. Tree stag-headedness and multistemmed development

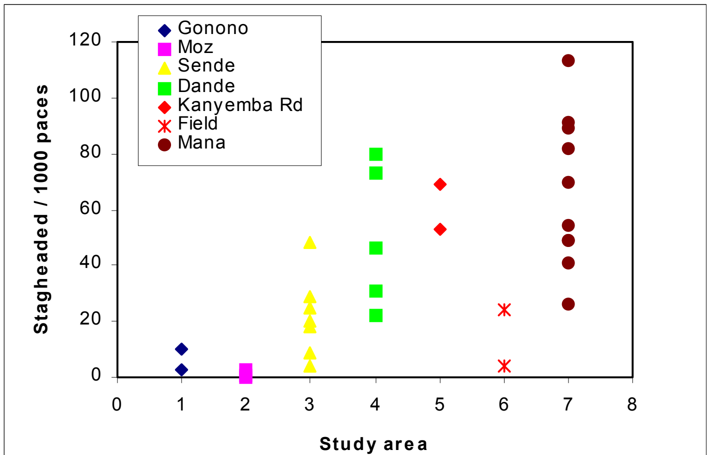

Figure 17. Index of the density of "stag-headed" trees

Some trees exhibit a "stag-headed" appearance in which the tips of branches in the crown have relatively few leaves, or are bare. Such crown die-back in *Pterocarpus angolensis* is thought to indicate stress from, for example, repeated burning, unfavourable soil conditions or drought (Coates-Palgrave 1977). Stag-headed crowns in the thickets and dry forests probably do not have a single cause. They may be associated with the recent series of droughts, and/or, in some cases, with fire and with debarking by elephants.

The incidences of stag-headedness and atypical multistem development were closely correlated (r = 0.857, n = 31 transects, $P < 0.01$) suggesting a similar origin (Figure 17, this page). Killing the terminal bud of a tree, as a result for instance of fire, frost, browsing or drought, often induces the simultaneous growth of several subsidiary buds. Unless one bud assumes dominance, an atypical multistemmed form will develop. Although multistemmed development was observed in some *Pterocarpus lucens* and *Pteleopsis* spp. trees in this study, it was most frequently seen in *Xylia torreana.* Many of the multiple trunks that we saw had developed many years ago and it was impossible to identify their causes.

4.6.2. Litter cover

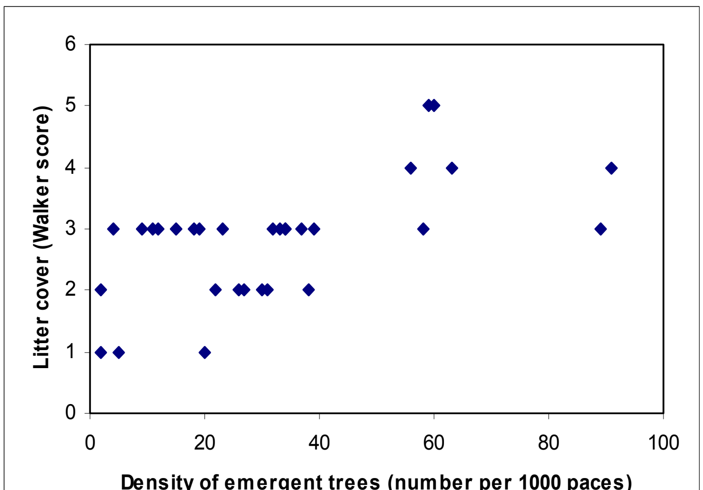

Figure 18. Litter cover on transects related to density of emergent

This study was undertaken during April of an unusually wet year, when trees and shrubs still retained most of their leaves. Little litter remained from the previous year and the litter layer was usually patchy and less than 5 mm deep. Litter cover increased with the density of emergent trees (Kendall rank correlation coefficient = 0.45, n = 31 transects, $P < 0.01$).

This suggests either that more litter is produced when there are many emergent trees, or that litter decays more slowly in the microclimate provided by canopy of tall trees. No clearly visible humus layer could be distinguished in the topsoil.

4.6.3. Seedling establishment

Relatively few seedlings (estimated at 10-30 along most transects) were seen in the dry forests and thickets. We were unable to record seedling establishment satisfactorily, beyond noting the species of seedlings seen along each transect. Seedlings of *Diospyros quiloensis* were seen along 26 transects. A few seedlings of ten other tree species were also noted: *Xylia torreana* (seedlings seen along 14 transects), *Strychnos decussata* (9 transects), *Pteleopsis spp*. (7, of which 6 were in Mana), *Pterocarpus lucens* (4), *Balanites maughamii* (4), *Cordyla africana* (3*), Friesodielsia obovata* (1), *Zanthoxylum lepriurii* (3*), Acacia ataxacantha* (1) and *Tamarindus indica* (1). The seedlings of large-fruited trees such as *Cordyla* and *Balanite*s had usually germinated recently from seeds in elephant dung, under gaps in the canopy where light could penetrate. No seedlings of shrub species were noted. To estimate seedling density, several plots of known area would have to be sampled and this was not compatible with the rapid techniques used here. Ideally, seedling establishment should be recorded during the early wet season, when those seedlings that have survived the previous dry season (i.e. become established) can be distinguished from seedlings that have recently germinated.

