SADC REGIONAL PROGRAMME FOR RHINO CONSERVATION

ECOLOGICAL EVALUATION FOR LIWONDE NP, MALAWI, WITH RESPECT TO THE DEVELOPMENT AND MANAGEMENT OF A VIABLE POPULATION OF BLACK RHINO (*Diceros bicornis minor*)

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Ecological Evaluation and Development of Guidelines for future management of black rhinos at Liwonde NP, Malawi
Semester 4 task 1.2-4.1

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- The Secretariat of the Southern Africa Development Community (SADC)
- IUCN-ROSA (The World Conservation Union - Regional Office for Southern Africa)
- The IUCN African Rhino Specialist Group
- WWF-SARPO - (World Wide Fund for Nature - Southern Africa Regional Programme Office)
- CESVI (Cooperazione e Sviluppo)

The ***Programme goal*** is to contribute to maintain viable and well distributed metapopulations of Southern African rhino taxa as flagship species for biodiversity conservation within the SADC region.

The ***Programme objective*** is to implement a pragmatic regional rhino strategy within the SADC region following the acquisition of sound information on, firstly, the constraints and opportunities for rhino conservation within each range state and secondly, the constraints and opportunities for rhino metapopulation management at the regional level.

DISCLAIMER

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INTRODUCTION

Since 1993, three pairs of black rhino (*Diceros bicornis minor*) have been re-introduced into Liwonde National Park (NP). This was the first step in re-establishing the species in this country where they were officially declared extinct in 1990 (Anonymous 1993, Bhima 1996, Bhima & Dudley 1996). While these introductions have been partially successful with four young born during this period, two adults, one male and one female with an advanced fetus, have died. These deaths were not caused by poaching but perhaps to a lack of information on the ecological requirements of the species and weakness of the park's management capacity.

In an attempt to address this problem, R. Bhima, requested assistance to develop and support a professional management system for the long-term survival of the black rhino in Malawi. As a first step in this plan, the SADC Rhino conservation programme provided funding to define ecological guidelines for the development of a management plan for rhino conservation in Liwonde NP. The report which follows, reviews past vegetation surveys and habitat studies in Liwonde NP, maps the park's vegetation at suitable scale for GIS format and, on this basis, produces estimates of the rhino carrying capacity for the entire Liwonde NP so as to be able to form a viable population. In addition, recommendations are made for a long-term ecological monitoring and evaluation programme. A full account of the terms of reference for this work is given in Appendix 1.

BLACK RHINO IN MALAWI

HISTORICAL ACCOUNT

Johnston (1897), in his classic account of British Central Africa (now Malawi), wrote "Although nowhere very abundant, the ordinary two-horned rhinoceros is probably found pretty generally over all British Central Africa except on the high plateau." In the most recent review of the historical distribution of rhino in Malawi, Ansell & Dowsett (1988) report that they were "In the past, found virtually throughout the country, except for the montane areas", even as high as the foothills of the Nyika Plateau (McClounie 1903). Their distribution map (map 100) shows that rhino, prior to 1975, were recorded in 38 of Malawi's ~170 1/4 degree squares with records extending from Karonga in the far north to the Mwabvi area in the southern end of the Lower Shire Valley. An earlier historical review regarding the past distribution of Malawi's rhino (and other large ungulates) is provided by Sidney (1965 cited by Hobbs 1976).

By 1984, Malawi's rhino were now confined to Kasungu NP in the country's Central Region and Mwabvi Game Reserve (GR) in Nsanje District (Jachmann 1984). Mwabvi GR (formally Thangadzi River Reserve in 1929) was primarily established to conserve the few (6-7) remaining rhino in the southern part of the country. This was not considered a viable population, but rather part of a larger metapopulation in the adjacent wilderness of Moçambique (Jachmann 1984). In fact, according to Jachmann over the last 50-60 years it was unlikely that more than 10 individual ever occupied the area of Mwabvi GR. Similar low numbers were estimated for the reserve by Ridding (5 animals, 1975) and Parker (4-7 animals, 1976).

In the same paper, Jachmann states that the Kasungu NP population (10-20 animals) was fairly stable due to strong anti-poaching activity, a well-run research unit and low numbers of rhino relative to dense vegetation. Yet, within 5-6 years this species was extinct in the country.

Hall-Martin (1969) and I are unaware of any records of rhino being present in Liwonde NP. However, there are a number of historical accounts of rhino in nearby locations. These were reviewed by Hobbs (1976) and Stead & Dudley (1977). Probably the first published record was that of O'Neill (1884) who reported the species present in the area from Lake Amaramba to Lake Shirwa (=Chilwa), an area little more than 30-50km from Liwonde NP. Johnston (1895) recorded that on the Chilwa and neighbouring plains "rhino still range". This was supported for the same period (1894) by Maugham (1929). Duff (1903) reported four rhino being shot in the Zomba District, the adjacent district to the present Machinga District, which contains the park. Perhaps more relevant to the park is the report in the *Handbook of Nyasaland* (Murray 1922) that "rhinoceros would occasionally be tracked to the Masanje River", a perennial river whose lower reaches pass through the northern section of the park where it empties into Lake Malombe. Earlier editions of the *Handbook* (Murray 1908, 1910) reported rhino in the Kirk Range 75km away on the western edge of the Rift Valley. Ansell & Dowsett's (1988) map of rhino distribution includes quarter degree squares 1435-C2 and 1435-C4, both squares include approximately 90% of the park and much of the Mangochi Forest Reserve. I do not know the actual records substantiating the presence of rhino in these squares.

Considering the wide historical distribution of this species in the country and its tolerance of a great range of habitats (Smithers 1983) from grasslands (Serengeti, Frame 1980) to deserts (Loutit, *et al.* 1987) the species assuredly was present in the area that is now Liwonde NP in the early part of the last century.

MODERN RE-INTRODUCTIONS

The initial introduction of rhino into Liwonde NP, were a pair from Kruger NP in South Africa (Anonymous 1993). They were released into an electrified fenced sanctuary (no 1, 15km^2) in late 1993 and at that time were about four years old. Three years later in June 1997 they produced the first calf (a male). A second calf (male) was born in 1999 (Bentley Palmer pers. com.). During this period, a second pair of rhino was placed in a second enclosure (no 2, 14km^2) to the south and adjacent to the first. In early 2000, this pair produced a calf (sex unknown).

Late in 2000, a third pair of rhino was introduced into a third sanctuary (no 3) adjacent to and to the east of the first two enclosures. The third site was delineated by Dudley (2000) at approximately 17km^2 but in actual layout in the field by J & B Circle personnel proved to enclose nearly 20km^2 (Labuschagne pers. com.).

In 1999, the fence dividing the sanctuaries no 1 and no 2 was removed. The arrangement and placing of the three sanctuaries is shown in Fig. 1.

Unfortunately, the year 2001 saw some setbacks to these re-introductions. Not long after the fence dividing the two sanctuaries had been removed, the first introduced male was found dead. It was first thought that this might have been due to aggression from the male in sanctuary no 2. It has been found in other sanctuary situations that adult bulls often will kill one another in restricted areas of less than 25km^2/bull (Walker 1994). According to Knight *et al* (1998 as cited by Pienaar & Dudley 1998), it is South Africa NP management practice to first separate new introduced black rhino through fencing and only remove the fencing once newcomers have established themselves completely. At Liwonde NP, the two sanctuaries totaled no more than 29km^2, well under the 50km^2 Walker claimed was needed. While many people in Malawi felt that the removal of the fence lead to the death of the first male through conflict with the second, M. Labuschagne (pers. comm.) feels that the cause of death was due to tryps (*Trypanosoma* sp) infection. Rhino are known to die from such infection if they have not had prior exposure to certain strains of tryps, particularly when under stress (Taylor 1986 and Mihok *et al.* 1992 as cited by Dunham 2001). Labuschagne said that the skeletal remains of the male showed no signs of damage. He reported that K. Lorenz, a vet based in Blantyre and with considerable wildlife experience, said that the introductions of buffalo from Kasungu NP in 1999 may have introduced the more aggressive strain of tryps, *T. brucei*, into Liwonde NP where only *T. congolensis*, a less virulent strain had previously been present. He suggested that this might have been the cause of death, particularly if the male was under some type of stress as well.

A second death was more unfortunate since it was a female in late stages of pregnancy. This was a member of the third pair in sanctuary no 3. Due to various problems in selection and translocation, and perhaps due to her pregnancy, she was considered to be under stress and not settling well within the enclosure. Labuschagne again suggested that from site observations, death might have been from tryps. While neither situation is proven, *Trypanosoma* infections must be considered a possible factor in the deaths of the two animals.