4.6.4. Birds

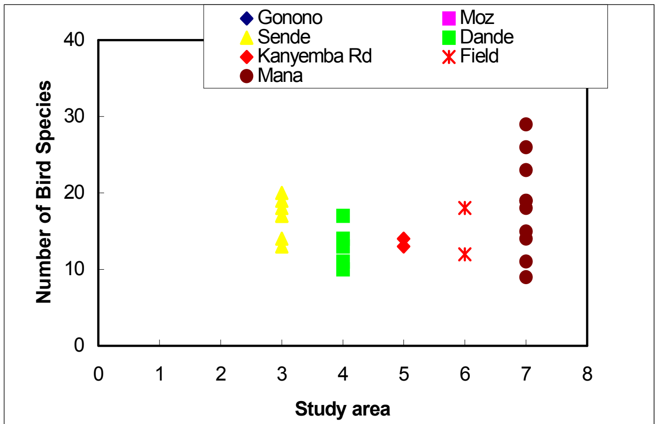

Figure 19. Bird species abundance

Because the sampling procedure was primarily designed around botanical requirements, some degree of bias is applicable to all bird species recorded, particularly the less common.

It was initially hoped to sample transects using (assumed) indicator species of birds, but after sampling a number of transects, it was apparent that this method was unsuccessful.

It was then decided to record all species heard or seen (Appendix C) to see if any meaningful results would emerge. Examples of sampling problems were the following:

- The time to complete transects was too short to provide an accurate assessment of species occurring in them. Recording was also heavily influenced by the time of day, with a greater number of species or perhaps different ones being active early and late in the day than in the quieter intervening mid-day period. Dense habitat specialists such as Livingstone"s Flycatcher would fit this category.
- Several possible indicators are migrant and either known to be absent at the time of the study (April) or could not be found in the time available.
- A number of common species (e.g. Yellow-bellied Bulbul, Terrestrial Bulbul) appeared in all or almost all transects. These species occurred in thicket as well as forest habitats.

Some indicator species can, however, allow comments relevant to conservation to be made. Dry forest is assumed to be an important bird habitat, though perhaps only as a component of a more variable forest/thicket mosaic. The forest is important for the conservation of large eagles such as the Crowned Eagle and Western-banded Snake Eagle. Although the Crowned Eagle is the more widespread, it is probably more vulnerable to the loss of true forest habitat than the Western-banded Snake Eagle, whose distribution is restricted to the Zambezi Valley but does occur there in riparian forest and woodland. Both eagles were encountered once during the study (site 3 and environs).

Interesting indicators found in Mana Pools (area 7 - though in a riparian forest component of a transect) and not in the Dande Safari Area (area 4) were Angola Pitta (nest) and African Broadbill. It is uncertain whether the true dry forest habitat is suitable for Pitta, though acceptable habitat may exist in the broader forest mosaic. The African Broadbill is expected to occur in the Dande Forests. The brood parasite of this bird, the Barred Cuckoo, was recorded from the Dande area; and the conservation of this species is probably strongly linked to the conservation of forest.

4.6.5. Observations on other taxa

Large mammals were nowhere abundant but signs of 17 species were seen: aardvark; baboon; buffalo; bushpig; civet: duiker; elephant; grysbok; honey badger; hyaena; jackal; kudu; lion; mongoose; porcupine; squirrel and warthog. With the exception of elephant, the signs of these animals were uncommon and so did not lend themselves to any kind of quantitative analysis. Black mambas were observed at three sites and spoor of various snakes was seen in every site. This suggests that rodents, the principal prey of many snakes, are common in the thickets. Fine-grained, deep and freely draining sands are suitable for burrowing rodents. *Tatera leucogaster* (Peter's gerbil) is common in the Mana thickets, *Mus minutoides* has been noted and *Saccostomus, Steatomys* and *Thallomys* species probably occur (C.M. Swanepoel pers. comm.). Insectivores are also likely to occur in the thickets and an elephant shrew, probably *Elephantulus brachyrhynchus* judging by its habitat requirements, has been observed in the Mana thickets (C.M. Swanepoel pers. comm.).
Clearings and roads in the thickets and forests appeared to attract large numbers of butterflies.

The abundance of dead logs and other litter, and the relatively mild temperatures and the seasonally moist environment among the understorey and at ground level, appeared to favour fungal growth during the wet season. We noted an unusual diversity of colourful macrofungi during our first visit in February, although all that remained in April were a few bracket fungi.

An interesting feature of the forest/thicket patches is the presence of seasonal water pans, either where the sand layer is thin, and impermeable soils are close to the surface or where clays have collected in hollows. Amphibians and a few fish species are present in or around these water bodies.

4.6.6. Summary of historical data

The aerial photographs of Mana Pools thickets and forests (from 1954, 1973 and 1981) are not uniform in several important characteristics, making it problematic to use them to study structural changes from forest to thicket. Problems of comparison arose because of variation in:

- Coverage (present sampling sites are not covered consistently)
- Scale (more recent series at 1:25 000; older series at 1:40 000)
- Timing (range June – October)
- Print quality
- Rainfall (wide variation in rainfall between the above years [range 406 – 999 mm] causing variation in the timing of leaf drop, which in turn causes tree canopies in the photographs to differ between years in tone, texture and contrast)

It is not possible to distinguish reliably the structure of thicket, from thicket with emergents, or from dry forest using black and white air photography unless:

- The photographs are taken before leaf-drop occurs, during May or June in most years in the Zambezi Valley. Dry forest and thicket species generally lose their leaves early in the dry season, because the unconsolidated sands on which they grow have a low water holding capacity.
- The scale is 1:25 000 or larger;
- The photographs are viewed in stereo, under at least 3x magnification.

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5. DISCUSSION

5.1. LIMITATIONS OF THE STUDY

This was a short study and a first attempt to describe the biological composition of dry forest and thicket in the Zambezi valley. It was of course impossible to give equal attention to all biological constituents of this habitat with the resources that were available and this report represents only a preliminary investigation. Nevertheless, a valuable initial assessment has been made and some recommendations for further conservation measures can be stated.

5.2. VEGETATION STRUCTURE

Although the separation of the habitat sub-types into forest, thicket with emergents and simple thicket was thought desirable after the initial reconnaissance and was useful for description and analysis, it has to be appreciated that in reality the three sub-types almost always occur in a mosaic and with intergrades.

Dry forest, with the most complex vertical structure, is also the rarest subtype. Thicket with emergents is the next most common, while thicket with its simple vertical structure is relatively abundant.

The structure of the Gonono/Mozambique forest and thicket patch has not yet been thoroughly explored: aerial reconnaissance suggests a greater range of structural types than we were able to sample.

The Sende and Dande patches support the entire range of thicket to forest. This horizontal structural diversity, sometimes described as habitat diversity, is of high conservation value because of its potential to support a variety of plant and animal species with differing requirements within a relatively small area.

It is likely that, for some taxa, a relatively undisturbed true forest habitat will support fewer species than a more structurally-diverse thicket/forest mosaic that may have resulted from some disturbance. This may sound alarmingly like a statement in opposition to the conservation of forest habitat, but it is important to stress that a forest is essential for the specialists it supports and therefore makes a high contribution to overall species diversity. In this regard, a small area containing a few "specialists" is often more important than a larger area which supports many "generalists".

5.3. PLANT SPECIES

The conservation value of the dry forests and thickets lies not so much in rare plant species, of which there are relatively few, notably *Xylotheca tettensis* and *Combretum kirkii*. Their importance lies in the abundance within these patches of species that are uncommon elsewhere (Timberlake & Cunliffe 1992). These include trees such as *Xylia torreana* and shrubs such as *Dalbergia martinii*, *Meiostemon tetrandrus*, *Citropsis daweana* and *Zanthoxylum lepriurii*. The herb layer of the thickets and forests is not well known and should be investigated further.

Eight of the indicator species that we identified occurred in almost every transect. These could be used to define *Xylia torreana* dry forest and thicket in future rapid surveys. Five indicator species proved useful in differentiating forest and thicket with emergents, from thicket. These are useful indicators of vertical structural complexity and of thus of probable biodiversity. Two species proved to be useful indicators of structural simplicity and thus of probable low levels of biodiversity. At a broader scale, the occurrence of both structurally simple vegetation indicators and of structurally complex vegetation indicators, within a single forest patch, suggests horizontal diversity, which is of conservation value.

5.4. FOREST CONDITION

5.4.1. Stag-headed and multistemmed trees

The series of droughts that Zimbabwe endured during the 1980s and 1990s caused several tree species, notably *Julbernardia globiflora* in the Zambezi Escarpment woodlands, to develop a stag-headed crown and, in extreme cases, to die. Trees can recover from drought and develop a normal crown, and we suggest that the many stag-headed trees that we noted in the thickets and forest are not a cause for current concern, except where stagheadedness has been induced by debarking.

The high incidence of multistemmed trees, particularly in *Xylia torreana*, a dominant tree in the dry forests and thickets, is probably not a cause for concern either. Most *Xylia torreana* trees growing in the Zambezi Valley forests and thickets are multi-stemmed, while the only *Xylia torreana* tree growing in the National Botanical Gardens in Harare is single-stemmed (Th. Muller pers. comm.). This plasticity of growth form may be an adaptive response to the severe effects of drought on trees growing on freely draining sands. Multistemmed shrub species which never develop into trees, such as *Combretum celastroides* and *C. eleagnoides* are a characteristic and obvious feature of thickets. But the development of a multistemmed form in species which are ordinarily single-stemmed is a seldom recognised feature of thickets on sand. Fifty years ago, both *Pterocarpus lucens* and *Pteleopsis sp*., which usually develop into tall canopy trees, had "assumed the general habit of jesse trees, that of a much branched trunk" in thicket growing on red sands in the Charara Safari Area (Lovemore 1955).