Recent good news is that another calf was born in the sanctuary October 2001. It has not been sexed yet.

LIWONDE NATIONAL PARK

GEOMORPHOLOGY

The geomorphic features of Liwonde NP have been interpreted and mapped by Dudley (1976) and Schroder (1979). I produced a revised map in 1978 that now forms part of this consultancy. Such maps assist in the rational use of the physical and biological environment through their symbolic incorporation of the material composition and dynamic processes governing the evolution of relief. This map was derived from 1:20,000 air photos with ground truthing and contains mostly morphogenic information. Such maps interrelate with all aspects pertinent to the analysis of the resources of the NP including current and potential soil erosion and deposition patterns, hydrological characteristics and vegetation dispersion, structure and floristics (Dudley 1976). Furthermore, such a map may highlight practical features such as problems of accessibility, and peculiar and difficult topographical features that have a bearing upon fence, bridge (or drift) and road construction and alignment.

SOILS

A reconnaissance soil survey was undertaken by Mitchell & Ntokotha (1974) in 1969/70 to assess the agricultural potential of the land before it was committed as a NP. Their conclusion was that little more than 30-45km^2 of the surveyed land could be classed as suitable for rain fed agriculture. Perhaps half the survey area might be suitable for rice cultivation but the costs of soil improvements and drainage probably would be high and not justified. No other significant soil study for the Liwonde NP area has been done.

Mitchell & Ntokotha (1974) mapped a total of seven soil/land types and provided a partial analysis from 17 auger holes (pH, exchangeable sodium and salinity). Three quarters of the area surveyed proved to be deep immature sandy clays with shallow topsoils and impeded drainage. Extremely hard, compact surface horizons (at 7-15cm) with impermeable sub-soils predominated. The soils were commonly sodium deflocculated.

Mitchell & Ntokotha (1974) accompanied their report with a map and an extremely brief description of the vegetation of the mapped soil types. The distribution of soil features provides some explanation to the distribution of vegetation communities within Liwonde NP (i.e. tall grass tree savanna (soil type 10), the mopane woodland/thickets (soil type 14) and the mopane woodland and mopane clump (termitaria) savanna (soil type 6b)). The relation of vegetation to their soil types 13 and 6c is not clear. A copy of their map at a scale of 1:50,000 has been produced for this report.

VEGETATION

The earliest recorded vegetation description with any useful detail for Liwonde NP is that of Hall-Martin (1969). Other reports (i.e. Shaxson 1977), where they exist, are too superficial to be of any use at this scale. Hall-Martin divided the park's vegetation into six communities with several subdivisions within two of these. (1) Riverine and flood plain vegetation included five wetland habitats: (a) aquatic communities (lagoons, edges of Shire River and Lake Malombe), (b) floodplain grasslands, (c) riverine thicket, (d) forests (along Shire banks and most east-west watercourses) and (e) *Hyphaene* palm savanna (within the southern floodplains). (2) Tree savanna included two types: (a) mixed deciduous tree savanna-*Adansonia digitata* and (b) deciduous tree savanna-*Terminalia sericea* (on better-drained soils towards the escarpment) which grades into the *Brachystegia* woodland of the Rift Valley walls. A more mesic (3) *Combretum* savanna woodland was noted on the Chiunguni and Nafiulu hills. Approximately 70% of the area was covered by (4) *Colophospermum mopane* woodlands. All types of stands occurred from true woodland with trees up to 15m or more high. Grassy dambos were common. The mosaic effect seemed to depend on the position of drainage lines and on the resultant soil catena. The last two communities were the ubiquitous (5) termitaria communities (thickets) and (6) dry forest (Namalembo) similar to that of Lengwe NP.). Most of these communities, although here very superficially described, fall within those proposed by Dudley (1994). The total flora listed by Hall-Martin was very small (33 species).

A more detailed classification of the vegetation and flora of Liwonde NP is that of Dudley (1994). This study remains the most intensive botanical research that has been undertaken with regards to the floristics and physiognomy of Malawi's deciduous woodlands. The flora proved to be considerably richer than might be expected from the literature describing other dry deciduous woodlands (particularly mopane woodland areas) and the small homogenous nature of the park's landscape. It stands at 1040 taxa. This is greater than the recorded flora of the much larger Tsavo East NP (931spp, 12,000km^2, Greenway 1967 vs. 1040spp, 548km^2, Dudley 1994). The Selous NP at 45,000km^2 (almost 100X larger) records a flora only about 2X as large at 2065 species (Vollesen 1980). For its size, Liwonde NP has a much richer flora than that recently described for South (1094spp, 9,000km^2, Astle *et al.* 1997) and North (924spp, 4,636km^2, Smith 1997) Luangwa NPs in Zambia, parks with similar vegetation to Liwonde.

Monocots comprise approximately 23% of the flora (237 spp, 21 families) of Liwonde NP while dicots account for 76% (783 spp, 87 families) (Dudley 1994). The legumes are prominently represented within the 15 largest families of dicots: Fabaceae (1st, 80spp), Mimosaceae (6th, 32spp) and Caesalpiniaceae (11th, 21spp). Other important families are Euphorbiaceae (2nd, 46spp), Rubiaceae (3rd, 42spp), Asteraceae (4th, 41spp) and Acanathaceae (5th, 35spp).

Dry deciduous vegetation communities predominate in Liwonde NP and occur roughly as north-south "bands" parallel to the Shire River. Soil moisture, salinity, chemistry and texture strongly influence the distribution of these communities as do fire and elephant. Dudley (1994) places the flora of Liwonde NP into seven vegetation associations or communities, one of these, the mopane woodland complex, is further divided into six facies or subtypes.

Floating meadows, lagoons and reed swamps
These occur along the Shire River and the south eastern shore of Lake Malombe, being most extensive in the south. More than 42 species of plants have been collected in these habitats (Blackmore *et al.* 1988) that occupy approximately 4.5% of the park.

Floodplain grasslands/grasslands and associated communities
The boundary between the floodplains and the more mesic grasslands is often indistinct and can vary greatly over the years due to changing water levels of Lake Malawi and to the action of the barrage on the Shire River, just south of the park. Associated with the grasslands are smaller communities of *Hyphaene* palm savanna and palm thickets. Again, the floodplain grasslands are much more extensive in the south. The total area of these communities is little more than 3%.

The most important genera of the grasslands are *Setaria*, *Digitaria*, *Sporobolus*, *Echinochloa* and *Panicum*. In some areas these grasses form nearly monospecific stands, occupying preferred soil moisture sites parallel to the swamps. Poaceae, with 98 species known, is the largest family in the park's flora.

The *Hyphaene* palm savanna has never been extensive and has further been reduced through past actions of palm tappers that killed numerous trees and through fire, inhibiting recruitment of young plants.

Hyphaene palm forest/thickets vary in size from 0.1-1.0ha and are rich in species (40spp/0.25ha). They are found on 'fossil' alluvial sand deposits, providing good penetration of water. Along with 16m palms, other tree species include *Adansonia* *digitata*, *Afzelia quanzensis*, *Erythrina* and *Acacia* species. Smaller (8-10m) trees of the subcanopy include *Diospyros* spp, *Grewia* spp and *Vangueria infausta*.

Mixed woodlands (MxW)
These woodlands are found on all the stony inselbergs of the park with some degree of variation in floristic composition, canopy cover and tree height. Dominant genera are *Combretum*, *Terminalia*, *Diplorhynchus*, and *Sterculia*. On Chiunguni Hill (909m) the woodland approaches that described by Shaxson (1977) as "open canopy woodlands of hills and scarps". Here can be found tall emergents (20-25m) trees of the species of *Brachystegia*, *Burkea*, and *Kirkia*. Fire damage to smaller trees (<10m) is considerable, particularly on the lower inselbergs. The community is small covering no more than 2.5% of the park.

Tall grass tree savanna (TGTS)
This vegetation type is more difficult to precisely define and shows great variation in percent tree cover (<5->20%). It is found along the narrow 'floodplains' of the east-west seasonal (Mwalasi, Namandanje, Nangondo and Ntengai) and perennial streams (Masanje and Likwenu) and in the northern extension of the park. Tall trees (16-20m), occurring individually or as small groups, are widely spaced and grass cover is thick (100%) and tall (2-3m). Important trees are of the genera *Sclerocarya, Cordyla*, *Adansonia*, *Combretum*, *Sterculia*, *Lonchocarpus*, *Xeroderris*, *Acacia* and *Piliostigma*. Some species are twisted and stunted by fire and are of only moderate height (4-6m). Seasonal regeneration of fire coppiced individuals of the species above can be vigorous. In spite of fierce seasonal fires, the community in many sites is slowly giving way to encroachment by woody species of the adjacent woodlands (*Colophospermum mopane* and *Dalbergia melanoxylon* amongst others) (Dudley 2000). In some locations in the northern extension, along the park's southern boundary and in the central eastern area around the Nafiulu Hills, the openness of this community is due to the actions of cultivators prior to the parks establishment. It is in these more open facies, that fire seems to be forcing the succession towards a more grassland habitat.

The vegetation type covers about 14% of the park's area but contributes little in the sense of adding new woody species to the flora. It is an important feeding area for elephant in the wet season.

Riverine semi-deciduous forest/thicket (RF/T)
Along the banks, oxbows and river terraces of perennial and seasonal east-west rivers can be found a band of fringing 'forest' or thicket (5-100m wide), the width of this band diminishing greatly to the east where stream channels are not so deeply incised. Where these streams empty into the Shire River and the water table is high and there are larger deposits of alluvial soil, sometimes forming high banks, the community is well developed and may cover many hectares. In some locations along the Shire, there are almost pure stands of *Borassus* palms (18-20m). Other sites are very mixed and may include emergent trees such as *Parkia*, *Khaya*, *Xeroderris*, *Terminalia*, *Diospyros*, *Acacia* and *Ficus* spp, some reaching heights of 33m. The main canopy layer (12-15m) contains genera such as *Trichilia*, *Garcinia*, *Kigalia*, *Diospyros* and *Albizia*. There are numerous lianas of considerable girth (>30cm) such as *Dalbergia, Saba* and *Artabotrys*. The species complement of this restricted park habitat (1%) varies from place to place depending upon soil type and water availability. Near the Shire a total of 50-60 woody species (85% trees) can be found per hectare.

The forest areas are sometimes joined by thickets on terraces and at the forest woodland interface. This dense vegetation includes species of *Friesodielsia*, *Markhamia* and *Diospyros* without emergent trees. The first species usually forms a band of thicket 10-15m each side of the riverbank forest. *Friesodielsia* also can form small thickets in mopane woodland areas when not too far from river-influenced ground or near sumps and waterholes. Other important species are in the genera *Byrsocarpus*, *Fretia*, *Antidesma*, *Jasminum*, *Lindackeria* and *Grewia*. Some of this vegetation may be secondary growth on past-cultivated land.

Presently, the riverine forest elements are undergoing some decline principally where the seasonal streams join the Shire. These areas act as congregating and feeding sites for elephant in the dry season and much of the lower canopy trees and lianas have been badly damaged. In addition, the historically high levels of Lake Malawi in 1977-1980 (Crossley 1980) killed many canopy and emergent trees. Consequently, large proportions of this vegetation type have been opened up through tree fall to the invasion by grass and thicket species and, thus, to the influence of fire.

Drought deciduous forest/thicket (DDF/T)
In spite of its small area (<1.5%) this community contains the richest and most interesting vegetation to be found in Liwonde NP. Several species were new to science while many more proved to be first or second records for the country or even the Flora Zambesiaca Region. More than 80 species of woody plants (80% trees) have been collected at a one-hectare site. Emergents include *Balanites* (25m), *Entandrophragma* (25m), *Fernandoa* (32m), *Lannea* (>20m), *Newtonia* (29m), *Terminalia* (30m), and *Xylia* (>20m). Underneath are found two canopy layers at 8 and 15m dominated by *Strychnos*, *Hymenocardia*, *Millettia*, various Rubiaceae, and several lianas of the genera *Combretum*, *Acacia*, *Dalbergia*, *Tiliacora* and *Hippocratea*.

The soil is deep sand and is probably derived from ancient alluvial deposits and may overlie a high water table. As with the riverine forest, elephant have recently damaged this community and along with woodcutters from the nearby villages, opened up the forest considerably.

***Colophospermum mopane* woodland complex**
This complex occupies about 74% of the park's area and gives it its somewhat uniform appearance. While it is correct that *C. mopane* dominates these communities (sometimes up to 80% of woody plants >2.0m), considerable variation is possible. Grass cover is short and often sparse and ground cover is greatly given over to species of Acanthaceae. Very shallow nearly flat drainage lines dissect these communities in a dendritic pattern. Six of the most prominent facies are described below.

Mopane woodland (MW): There is often great uniformity in mopane height (12-15m) and canopy cover can be greater than 50%, generally always over 25%. There is little evident clumping of the canopy trees. Other canopy species seldom reach 10% of the facies. Numerous *Euphorbia ingens* (6-8m) and baobabs are present. A patchy second canopy layer of *Dalbergia melanoxylon* (3-8m) and *Balanites aegyptica* (7-8m) may occur as scattered stands. Also present are species of *Albizia* and *Canthium*. Dense regenerating patches (0.5-3.0m) of mopane, *D. melanoxylon* and *Acacia* spp also occur. Where fire has been infrequent, these understory stands may form dense thickets and cover 10-30% of the area. The semi-woody *Anisotes formosissimus* and *Ecbolium clarkei* may be dense at ground level (1-1.5m). Few termitaria thickets are seen.

Open mopane woodland: This is similar to the above except that the soils are deeper and the trees are taller (20-25m) and more widely spaced (cover 20-40%). A second canopy layer is less in evidence

Mopane clumped (termitaria) savanna (MCS): This is a widely distributed subtype, mostly occurring in the eastern two thirds of the park. The trees (10-30% cover) are restricted to regularly spaced termite hills, many of which may be very ancient. Separating these termitaria, are wide grassy glades, often seasonally waterlogged. This vegetation type intergrades with other forms of mopane woodland complex and is quite variable. The mopane trees can be large (20-25m) yet can number up to 13/termetaria. A well-developed secondary canopy exists (8-12m) including species of *Drypetes*, *Markhamia*, *Cassia*, *Albizia, Euphorbia*, *Lannea*, *Tamarindus* and *Dalbergia*. *Fockea multiflora*, *Combretum kirkii*, *Hippocratea* and *Capparis* species are well-developed lianas. The dense shrub layer (~2-3m) contains species of *Combretum*, *Thilachium*, *Grewia*, *Boscia*, *Friesodielsia*, *Fretia* and *Allophylus*. Fire is an intense modifying force.

Mopane woodland/thicket (MW/T): These spiny woodland thickets are primarily restricted to the more compact, impermeable and alkaline soils of the southwestern part of the park. They include many succulents, especially *Euphorbia ingens* and *E. lividiflora* as well as *Fockea* and *Adenium*. The thicket aspects (2-5m), often associated with small termite hills, are mainly made up of species of *Acacia*, *Commiphora*, *Ziziphus*, *Croton* and *Salvadora*. Mopane is the principal canopy tree (10—12m) but is not so dominant. In recent years elephant have opened up this association greatly. In a recent survey, one 0.25ha plot showed a decline of nearly 70% in individuals of woody species from 1984-2001 (Nyoni unpublished data). The community is very rich, containing up to 60 woody species per 0.5ha.

Mopane woodland with coppice: This gives the impression of a tea field on air photos and consists of dense, almost impenetrable patches of mopane (1.5-2.5m, 20-30% cover) intermixed with few taller mopane (12-15m) (Dudley 2001). Elephant browsing maintains the coppice form. In some areas there appears to be an additional influence of soil factors. These types generally occur near the Shire predominately north of the Mwalasi River and on very impermeable alkaline soils.

Albizia harveyi woodland: This association exists as small to medium sized (0.5-72.0ha) enclaves within the mopane woodland complex and consists of stands of almost pure *Albizia harveyi* (>90%) reaching 10-12m in height and with canopy cover of 40-50%. The understory (1-3m) is primarily mopane and *D. melanoxylon*. These trees are declining rapidly due to root disease and elephant browsing (as much as a 62% decline in canopy individuals in 23 years, Dudley 1999).

Waterholes

Waterholes have their own specific characteristic vegetation. This includes trees species of the termite hills in the drier areas and shrubs and trees of the riverbanks, such as *Diospyros mespiliformis*. Often there is considerable shrubby cover as well at the edges.