5.4.2. Seedling regeneration

There are two possible explanations for the apparent rarity of seedlings along our transects. Either:

- We missed many seedlings because they had already shed their leaves and were inconspicuous (*Diospyros quiloensis*, which was common as a seedling, is evergreen and more likely to be noticed); or
- Established seedlings are much less numerous in dry forests and thickets than in the neighbouring savanna woodlands, where the density of suppressed seedlings may reach many thousands per hectare.

The second is the more likely explanation. This failure of most seedlings to persist in the dry forests and thickets - in contrast to the riverine forests, where numerous seedlings were seen during the February reconnaissance visit - has not been noted previously. It may be due to the permeable sands that do not retain moisture within the reach of shallow-rooted seedlings, or to low light levels. The conditions required for the germination and establishment of woody plants in these thickets and forest have never been investigated. Perhaps light gaps, caused by the death of trees and shrubs, are required.

5.5. CHANGES IN VEGETATION STRUCTURE

Although it is not possible to use historical air photographs of Mana Pools National Park to establish whether the thicket there was once dry forest, other studies suggest that a mixture of thicket and thicket with emergents, with at best small patches of forest, is characteristic of this vegetation type in the interior regions of the Zambezi basin. Guy (1977) described no dry forest in the Zambezi Valley during the early 1970s. He mapped the Mana Pools "jesse" as *Commiphora-Combretum* thicket, describing it as having occasional trees, seldom more than 6m tall, rising above a thicket. Similar vegetation sampled in this study and growing on deep red sands in the Dande Safari Area and in the communal lands of the eastern Zambezi Valley, which has not endured high densities of elephant until relatively recently (Evans 1967), is currently a mosaic of thicket, thicket with emergents and dry forest.

Differences in the soil moisture regime may account for the mosaic nature of this vegetation type in the Zambezi Valley (Cunliffe 1995). Trees tend to be shorter towards the crests of the sand lenses on which dry forest and thicket grow (Anderson 1987). This observation, which was borne out by the distribution of dry forests and thicket as seen on high quality aerial photographs and by field observations, suggests that short thicket is most common near the middle of the sand lenses, where the sand is deepest. Tall dry forest is more likely to be found near the edges of the patches, where it often merges into riverine thicket and forest. Dry forest growing on acid, sandy loam soils in Lengwe National Park, Malawi (mean annual rainfall 833mm) also grows in a mosaic with thicket with emergents and shrub thicket. The distribution of dry forest in Lengwe follows very closely the zone where the water table is highest (Hall-Martin 1975).

Thus it appears there is insufficient evidence to support a "structural change hypothesis" if this is taken as involving the transformation of dry forest into thicket in the Mana Pools National Park. Elephants have changed the structure of the "jesse" of Mana Pools: they continue to fell trees, remove bark and break branches. The probable long-term outcome of the continued activities of elephants living at high densities is a structurally simple thicket. But in most of the "jesse" areas of Mana Pools National Park, the evidence currently available suggests that what was lost was thicket with emergents, rather than dry forest.

The evidence does not support another feature of the "structural change hypothesis", namely that *Combretum* shrubs generally replace other species once the larger trees are removed by elephant. To the contrary, in the northern section of the Mana jesse, near the Zambezi river, where elephant densities are especially high, *Croton scheffleri* is dominant in the shrub layer and *Combretum* species are not abundant.

5.6. FOREST DISTURBANCE

5.6.1. Elephant impacts

Elephant browsing of woody plants was not heavy enough to threaten the survival of any species. Selection of browse species was similar in transects inside and outside Mana Pools. Debarking of indicator trees was confined to a few emergent species of which *Pterocarpus lucens* was the most frequently selected. It is known from previous work (Thompson 1975) that the ultimate cause of tree death (e.g. micro-organisms) may be closely linked to a proximal cause (e.g. elephant damage). Thus elephant damage may be an insidious threat to some species. It is possible that debarking constitutes a threat to the survival of *P. lucens* and *Pteleopsis* species or other emergent trees. This could be a serious conservation problem, as without the upper canopy layer of tall *P. lucens* trees most forest groves would disappear and all that would remain would be thicket and thicket with emergents.

5.6.2. Human impacts

Human impacts inside forest patches were generally low. Signs of fire, animal poaching, and the debarking or chopping of trees by people were infrequent. No alien plant species were recorded. Anthropogenic disturbance is, however, an area of constant concern to the conservation of these habitats. Signs of fire were more frequent close to human settlement. Honey harvesting and animal poaching, activities that are likely to increase in the future, can introduce fires into these habitats. Tree-felling and road building can increase the fire hazard, by opening up the forest canopy and encouraging the growth of narrow-leaved perennial grasses, which cannot survive under the heavy shade of a closed forest or thicket canopy. Perennial grasses produce a heavier fuel load than the broad-leaved annual grasses which are characteristic of intact forests and thickets. Many of the canopy trees and emergents are thin-barked and vulnerable to fire.

Thickets and dry forest on sand were once favoured as sites for fields (Lovemore 1955). This is no longer the case, as cattle and tractors have made it possible to cultivate heavier soils and to raise cash crops (Anderson 1987, Timberlake & Cunliffe 1997). We saw only one recent field among the dry forests and thickets, which had been used to grow millet for a couple of years before being abandoned. However, there is a threat of cultivation spreading from the preferred alluvial soils that often bound the sands, for instance along the Angwa River, into the thickets as people settle along the rivers and population pressure increases.

Extraction of selected large trees to construct dugout canoes was noted during aerial reconnaissance, particularly in Mozambique, where canoes are used for fishing and transport around Lake Cabora Bassa. Although this is not necessarily damaging to the thicket and forest overall if practised judiciously, there are indications that people are now harvesting these large trees far from rivers, constructing the canoes on site and then dragging the finished product through large tracts of forest. There are also reports of large *Afzelia quanzensis* trees being chopped for timber in the Sende forest (H. Fritz pers. comm.). Honey harvesting is likewise a widely-practised and legitimate rural activity, but unfortunately sometimes an entire large tree is felled to extract honey. The dry forests and thickets were also used occasionally as a source of straight slender trunks for hut poles. Fuelwood collection is not a current threat, probably because there are more desirable fuelwood trees such as *Acacia* spp., *Julbernardia globiflora* and *Colophospermum mopane* in neighbouring woodlands.

5.7. OTHER BIODIVERSITY INDICATORS

Many taxa require specialist sampling regimes before any definitive statements can be made about their abundance and species diversity. Such taxa that may yield important information could not be sampled adequately in this short study. However, a number of statements based on broad observation by the team of experienced naturalists are worth noting. The macrofungi that we observed in February may be saprophytes (living on dead plant material) but the possibility that some are ectomycorrhizae (living on the outside of roots), which assist nutrient uptake in plants growing on infertile soils, has never been investigated. *Afzelia quanzensis*, an occasional emergent tree in the thickets and forests, is known to be ectomycorrhizal (Hogberg & Piearce 1986). However, the majority of plants growing in the thickets (i.e. *Pterocarpus lucens*, *Xeroderris stuhlmanni* and many *Combretum* spp.) form associations with endomycorrhizae (living within roots) that do not produce large fungal fruiting bodies.

The abundance and species richness of lepidoptera might be a useful indicator of structural change in forests because, for example, forest clearings and roads appeared to attract large numbers of butterflies. An earlier butterfly survey of Guruve District (Gardner & Niemeyer 1997) showed that species diversity was considerably greater in dry forest than in surrounding woodland.

Seasonal water pans are an interesting feature in some dry thickets. These may contain unusual species of flora and fauna and almost certainly enhance the "refuge value" of these habitats for larger species of water-dependent wildlife. There are, for example, occasional, unconfirmed reports of signs of Black Rhinoceros from the Zimbabwe - Mozambique border thickets. Only after seasons of exceptionally high rainfall do these pans retain water throughout the year.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

1. The Zambezi Valley dry deciduous lowland forests have particular conservation significance in southern Africa because they are examples of a vegetation type which is rare and threatened wherever it still occurs. The conservation of this habitat is of global importance because it is usually poorly represented in protected areas. Although it is present in several southern Africa protected areas, it may be threatened by the elephants that share those areas.

2. The patches of the dry deciduous lowland vegetation commonly referred to as dry forest, or locally as "jesse", examined for this study, and occurring on "lenses" of deep, unconsolidated red sands, include at least three structural vegetation types – forest (most rare); thicket with emergent trees; and thicket (most abundant). But in reality they almost always occur as a mosaic and with intergrades. The ultimate structure and composition of these types is greatly influenced by factors such as sand depth and moisture availability.

3. Patches that support the entire range from thicket to forest (as in Sende and Dande) are of high biodiversity and conservation value because of their potential to support, within a relatively small area, a variety of plant and animal species with differing requirements. These patches should be priority areas for conservation.

4. In the case of Zambezi Valley dry forests, it is not necessarily the species richness per se that is of conservation importance, but the unusual species assemblage that is important: this assemblage includes species with restricted distribution; rare species; and species whose survival may depend on this habitat.

5. Debarking of emergent forest trees is a cause for concern, as reduction of the upper canopy layer would result in major changes to the structure of the forest

6 . While elephants have changed and continue to change the structure of the vegetation in Mana Pools, it is largely thicket with emergents, rather than dry forest, that has been lost in this National Park.

7. Human impacts on dry forests have been generally low, partly because the sands on which this vegetation type grows are not favoured for agriculture. But this could change rapidly as pressure for land increases and resources diminish elsewhere. The felling of large trees for making canoes, for timber and for obtaining honey may be a conservation problem in the future.

8. Fire constitutes a threat to many forest canopy trees and emergents which are thin-barked and therefore vulnerable to burning The risk of fire is likely to rise with any increase in human activity (e.g. honey gathering, animal poaching, tree felling or road building).