Rhino sanctuaries

The vegetation map produced for the park for this report utilized air photos at a scale of 1:34,000 to 1:40,000 and taken well into the dry season (August) when trees had lost a very high proportion of their leaves. Analysis of the vegetation of the present sanctuaries was undertaken at a finer scale (1:5,000 and 1:25,000) with the latter taken earlier in the year (May and July). For the investigations of the sanctuaries, considerable field observations were possible. In the field, species, height and cover of woody plants were important factors, particularly for those plants <3m high. For air photo analysis, sanctuary sites were located on air photos. Homogenous appearing units of vegetation were then marked off and mapped and the area of each of these units was estimated. Subsequently, each unit was ground checked and described in terms of general structure and floristics. Three major vegetation communities were identified in the sanctuaries. These were further subdivided into important variants. Table 1 compares the vegetation of the three sanctuaries. Two facies of the mopane woodland complex are shown while several of the minor subtypes are combined.

Table 1. A comparison of the vegetation of the three rhino sanctuaries in Liwonde NP. Values are in percentage cover. RF/T = Riverine forest/thicket combined, TGTS = Tall grass tree savanna, MW = mopane woodland with or without coppice, MCS = Mopane clump (termitaria) savanna and misc = miscellaneous minor types.

Sanctuary	RF/T	TGTS	MW	MCS	misc
1	10	35	45	9	1
2	8	11	75	5	1
3	3	25	19	51	2

There appear to be important differences with respect to areas given to the mopane complex at the expense of RF/T and TGTS. As expected with the most eastern sanctuary, MCS formed the majority of the land cover.

Mangochi Forest Reserve
I was asked to highlight the implications of extending the management of the park to (into?) the Mangochi Forest Reserve (FR).

The Mangochi massif lies immediately to the north of Liwonde NP, having a continuous connection to the park's northern extension (corridor) of 7-8km at the base of the steep escarpment. The whole mountain is very rocky with its highest point 1,742m a.s.l. On the upper slopes the rainfall is probably at least 1,300mm p.a. as at Namwera (900m) rainfall averages ~1,100mm (Waldon 1976). At the highest elevation mists frequently occur in the dry season.

Knowledge of the Mangochi FR is very scarce and, to a considerable degree, is limited to the animal and plants of the evergreen forests of Mangochi Mountain itself (Chapman & White 1970, Dowsett & Hunter 1980, Johnston-Stewart 1984)
The evergreen submontane forest covers the upper part of the main peak (1580-1740m) and covers about 2,500ha (Chapman & White 1970). Well below the forest on a plateau between the mountain's peak and its lower ramparts lies the abandoned Fort Mangochi built in 1896. The forest's upper canopy reaches to 36m and includes species of the genera *Chrysophyllum*, *Drypetes*, *Ficus* (stranglers), *Cola*, *Teclea* and others. A secondary canopy is conspicuous. The forest/grassland edge is sharp indicating repeated dry seasonal fires. Much elephant damage is in evidence where woodlands approach the forest. Elephant probably occur in small numbers throughout the year at these upper elevations (Johnston-Stewart 1984).

The woodlands of the lower slopes can be generally called *miombo* and *Brachystegia/Julbernardia/Uapaca* species dominate. Waldon (1976) described the woodland/savanna vegetation and the physical features of the lower reaches of the mountain from a land husbandry/forest plantation development point of view by tree density, photo tone and texture using air photos and ground surveys. Typically, his groupings included woodland, wooded savanna, tree savanna, tree/bush savanna, grasslands and dambos. In most situations tall dense *Hyparrhenia* grass was present. Tree height ranged from 6-15m while canopy was 20 to nearly 100% cover. Slopes are steep in places ≥25% and much dissected and showed considerable soil erosion (up to 75% of top soils lost). However, little information was provided regarding the woody vegetation at the 1-3m level.

Rhino would certainly be able to survive in this habitat. Water should be available throughout the year, although sources would be scattered and limited in the dry season. Food resources fall within the range of suitability. However, sufficient monitoring and protection activities would be problematical because of the inaccessible nature of the massif due to the lack of any roads and steep dissected topography, particular along the southern escarpment. From a more general conservation point of view, bringing the FR within the NP management scheme would be ecologically sensible. The conservation area would include the full range of communities within the greater ecosystem of the Rift Valley wall, from the evergreen forest and montane 'grasslands', through the escarpment woodlands and their canyons, across the plains of mopane, mixed woodlands and riverine forest/thickets to the wet grasslands and marshes of Lake Malombe and the Shire River. Managing this vast ecosystem would be another matter.

RHINO FOOD SELECTION AND DIET

Black rhino have a very rich selection of food plants. Smithers (1984) states that over 200 species are recorded in the literature and the list includes both forbs and woody plants. However, as I show below, at least 614 species of plants have been recorded in the black rhino's diet by researchers in East, Central and Southern Africa.

Goddard (1968) recorded 120 species (32 families) eaten by rhino in Ngorongoro NP, 63 species (31 families) taken in Olduvai Gorge (overall 173 different species and 42 families, somewhat smaller than the 191 species and 49 families he claims in his paper) and in 1970 listed 102 species (30 families) selected in Tsavo NP. In all cases there was a large percentage of herbaceous species in the diet but their contribution to the total food intake was hard to estimate. Species of leguminous plants and members of the Euphorbiaceae, as well as other plants with high moisture content, were important dietary items and were stated to be the key to an optimum habitat.

Mukinya (1977) observing black rhino in the Masai Mara GR listed 70 species (28 families), again listing herbs and shrubs. Important families were Capparaceae, Solanaceae, Euphorbiaceae and Mimosaceae.

Oloo *et al.* (1994) made a number of indirect observations on the diet of rhino in Laikipia, Kenya over a period of six months. They recorded 103 species (37 families). The most important families, in rank order, were Acanthaceae, Papilionaceae (=Fabaceae), Asteraceae, Euphorbiaceae, Mimosaceae, Verbenaceae, Anacardaceae and Rhamnaceae. *Acacia* was a very important food plant.

Hall-martin *et al.* (1982) recorded 111 species (37 families) in their feeding study of the rhino of the Addo Elephant NP. Woody shrubs were major preferences but rhino also consumed forbs, grass and succulent plants, the latter being favoured in the dry season.

Loutit *et al.* (1987) investigating the rhino of the extremely arid Skeleton Coast Park, Namibia, noted 103 species were selected (42 families), representing a high proportion of plants available in this habitat.

Closer to Malawi, Dunham (2001) obtained a small list (compiled by P. Berry) of some of the plants (17 species, 15 genera, 9 families) that rhino have been observed to eat in the Luangwa Valley, Zambia. Legumes, Euphorbiaceae and Combretaceae predominate. Furthermore, Dunham cites information, provided by T. Woodfine, regarding the ten species most favoured by rhino in Matusadona NP in the Zambesi Valley (*Karromia tattensis*, *Combretum zeyheri*, *C. celastroides*, *Diospyros quiloensis*, *Baphia massaiensis*, *Carphalea pubescens*, *Diplorhynchus condylocarpon*, *Acacia nigrescens*, *Grewia bicolor* and *Colophospermum mopane* (*Catunaregam spinosa* and *Croton gratissimus*. replace *D. condylocarpon* and *G. bicolor* in the dry season.). In the midlands of Zimbabwe, Coates-Palgrave (unpublished, cited by Dunham 2001) noted that rhino feed heavily upon *Combretum apiculatum*, *C. molle*, *C. hereroense* and *Terminalia prunioides* as well as *Acacia gerrardii*, *Flueggea virosa* and *Pseudolachnostylis maprouneifolia*.

Our current list of 61 species (46 genera and 25 families) eaten by the rhino in the sanctuaries of Liwonde NP is shown in Table 2. With the exception of *Annisotes* and *Ecbolium* that are semi-woody shrubs, the remaining species are strictly woody reflecting the dry-season bias in observation. The list should greatly increase once herbaceous species are included and longer, more intense observations made. While this list contributes little to our knowledge of the importance of any of these species individually to the bulk and nutrition of the rhino's diet it does emphasize the significant plant families and genera that contribute to the diversity of its diet. Mimosaceae (8 spp), Fabaceae (6 spp), Euphorbiaceae (6 spp), and Combretaceae (4 spp) are noticeable families while *Acacia* (5 spp), *Combretum* (4 spp), and *Grewia* (3 spp), stand out as important genera. In terms of the number of individual plants utilized throughout the year, *Colophospermum mopane*, *Dalbergia melanoxylon*, *Combretum fragrans*, *Ziziphus mucronata*, *Euphorbia ingens, Acacia nigresens* and *Annisotes formo-*

Table 2. List of plant species eaten by rhino in Liwonde NP, Malawi.

Acanthaceae	**Euphorbiaceae**	**Tiliaceae**
Anisotes formosissimus	*Antidesmea venosum*	*Grewia bicolor*
Ecbolium clarkei	*Croton gratissimus*	*G. monticola*
	C. megalobotrys	*G. stolzii*
Anacardiaceae	*Euphorbia ingens*	
Lannea schweinfurthii		
stuhlmannii	*Phylanthus reticulatus*	**Verbenaceae**
Sclerocarya birrea caffra	*Securinega virosa*	*Vitex ?payos*
Annonaceae	**Fabaceae**	
Cleistochlamys kirkii	*Dalbergia arbutifolia*	
Friesodielsia obovata	*D. boehmii*	
	D. melanoxylon	
Asclepiadaceae	*Lonchocarpus capassa*	
Fockea multiflora	*Melletia usaramensis*	
	Pericopsis angolensis	
Apocynaceae		
Strophanthus nicholsonii	**Flacourtiaceae**	
	Oncoba spinosa	
Bignoniaceae		
Kigelia africana	**Malvaceae**	
	Azanza garckeana	
Boraginaceae		
Cordia goetzei	**Mimosaceae**	
Ehreia amoena	*Acacia latistipulata*	
	A. nigrescens	
Burseraceae	*A. nilotica*	
Commiphora africana	*A. sieberiana*	
	A. xanthophloea	
Caesalpiniaceae	*Albizia anthelmintica*	
Cassia abbreviata	*A. harveyi*	
Colophospermum mopane	*Dichrostachys cinerea africana*	
Tamarindus indica		
	Rhamnaceae	
Capparaceae	*Ziziphus mucronata*	
Capparis erythrocarpos		
C. tomentosa	**Rubiaceae**	
Thilachium africanum	*Canthium frngula*	
	Crossopteryx febrifuga	
Combretaceae	*Fretia aeruginescens*	
Combretum apiculatum	*Xeromphis obovata*	
C. fragrans		
C. imberbe	**Salvadoraceae**	
C. kirkii	*Salvadora persica*	
C. mossambicense		
Terminalia stenoctachya	**Sapindaceae**	
	Allophylus africanus	
Cucurbitaceae	*Lecaniodiscus fraxinifolius*	
Momordica foetida		
	Solanceae	
Ebenaceae	*Solanum incanum*	
Diospyros truncatifolea		

sissimus would seem to be key species. These observations fall closely in line with those of Emslie & Adcock (1994a) and the feeding studies of Goddard (1968, 1970), Mukinya (1977) and Oloo *et al*. (1997) and the information provided by Dunham (2001).

Combining the check lists of the above, at least 614 species (76 monocots, 538 dicots), representing 76 families of plants, are reported to be eaten by black rhino. Table 3 shows the ten families with the largest representation of species. The herbaceous families Asteraceae and Acanthaceae are the largest, closely followed by the legume family Fabaceae. The other two legume families, Mimosaceae and Caeslpinaceae follow Euiphorbiaceae. Poaceae ranks fourth! This ranking of Asteraceae, Acanthaceae and Poaceae is at odds with the literature. However, for an animal with such a wide ranging diet, species selection is probably influenced by the absolute species richness of the families. For example, Fabaceae with 10.2% of the dicot flora of Liwonde NP (80+ species), would be expected on chance alone to provide a high proportion of the rhino's diet. Yet, this is not the full explanation as Asteraceae, Acanthaceae, Caeslpinaceae and Malvaceae are well above their expected proportions while Aizoaceae, and especially, Rubiaceae, are well under. Overall, species of the ten top families are represented more often than would be expected to be the case based on simple species richness of these families.

Table 3. The number of plant species of the 10 largest families from the list of 538 known dicot species eaten by black rhino in East, Central and Southern Africa. %A = proportion of 538 species within the rhino's known diet, %B = proportion of Liwonde NP flora (783 dicot species).

Family	No. species	%A	%B
Asteraceae	46	8.6	5.2
Acanthaceae	45	8.4	4.5
Fabaceae	44	8.2	10.2
Poaceae	36	-	-
Euphorbiaceae	30	5.6	5.9
Mimosaceae	25	4.6	4.1
Caesalpiniaceae	24	4.5	2.7
Malvaceae	20	3.7	2.2
Aizoaceae	18	3.3	0.5
Liliaceae	18	-	-
Total (8 dicot families)	252	46.8	35.2
Rubiaceae	11	2.0	5.4

Using the same type of comparison but using only the 153 species of plants utilized by rhino that also occur in Liwonde NP, gives a dramatically different result (Table 4). Asteraceae and Malvaceae do not rank in the top ten, Combretaceae places high, while Rubiaceae remains under represented with few selected species. Mimosaceae, Combretaceae and Capparaceae are represented well over expected values. The important families, at least in terms of proportions of species selected, agree with the literature. Again, species of the ten top families are represented more often than would be expected to be the case based on simple species richness.

It is obvious then, that it is much more than richness of the family that explains food selection. For example, from observations of many biologists (Goddard, 1968, 1970; Mukinya 1977; Oloo *et al.* 1997) Poaceae does not form an important part of the black rhino's diet even though in some studies many species were selected. Absolute abundance, seasonal availability, moisture content, palatability, plant life form, presence of fire, bulk portion consumed, etc all have a bearing upon a serious analysis of the animal's diet. In a further comparison (Table 5), the diet check lists in the same African conservation areas are measured against the floral check list of Liwonde NP (Dudley 1994). Not surprisingly, the species in the diets of East African rhino have more in common with Liwonde than with the southern sites which are of more dramatically different climatic and floral regions. Masai Mara stands out as

Table 4. The number of plant species of the 10 largest families from the list of 153 known dicot species, within the Liwonde NP flora, eaten by black rhino in East, Central and Southern Africa. %A = proportion of 153 species, %B = proportion of Liwonde NP flora (783 dicot species).

Family	No. species	%A	%B
Fabaceae	15	9.9	10.2
Mimosaceae	14	9.8	4.1
Combretaceae	10	6.5	2.2
Euphorbiaceae	10	6.5	5.9
Poaceae	8	-	-
Capparaceae	7	4.6	2.2
Rubiaceae	5	3.3	5.4
Caesalpiniaceae	5	3.3	2.7
Acanthaceae	5	3.3	4.5
Tiliaceae	5	3.3	1.9
Total (9 dicot families)	76	50.0	9.7
Asteraceae	3	2.0	5.2

more comparable to Liwonde with 32 species (46%) of the rhino's diet also being present in Liwonde. In all East African lists, generic similarities to Liwonde were high (76-88%). Because family is a broader taxon, similarity was even more marked (73-100%). Without getting into a detailed discussion regarding floral comparisons, little can be said as to reasons for the rankings of similarities for these sites. However, clearly woodland, thicket and grassland habitat proportions and climate (principally rainfall) are important. What is noticeable is the narrow range, in all areas, of variation in the actual number of species in common with Liwonde NP.

Table 5. A comparison of the number of species, genera and families of plants eaten by black rhino in various conservation areas in Africa. The number in brackets is the number of species genera and families on the list that also are found in Liwonde NP.

Conservations area	**species**	**genera**	**family**	**source**
Tsavo NP, Kenya	102(18)	49(37)	30(27)	Goddard 1970
Ngorongoro NP, Tanzania	120(18)	82(62)	32(30)	Goddard 1968
Olduvai Gorge, Tanzania	63(19)	51(45)	31(29)	Goddard 1968
Masai Mara GR, Kenya	70(26)	59(51)	28(28)	Mukinya 1977
Ol Ari Nyiro Ranch, Kenya	103(18)	71(58)	34(32)	Oloo *et al.* 1994
Addo Elephant NP, RSA	111(8)	71(40)	36(32)	Hall-Martin *et al.* 1982
Skeleton Coast Park, Namibia	103(10) *	80(41) *	41(30) *	Loutit *et al.* 1987
Luangwa NP, Zambia	17(15)	15(13)	9(8)	Berry in Dunham 2001
Matusadona NP, Zambia	12(10	10(8)	8(8)	Woodfine in Dunham 2001
Zimbabwe Midlands	7(6)	5(5)	3(3)	Coates Palgraves in Dunham 2001

The second section of Table 5 compares, in a similar fashion, the rhino diets for the nearby Luangwa Valley NP (LVNP), the Zambezi Valley and the Zimbabwe Midlands. The sample size is much smaller yet contains a selection of what are probably the most noticed food resources. The results are much closer to Liwonde NP, particularly at species level. This is not surprising as of all the areas considered, LVNP is likely to have the most comparable total flora to Liwonde NP (i.e. 33% North LVNP (Astel *et al.* 1997), 53% South LVNP (Smith 1997)).