9. Fungi and lepidoptera may be useful indicator taxa for future studies on the condition of dry forests.

6.2. RECOMMENDATIONS

- In view of the regional conservation significance of dry deciduous forests, pre-emptive strategies for their conservation should be identified urgently.

- This study suggests that the biology of the tree *Pterocarpus lucens* needs to be further investigated, with particular attention paid to elephant debarking of this and other emergent trees. A proposal has been drawn up for a separate study of this topic to take place during early 2002.

- Fungi and lepidoptera are taxa which merit further investigation in the dry forests. There may be species that are endemic to these habitats and so these taxa should be studied in more detail by specialists.

- Birds are one taxa that can quickly be identified by specialists. Additional research, dedicated to birds and addressing the problems encountered during this preliminary study, is recommended.

- Monitoring of the use of mature trees for constructing dugout canoes would be desirable and some controls on this might be appropriate. The provision of artificial bee hives could be investigated to reduce the collateral effects of wild honey collection.

- The assessment protocol developed during this study could be further refined to produce a protocol that is suitable for use by local people who wish to monitor the status and condition of, and disturbance in, their thickets and forests.

This study could be extended to thickets and dry forests elsewhere in the Zambezi Valley, particularly those in Mozambique.

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7. REFERENCES

Anderson, I. (1987). *Communal Land Physical Resource Inventory. Guruve District*. Report no. A 536. Chemistry & Soil Research Institute, Department of Research and Specialist Services, Ministry of Lands, Agriculture and Rural Resettlement, Government of Zimbabwe.

Bennet, J.G., Anderson, I. & Brinn, P.J. (1985). *The soils of the Mana Pools National Park.* Soils Report no. A 517. Chemistry & Soil Research Institute, Department of Research and Specialist Services, Ministry of Lands, Agriculture and Rural Resettlement, Government of Zimbabwe.

Broderick, T.J. (1990). An interpretation of the geology of the Cabora Bassa Basin, mid-Zambezi Valley. *Ann. Zim. Geol. Surv*. **14**: 1 -11.

Coates-Palgrave, K. (1977). *Trees of Southern Africa*. Struik Publishers, Cape Town.

Cumming, D.H.M. *et al.* (12 co-authors) (1997). Elephants, woodlands and biodiversity in southern Africa. *S. Afr. J. Science* **93**: 231 – 236.

Cunliffe, R.N. (1995). *Vegetation Survey of the Gonono Ward, Dande Communal Land, Guruve District.* Consultant's Report for WWF, PO Box CY 1409, Causeway, Harare. 21 pp.

Davies, C. (1999). *Aerial survey of elephants and other large animals in the Zambezi Valley floor and Dande Safari Area/Guruve Communal Lands*. Project Paper 73. WWF-SARPO, Harare. 39 pp.

Du Toit, R. (1993). Reconnaissance vegetation survey of the Chewore-Angwa-Kanyemba area of the Zambezi Valley, Zimbabwe. *Kirkia* **14**(1): 61-77.

Evans, J.R.D. (1967). *Early days at Mana Pools*. Letter in the files of the Zambezi Valley Research Unit, DNPWL, Mana.

Gardner, A.J. & Niemeyer, E.M. (1997). *Mid- Zambezi valley invertebrate diversity: butterflies as indicators*. Consultant's Report to CIRAD, PO Box 1378, Harare. 9 pp.

Guy, P.R. (1977). Notes on the vegetation types of the Zambezi Valley, Rhodesia, between the Kariba and Mupata Gorges. *Kirkia* **10** (2): 543-557.

Hall-Martin, A.J. (1975). Classification and ordination of the thicket and forest vegetation of the Lengwe National Park, Malawi. *Kirkia* **10** (1): 131-184.

Hogberg, P. & Piearce, G.D. (1986). Mycorrhizas in Zambian trees in relation to host taxonomy, vegetation type and successional pattern. *Journal of Ecology* **74**: 775-785.

Lovemore, D.F. (1955). *An ecological tsetse survey of the Upper Kariba,Charara River Valley, Chipatani - Ambakwe Hill Area, March – April 1955*. Unpublished report for the Branch of Tsetse & Trypanosomiasis Control, Department of Veterinary Services, 43pp.

Magurran, A.E. (1988). *Ecological diversity and its measurement*. Croom Helm, New South Wales.

Muller, Th. & Pope, G.V. (1982). Terrestrial Vegetation. In: Du Toit R.F. (ed.) *A preliminary assessment of the environmental implications of the proposed Mupata and Batoka hydro-electric schemes (Zambezi River, Zimbabwe).* Natural Resources Board of Zimbabwe, Harare. pp. 53-65.

Olsen, D.M. & Dinerstein, E. (1998). The Global 200: A Representation Approach to Conserving the Earth's Most Biologically Valuable Ecoregions. *Conserv. Biol.* **12** (3): 502–515.