Table 6 gives an analysis of the number of species within the flora of Liwonde NP that are eaten by black rhino either in Liwonde or in other studies in Africa. A list of these species in provided in Appendix 1. Nearly 15% (153/1030spp) of the total flora (excluding ferns) of Liwonde is known to be eaten by black rhino. The present information from Liwonde's small list of 61 adds 23 new species and 13 new genera to the overall list. This supports the catholic diet of the black rhino and its ability to take advantage of a wide range of plant species in whatever habitat it finds itself. However, as Emslie & Adcock (1994a) point out, only a few woody species (i.e. about 10) invariably account for the bulk of the black rhino's diet, with legumes and *Euphorbia* species ranking highly.

Table 6. Species of the flora of Liwonde NP that are eaten by the black rhino either in Liwonde NP or in other regional areas in Africa. Only new values added are listed from each area. Sources as in Table 5.

Conservations area	**species**	**genera**	**family**
Liwonde NP, Malawi	61	46	25
EA, SA & Namibia	73	52	17
Zambia & Zimbabwe	19	12	4
Total	153	110	46

Where are these plants found and in what type of abundance? Table 7 records the number of species eaten by rhino and present in Liwonde against plant community or facies. Tall Grass Tree Savanna (TGTS), Mopane Woodland (MW), Mixed Woodland (MXW), Mopane Clumped (termitaria) Savanna (MCS), and Mopane Woodland with Thicket (MW/T) are at the top of the list. Both TGTS, MW and MWT are the largest habitats in area within the park and sanctuary. Because of its high grass content, TGTS is regularly burned and is a source of regenerating woody plants. Mukinya (1977) remarks that in his study rhino concentrated between 66% and 90% of their feeding on regenerating plants. Drought Deciduous Forest Thicket

(DDF/T), MXW and MWT are not present within the sanctuaries so have not had the benefit of selection by rhino. Approximately 75% of the species eaten in these communities can be considered common to exceptionally common. Common means that they are normally found in at least a third of all 10X10m^2 quadrants sampled within the given community. Exceptionally common species are found in nearly all quadrates sampled, often as more than one individual.

Table 7. Number and commonness of the 152 species known to be eaten by black rhino that are present in the principal plant communities found in Liwonde NP.

Habitat	R	UC	C	VC	EC	TOTAL
TGTS	0	7	16	8	3	34
MW	1	6	11	11	5	34
MCS	0	8	12	7	3	30
MXW	2	12	5	10	1	30
MWT	0	5	15	7	2	29
RFT	2	4	11	6	0	23
MWC	0	2	4	6	3	15
DFT	0	5	9	3	0	17
Totals	5	49	83	58	17	-

RHINO HABITAT PREFERENCE

Libierg (1973 in Dunham 2001) stated that the ecotone between the *Combretum-Terminalia* and the miombo vegetation type was especially preferred by black rhino in Luangwa Valley NP. This was where the highest density of rhino could be found. Leader-Williams (1985 in Dunham 2001) described the female rhino's home range area as containing water at the end of the dry season (October) and containing some area of thicket. The less significant areas were mopane, miombo and *Combretum-Terminalia* scrub. Dunham's (2001) analysis shows that the rhino sightings of Caughley (1973, sight data from the air during the day, only presence or absence noted) were correlated with closeness of permanent water and percent of sampling unit (10X10km^2) covered by mixed thicket and riverine complex. Nevertheless, it explained only 16.7% of the variance (R^2 = 0.167). Such an analysis would be unsuitable for this small park (545km^2). Dunham pointed out that carrying capacity is more than the proportions of the various habitats but is also related to their special arrangement.

From the available literature, Liwonde NP would seem to have less thicket than Luangwa Valley NP. However, I believe that this judgement could change if the two parks could be compared directly. One of the problems is the small size of Liwonde. For instance, only five of Caughley's (1973) 10X10km^2 sample squares would fit into the whole of the Liwonde area. While considerable mixed open and partially closed woodland occurs, much of this has been badly damaged by uncontrolled bush fires, elephant and former cultivation and wood removal. Miombo elements are only present on Chiunguni Hill and on the Mangochi FR escarpment outside the park. Thickets, as determined by air photo analysis amount to less than three percent of the park's cover. However, smaller patches (0.5 - 1.0ha) of thicket, such as that produced by *Colophospermum mopane*, *Dalbergia melanoxylon*, *Acacia nigresens*, *Friesodielsia obovata*, *Markhamia obtusifolia* and *M. acuminata,* are very common throughout the woodland sections of the park and adjacent to the rivers. Additional small (0.25 - 0.5ha) thickets surround the larger waterholes and, of course, there are the uncountable thickets of the termitaria, some of which can be very large. Liwonde NP has considerably more thicket vegetation than what can be assumed from air photo analysis alone.

Water is more difficult to evaluate. The only real permanent water is the Shire River and Lake Malombe. Even the two perennial rivers (Masanje and Likwenu) can be without water for much of their length when we have a series of exceptionally dry years as we did in the early 90s (Bhima & Dudley 1997). The other sources of water after the rains stop in April are scattered pools along the major east-west flowing seasonal rivers and in water holes scattered throughout the park. In normal rainfall years the largest of these dry up by September. In drier years by August. This means that late in the dry season most of the park will be waterless and rhinos will have to drink close to the Shire. Given the narrow nature of Liwonde NP, this should not prove to be much of a problem for rhinos which are known to regularly travel as much as 10-15Km for water, having to drink once every three days or less (Adcock 1994, Cilliers 1989, Emslie & Adcock 1994b, Smithers 1983). The rains and water may not return to Liwonde until December. To some degree rhino are able to obtain some of their moisture requirements from the succulent plants that they eat (Goddard 1968, Bradley Martin & Bradley Martin 1982). In 1994, it appeared that the two rhino in the first sanctuary obtained all their water requirements for 3.5 months from *Euphorbia ingens*, a common plant with the park (Dudley 1997). The destruction of this species was severe within the sanctuary and it is unlikely that such a reliance on this plant for water would be possible again in the future.

The limited direct observations of rhino in the sanctuaries suggest that rhino use riverine forest/thickets for shade and concealment during the middle part of the day (B. Palmer, J & B circle pers. Com.). During the night they move out to feed at the edges of the riverine vegetation and then well into the TGTS communities. Early in the morning they walk to the artificial waterhole to drink before moving back to their place of concealment. This conforms to the pattern reported by Goddard (1967b) for rhino in East Africa. During the dry season the home range of the group of two females, three calves and one male is quite small as shown on the sanctuary map (Fig. 1). Sometimes the male (originally from the second Sanctuary) wanders into the former second sanctuary but does not remain long. At present I am unable to see signs of feeding in this latter location. During the rainy season the animals move much more widely. The male is more commonly seen, in what looks, from air photo interpretation, as more open habitat.

It would appear that the rhino in sanctuary 1+2 utilize no more that about 3-4km^2 of the resources available to them and the male of sanctuary 3 little more. Nevertheless, these observations, while correct on their own, are rather casually made and so not really quantifiable. At present, even at the end of the dry season, one that has had some unusually fierce fires, all rhino appear in good health (B. Palmer, J & B circle pers. Com.).

RHINO CARRYING CAPACITY OF LIWONDE NP

DENSITY

There are a number of references to rhino carrying capacity in East, Central and Southern Africa. Perhaps the earliest is that of Goddard (1969, 1970). At Tsavo, rhino densities varied between 1/6.5-1/26km^2 (0.15-0.04 rhino/km^2) for grasslands and 1/1.1–1/2.4km^2 (0.91-0.42 rhino/km^2) for the bush, grassland–bush and woodland habitats. For Ngorongoro he reported densities of 1/3.1km^2 (0.32 rhino/km^2)and for Olduvai Gorge 1/6.5km^2 (0.15 rhino/km^2). He believed that the carrying capacity of Ngorongoro was twice that of Olduvai. These last two areas would seem to contain more open vegetation than Liwonde NP.

Oloo *et al.* (1994) in a well protected ranch indicated that there was approximately 1 rhino/2.5-1/2.7km^2 (0.37-0.40 rhino/km^2). The ranch appeared to be well wooded like Liwonde.

Dunham (2001) reviews the information of rhino densities for the Luangwa Valley NPs and Game Management Areas. His best estimate of rhino density before the slaughter of the late 70s through 90s was 1 rhino/2.5km^2 (0.40 rhino/km^2). He analyzed data taken from the road and air surveys extracted from Caughley (1973), Kuper (1975) and Liberg (1973). Goddard (1967a, 1969) and Cilliers (1989)described the shortfalls of aerial censusing and showed that light aircraft is of limited value for appraising black rhino populations, even in open bush habitat. Consequently, Caughley (1973) used the correction factor taken from Goddard (1967a) for his aerial counts in woodlands.

The only published work on rhino densities in Malawi is that of Jachmann (1984). For Mwabvi GR, a much drier and harsher habitat, he reported 1 rhino/7-8km^2 (~0.13 rhino/km^2) in a 52km^2 area of the reserve. As stated before, this was not a viable population and relied upon immigration from the larger metapopulation in nearby Moçambique. However, Goddard (1967b) wrote that population dispersal from adjacent, inaccessible areas, into the available niches created by mortality is probably extremely low due to rhino's sedentary nature.

Presently, in the sanctuary at Liwonde NP, rhino have remained in good condition even during the droughts of the 90s and while suffering the intense dry season fires of the last two years. Sanctuary 1+2 of 29 km^2 contained four adults and two calves prior to the death of one of the males last year. While this male may have died due to a fight with the second male there is a case that death may have been due to tryps. If the latter is true then 1 rhino/5.8km^2 (0.17 rhino/km^2) (would be a possible figure for habitat such as occurs in this sanctuary. Now, after further observation, it appears that even during the height of the dry season three adults can live healthily in little more than 3-5km^2 (0.60-1.0 rhino/km^2). There is no sign of over-browsing.

HABITAT SUITABILITY

How does this translate into carrying capacity for the whole of Liwonde NP? It would be very tempting to say that Liwonde NP has as favourable climate and vegetation as any of the parks that I have referred to above. A good source of water is available in the dry season while small water sources are scattered throughout the park from December until at least August. The Shire River or Lake Malombe are within easy walking distance from any place in the park during the dry season. While extensive thickets may be lacking these would not seem to be a prerequisite. Goddard (1967b) states that the absence of shade did not appear to affect rhino adversely at Olduvai even at high temperatures. In the wet season, Ngorongoro rhino make extensive use of the plains and remain in the open. The RFT habitats are extremely linear and consequently may be more useful per unit area that a more compact arrangement. Rhino do not favour high grass areas yet it is in just such areas that much of the available food occurs in Liwonde (i.e. TGTS). A properly managed fire programme should be able to develop these areas into a useful source of browse. Mopane is not noted in the literature as ideal habitat for rhino (Dunham 2001, Jachmann 1984) yet this park, nearly 75% covered by the mopane woodland complex, contains 152 (~25%) of the species of plants known to be utilized by black rhino in East, Central and Southern Africa. There is a 50% or more congruence between the plants found in Liwonde NP and Luangwa Valley NPs.

I have already referred to fire management. At present there is none and fires are started by accident, by poachers, by honey gatherers, illegal woodcutters, and park staff or their families. Consequently, some areas are burnt too often and too intensely while others are (occasionally) burnt too little (Pienaar & Dudley 1998). For park conservation one needs a mosaic of burning strategies so as to maintain unique plant communities (DDF/T, RF/T) and protect soil and river banks from erosion (RF/T, MXW of hills), prevent invasion of woody species into open grasslands and floodplains (TGTS), provide fresh regrowth for browsers and grazers during the late dry season, etc. Fire management is an activity that the management in Liwonde NP ignores.

Competition from other mammals would appear limited to elephant as kudu are in very low numbers. Currently the elephant population is somewhere around 500 and growing at a maximum rate as little mortality occurs either through poaching or natural death and the park's elephant density is very near 1/km^2. This high density is exacerbated by the fact that during the late dry season the elephant concentrate along a narrow strip of the park along the Shire River. Damage to the RF/T is considerable with fire now a common element in this community. Elephant are also opening up the DDF/T as well by their movement and feeding. Other potentially important communities for rhino are also showing decline, including the MW/T. Aggression between elephant and rhino is not uncommon and rhino, particularly with young calves, may both be killed by female elephant (Ritchie 1963). Elephants of Liwonde NP, although presently calmer, have in the past been known to be extremely aggressive to disturbance by humans and, thus, might cause some mortality to rhino. Two of three large bull elephants managed to force their way into (and out of) sanctuary 1+2, but no aggressive interactions between these elephant and the rhino are known. Ritchie (1963) also remarked that there was little direct conflict between bull elephant and rhino.

Rhino are vulnerable to predation by lion and hyena although this is rare and usually a threat to calves unprotected by their mothers (Goddard 1967b, Ritchie 1963).

Buffalo and zebra have been recently introduced into the park (Dudley 2000). They seem to be thriving and historically were very abundant in this area (Faulkner 1868). Both species should improve the habitat for rhino by reducing the rank grass. There would be an interaction with fire as fuel loads would be reduced. Thus, woody plant invasions would be more aggressive and food sources for the rhino might grow out of their reach.

Rhino home ranges vary greatly depending upon sex, climate, vegetation type and water resources (Goddard 1967b). In the Lerai *Acacia xanthophloea* forest of Ngorongoro where green food and water were abundant throughout the year, home ranges were as little as 2.6km^2 while on the plains of the caldera in open grassland and marshes ranges averaged 15.5km^2. For the arid *Acacia-Commiphora* bush where water points were scarce and widely distributed the home ranges averaged 30.4km^2. There was up to 40% overlap of adult home ranges with greater area of the range used in the wet season. Animals were very regular in movements and 20% could be regularly observed in the same place at the same time. Animals appeared attached to home ranges throughout their life.

Perhaps the last aspect to consider is intra-specific competition between rhino bulls. This may be significant in a relatively small enclosed area. Walker (1994) found the on his 100km^2 fenced sanctuary, four bulls was the carrying capacity. New bulls were introduced (one at a time) from 1986-89. All four of these bulls were killed by the resident bulls. Goddard (1967b), in his discussion of home range and territorial behaviour concludes that territorial behaviour is not apparent among individuals of the same 'community'. However, if a 'stranger' of either sex enters the 'community', territorial behaviour becomes violent. In the unconfined and heterogeneous space of the greater Liwonde NP I would expect that the problem of territoriality would not be serious. Considering Goddard's (1967b) observations, the death of the one bull in sanctuary 1+2 cannot be definitely attributed to an attack by the second bull.

Liwonde NP is approximately 540km^2. Not all of this area is really usable. The 1km wide strip on the west bank of the Shire River should not be considered for obvious reasons. The extension may be another area that should be excluded until it is clear how this area is going to be managed. Well before this is done the security of the lower park must be assured through fencing and patrols, etc. This area probably covers about 440km^2. All of this remaining area is not of equal suitability. Prime areas would feature around the lower reaches of the major seasonal rivers, the Namisundu, Mwalasi, Namandanje, Nangondo and the Ntengai. The Masanje and the Likwenu Rivers being, in part, park boundary rivers, are less significant. Of the seasonal rivers the Ntengai and the Mwalasi have the most luxuriant vegetation. The 'uplands' to the east would be areas of lower capacity due to the more trying conditions late in the dry season when fierce fires take their toll of the vegetation and free water is far to the west. Professional fire management could modify this situation.

Considering densities of rhino recorded in the literature, the suitability of the Liwonde NP habitat, competition from elephants and the harsher conditions during the late dry season in much of the park, it would seem best to suggest a conservative value for initial rhino density. Under the best conditions, information from the present rhino sanctuary indicates that values in the range of one rhino/2.5km^2 (0.40 rhino/km^2) would easily be supported. In areas of the park to the east that are less favourable, perhaps this density should be no more than 1/8km^2 (0.13 rhino/km^2). This would put the carrying capacity of the total park (440km^2) to roughly 90+ individuals. Under better park management this figure might be upgraded. With a potential recruitment rate of about 7% (Goddard 1967b) and a secure environment, reasonable population growth could be anticipated. I am unsure how intra-specific competition between prime rhino bulls might affect these projections but am assuming that, in the larger environment with greater freedom to disperse, the 25km^2 figure mentioned by Walker (1994) would not be appropriate and that the situation described by Goddard (1967b) would prevail. In all cases, these values are based on greatly improved park management and security. Without this no animals should be released into the open park.

The present carrying capacity of sanctuary 1+2 might be on the order of 8-10 adults and 4-6 for sanctuary 3 providing that aggression between competing bulls can be avoided. I used the more conservative figure of 1 rhino/3km^2 (0.33 rhino/km^2) here as, when rhino are confined to a restricted area, their effect on the vegetation is relatively more intense (Hall-Martin *et al.* 1982).

There is pressure to limit the building of additional sanctuaries and even to reduce the size of sanctuary 3 or remove it completely (Labuschagne 2000). He proposes that these fenced areas may hinder east-west movement of elephant and exclude needed habitat.