Petraitis, P.S., Latham, R.E. & Niesenbaum, R.A. (1989). The maintenance of species diversity by disturbance. *Quart. Rev. Biol*. **64**: 393-418.

Price Waterhouse (1996). *Elephant Census in Zimbabwe 1980 to 1995: an analysis and review*. Price Waterhouse Wildlife, Tourism & Environmental Consultants, Harare. 46 pp + 3 appendices.

Thompson P.J. (1975). The role of elephants, fire and other agents in the decline of a *Brachystegia boehmii* woodland *J. Sth. Afr. Wildl. Mgmt Ass*. **5**: 11-18.

Timberlake, J., & Cunliffe R. (1997). *Sites of interest for botanical conservation in the communal lands of the Zambezi valley in Zimbabwe.* Biodiversity Foundation for Africa and Zambezi Society, PO Box HG 774, Highlands, Harare. Phase I, 52 pp & Phase II, 46 pp.

Timberlake, J. R., Nobanda, N., Mapaure, I. (1993). Vegetation survey of the communal lands – north and west Zimbabwe. *Kirkia* 14 (2): 171-270.

Timberlake, J. R. & Mapaure, I. (1992). Vegetation and its conservation in the eastern mid-Zambezi Valley, Zimbabwe. *Trans. Zim. Scientific Assn.* **66:** 1–14.

Walker, B.H. (1976). An approach to the monitoring of changes in the composition and utilization of woodland and savanna vegetation. *S. Afr. J. Wild. Res.* **6**(1): 1-32.

White, F. (1983). *The vegetation of Africa*. A descriptive memoir to accompany the UNESCO/AETFAT-FAT/UNSO vegetation map of Africa. Unesco, Paris.

Zambezi Society and Mid-Zambezi Elephant Project (2000). *Elephant Research and Management in Muzarabani District and the mid-Zambezi Valley*. Zambezi Society, PO Box HG 774, Highlands, Harare. 19 pp.

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8. APPENDICES

APPENDIX A. AERIAL PHOTOGRAPHY

Details of the aerial photographs of Mana Pools National Park examined to search for changes in the structure of thicket and dry forest between 1954 and 1981.

Series name and year, scale, date taken and Surveyor General's identity numbers						**Vegetation structure during 2001**	**Location**	**Transect number**
Zambezi Valley 1954		**Mana Pools 1973**		**Mana Pools/ Kanyemba 1981**				
Scale 1:40000		Scale 1:25000		Scale 1: 25000				
Date	S.G. no.	Date	S.G. no.	Date	S.G. no.			
Unknown	0540 0541	October	-	22 June	240 241	Thicket	North of Mana airstrip	MN 23
Unknown	0540 0541	October	-	22 June	240 241	Thicket with numerous tall emergents	West of Chiruwe River	MN 24
Unknown	0539 0540	October	249 250	22 June	238 239	Thicket with emergents	Gravel pits	MN 25
Unknown	-	October	294 295	8 August	309 310	Thicket	Northern section	MN 26
Unknown	0613 0614	October	-	8 August	448 449	Thicket	Middle section	MN 27
Unknown	-	October	-	8 August	448 449	Thicket	Southern section	MN 28
Unknown	0541 0542	October		22 June	two x 241 (242 n/a)	Thicket with numerous emergents	East of the Chiruwe River	MN 29
Unknown	0541 0542	October	-	22 June	two x 241 (242 n/a)	Thicket	East of the Chiruwe River	MN 30
Unknown	-	October	-	9 July (poor quality) 23 June	520 521 602 603	Thicket	South-west of fourways crossing	MN 31
Unknown	0539 0540	October	250 (251 n/a)	8 August	309 310	Thicket with emergents	Northern section	MN 32

APPENDIX B. ZAMBEZI VALLEY DRY FOREST ASSESSMENT (DATASHEET)

Site No.:……… Location:………………………………… GPS start ………………………………..
Observers:…………………………. Recorder……………..…GPS end…..……………………….……
Date:……………………… Time start:…………………….. Time end:…………………….…...…..
Paces:………………… Distance: …………………………..GPS distance:…………………….……..

FOREST LAYER	**ITEM**	**Present/ Absent**	**Few** 1-5 individuals	**Common** 6-10 individuals	**Abundant** >-10 individuals
	Pterocarpus lucens				
	Adansonia digitata				
	Schinziophyton rautanenii				
	Entandrophragma caudatum				
	Pteleopsis species				
	Balanites maughamii				
	Afzelia quanzensis				
	Berchemia discolor				
	Acacia nigrescens				
TREES	*Boscia mossambicensis*				
	Diospyros quiloensis				
	Commiphora karibensis.				
	Other *Commiphora* species				
	Kirkia acuminata				
	Xeroderris stuhlmannii				
	Xylia torreana				
	Strychnos decussata				
	Schrebera trichoclada				
	Combretum collinum				
LIANE	*Combretum kirkii*				
	Strophanthus kombe				
	Monodora junodii				
	Acacia ataxacantha				
	Cleistochlamys kirkii				
	Meiostemon tetrandrus				
	Neoholstia tenuifolia				
SHRUBS	*Croton scheffleri*				
	Combretum celastroides				
	Combretum eleagnoides				
	Citropsis daweana				
	Fagara/Zanthoxylum spp.				
	Zanthoxylum leprieurii				
	Xylotheca tettensis				
	Karomia tettensis				
	Acacia eriocarpa				
	Broad leaved grasses	Walker's scale			
GROUND	Narrow leaved grasses	Walker's scale			
	Forbs	Walker's scale			

Tree Aerial Cover	Crown-Gap Ratio		% Cover	
Shrub Aerial Cover	Crown-Gap Ratio		% Cover	
Presence of Woody Layers	Forest Canopy	Emergents	Thicket Canopy	Shrubs

Appendix B: (continued)

Lianes	Number	
Emergents	Number	
Standing dead (Trees > 2 m tall; stumps < 2 m tall)	Number of Trees	
	Number of Stumps	
Atypical multistem *Xylia*	Number multistemmed out of first twenty *Xylia* encountered	
Tree "stag-headedness"	Species & Number	
Wood chopping	Species & Number	
Debarking by people	Species & Number	
Debarking by elephants	Species & Number	
Browsing by elephants	Species & Number	
Felled trees	Species, Number & Cause	
Logs > 15 counter-measure diameter	Number	
Elephant path	Number	
Elephant dung	Number	

Appendix B: (continued)

Wild large mammal Signs	Species & Number			
Domestic animal dung	Species & Number of piles of dung			
Epiphytes	Absent	Number and Details (moss, orchid, fig, fern, etc)		
Fire sign	Absent	Details		
Poaching sign (snare, trap, etc.)	Absent	Number & Details		
Tree seedlings	Absent	Species	Few (1-10)	Many (>10)
Litter	Walker's scale			
Alien invaders	Absent	Species		

Walker's scale (Walker 1976)

0 = none; **1** = 1-10%; **2** = 11-25%; **3** = 26-50%; **4** = 51-75%; **5** = 76-90%; **6** = 91-99%; **7** = 100%

Notes on the use of this datasheet

1. There are 3 pages when A4 format is used
2. A transect sample of 500 - 1000 paces in length should be used
3. Occurrences are best ticked in groups of five thus: ~~1111~~ (strikeout is the 5th occurrence)
4. Where appropriate, species names in vernacular language can be substituted if agreed to beforehand. This may need rearrangement of the first page format.

APPENDIX C BIRD SPECIES LIST

SPECIES	No. of transects in which bird species was seen (n=26)	SPECIES	No. of transects in which bird species was seen (n=26)
Marabou Stork	1	Fork-tailed Drongo	5
Hadeda Ibis	2	African Golden Oriole	17
White-backed Vulture	7	Southern Black Tit	2
African Hawk Eagle	1	Black-eyed Bulbul	5
Crowned Eagle	1	Terrestrial Bulbul	13
Black-breasted Snake Eagle	1	Yellow-bellied Bulbul	26
Western Banded Snake Eagle	2	Yellow-spotted Nicator	18
Bateleur	5	Kurrichane Thrush	1
Crested Francolin	4	Natal Robin	1
Crested Guineafowl	12	White-browed Robin	1
Red-eyed Dove	20	Bearded Robin	15
Cape Turtle Dove	16	Willow Warbler	2
Laughing Dove	2	Long-billed Crombec	3
Green-spotted Dove	26	Grey-backed Bleating Warbler	24
Green Pigeon	1	Rattling Cisticola	1
Cape Parrot	2	Tawny-flanked Prinia	1
Meyer's Parrot	5	Blue-grey Flycatcher	4
Purple-crested Lourie	1	Chin-spot Batis	6
Emerald Cuckoo	3	Livingstone's Flycatcher	3
Spotted Eagle Owl	1	Paradise Flycatcher	12
Böhm's Spinetail	1	Tropical Boubou	13
Red-faced Mousebird	1	Puffback	14
Narina Trogon	1	Three-streaked Tchagra	3
Brown-hooded Kingfisher	2	Orange-breasted Bush Shrike	3
European Bee-eater	7	White Helmet Shrike	9
Red-billed Wood Hoopoe	6	Red-billed Helmet Shrike	2
Scimitar-billed Wood Hoopoe	1	Plum-coloured Starling	1
Trumpeter Hornbill	4	Long-tailed Starling	9
Grey Hornbill	1	White-bellied Sunbird	21
Red-billed Hornbill	3	Scarlet-chested Sunbird	3
Crowned Hornbill	20	Collared Sunbird	1
Yellow-fronted Tinker Barbet	6	Southern Grey-headed Sparrow	1
Greater Honeyguide	3	Red-headed Weaver	1
Cardinal Woodpecker	3	Red-billed Quelea	1
Bearded Woodpecker	3	Melba Finch	4
African Broadbill	1	Red-billed Firefinch	5
Angola Pitta	1	Paradise Whydah	2
uropean Swallow	4	Steel-blue Widow Finch	1
Brown-throated Martin	1		