RHINO POPULATION MANAGEMENT, MONITORING AND EVALUATION

Brooks (1989) and Emslie & Brooks (1999) discuss many of the important parameters to evaluate and manage in order to successfully maintain a healthy black rhino population. In addition, Books (1989) provides a rating procedure for reintroductions, this rating covering biological, genetic and security concerns. Although I have referred to management concerns earlier in this report I will try to more clearly highlight them in this final section.

It is unfortunate that ecological management and evaluation at any level within Liwonde NP, including the sanctuaries, has been much neglected and little in evidence. This will have to change if a viable population of black rhino is to be established and maintained in the wider park. Of fundamental importance is the quality of the habitat. Primarily this means the structure, dispersion and floral composition of the vegetation and the amount and distribution of water.

Water

Outside the sanctuaries free water is present throughout the park for normally nine months of the year and for the remaining months the Shire River provides an ample source. As the Shire flows along the length of the park's western border, it may set some limits to the configuration of rhino home ranges. Dunham (2001) and others pointed out that home ranges normally included a source of water during the late dry season. This would mean that home ranges for rhino in Liwonde NP might have to always include sections of habitat near or adjacent to the Shire River. Additionally these perennially wet areas also maintain lusher vegetation. This also may attract rhino during the dry season. (i.e. Ngorongoro, Goddard 1968). It might be suitable to maintain a number of artificial waterholes in the drier uplands during the months of September through December to encourage rhino to utilize this area more efficiently and consistently.

Habitat

As discussed in an earlier section, Liwonde NP contains a high proportion of the species of plants known to be eaten by black rhino in East, Central and Southern Africa. Considering the good condition of the rhino in the sanctuaries, even during the drought years, it would seem that the other characteristics of the vegetation, such as structure and dispersion, are also adequate for a moderate population density.

Once rhino move in the wider park, a serious feeding study should be commenced so as to obtain a more critical evaluation of the rhino's diet including species of plants selected and preferred and their relative importance in the diet.

The situation in the wider park may not be as suitable in the long run without close evaluation and monitoring of the vegetation. The sanctuaries, until the last few years, have had only small proportions burnt. In addition, except for 2-3 elephant bulls that forced their way in on several occasions, the areas have avoided the impact of elephant browsing. Consequently, the original sanctuary 1 is noticeably better vegetated than similar adjacent areas outside fence. Sanctuaries 2 and 3 have been protected for a shorter time and this difference is not so apparent.

In the park at large, a very large (though unknown) proportion of the vegetation is burnt by fires annually. These fires happen incidentally and haphazardly, their origins usually being outside the park and certainly outside the park management's initiation.

Elephant now number over 500 or close to $1/km^2$. This is well in access of the density ($1/0.5km^2$) considered destructive to savanna woodlands and forests (Cumming *et al.* 1997). Densities increase dramatically late in the dry season when elephants begin to spend most of their time in the vicinity of the Shire River and the RF/T areas of the lower reaches of the east-west seasonal rivers. The RF/T areas are showing considerable declines in tree and under canopy cover with fire becoming an important factor. A continued trend of this nature would certainly be detrimental to the park's carrying capacity for rhino. On the other hand, heavy browsing pressure in the mopane woodland alters its structure markedly (Dudley 2000) and consequently maintains many woody species within height ranges favourable to rhino feeding.

As a first and perhaps easier priority, fires throughout the park need to be controlled. At one time, the park's research section had a burning plan and a number of burning research plots. These need to be re-established and re-evaluated and, perhaps, re-formulated. As Pienaar & Dudley (1998) noted rhino do not favour habitat with high dense grass. In this situation fire would be beneficial as it would burn away the herbaceous cover and keep the intermixed woody shrubs at preferred feeding height. On the other hand, the various thicket and hillside woodland communities need protection through early burning (Dudley 1985a, b & c). Fire breaks may need to be established.

Elephant management, through population reduction, is a much more difficult problem. Elephant numbers may need to be cut in half to allow a recovery of thicket vegetation (provided fire is controlled). How this is to be done will need to be discussed by others more knowledgeable than myself. Culling would certainly be very controversial while translocation (to Majete WR ?) would be expensive and quite technical. Even serious declines in vegetation parameters are little noticed by most people. These declines, where they exist, need to be measured and quantified. I would recommend that the numerous monitoring plots established in various habitats in the park in the late 70s and early 80s and in sanctuary 1 in the early 90s be re-evaluated to establish the seriousness of the vegetation decline. As these plots do not cover all habitats equally, I suggest that new plots be marked out in areas that need information such as RF/T, MXW and CCS. Vegetation changes through browsing, fire and natural succession have a marked effect on rhino carrying capacity in savanna areas (Emsile & Brooks 1999).

I mentioned earlier in this report the possibility of rhino mortality from Liwonde NP elephants. These are more aggressive, at least to humans and cars, than is common elsewhere. Whether this would translate into serious aggressive behaviour towards rhino is unknown. Nevertheless, considering the very high elephant densities in the park, encounters between the two species would be common and this may be another reason to reduce the elephant population.

Given the low population of kudu, I do not see any competitive threat between these two species. Similarly, with lion number being extremely small (2-4) and suitable game densities high, this species is unlikely to be a predator of rhino calves.

Rhino population management
It is assumed that once security and sufficient management capacity is present in Liwonde NP that a founder population of 20+ nearly mature rhino will be simultaneously introduced into the greater park. This population initially will be made up of a balanced sex ratio. At this time, every individual should be marked for easy identification later in the field. Considering the possible problem due to tryps, the source of origin of the animals should be considered *viz a vi* the strain of *Trypanosoma*. Also, microchip transponders should be transplanted into horns and shoulders of each individual to allow tracing of horn and identity of the body of any animal that dies.

Once the population is released a number of parameters will have to be measured, initially at three year intervals, but as numbers grow, perhaps annually. These parameters include, amongst other variables, population size, age and sex structure and body condition. All mortalities must be carefully recorded including details of cause and place of death. Skulls must be collected and retained. Any new rhino immobilized for any reason should be ear notched for individual recognition. Personal history records should be kept of all rhino, if possible, and include photo identification information, sex, age, reproductive data, movement, territorial behaviour, mortality etc. Such information provides standardized population growth characteristics and allows the assessment of progress towards national goals. A primary goal should be to reach 75-80% of the ecological carrying capacity so as to maintain population growth rate at maximum levels.

Finally, a committee or body should be formed to establish, in a more rational way, the policies and goals of rhino conservation and management in Malawi. This committee should bring together all the relevant stakeholders concerned with this goal. At times, various interested and committed partners are pulling, often unknowingly, in different directions and this reduces the effectiveness of the rhino programme.

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APPENDIX 1. List of plant species known to be eaten by black rhino and presently found in Liwonde NP Malawi.

Acanthaceae
Anisotes formosissimus
Ecbolium clarkei
Hypoestes forskaolii
Justicia betonica
J. striata
Monechma debile

Aizoaceae
Glinus lotoides

Amaranthaceae
Achyranthes aspera
Aerva lanata
Pupalia lappacea

Anacardiaceae
Lannea schweinfurthii stuhlmannii
Ozoroa reticulata
Sclerocarya birrea caffra

Annonaceae
Cleistochlamys kirkii
Friesodielsia obovata

Arecaceae
Hyphaene petersiana

Apocynaceae
Diplorhynchus condylocarpon
Strophanthus nicholsonii

Asclepiadaceae
Fockea multiflora
Gomphocarpus furcticosus

Asteraceae
Aspilia mossambicensis
Bidens pilosa
Plluchea dioscoridis

Balanitaceae
Balanites aegyptiaca

Bignoniaceae
Kigelia africana
Markhamia acuminata
M. obtusifolia

Boraginaceae
Cordia goetzei
Ehretia amoena

Brassicaceae
Rorippa madagascariensis

Burseraceae
Commiphora africana
C. merkeri

Caesalpiniaceae
Bauhinia petersiana
Brachystegia sp.
Cassia abbreviata
Colophospermum mopane
Tamarindus indica

Capparaceae
Boscia angustifolia
Capparis erythrocarpos
C. tomentosa
Merua edulis
M. juncea
M. triphylla
Thilachium africanum

Celastraceae
Maytenus senegalensis
M. heterophylla

Combretaceae
Combretum apiculatum
C. celastroides
C. fragrans

C. imberbe
C. kirkii
C. molle
C. mossambicense
C. zeyheri
Terminilia sericea
T. stenoctachya

Commelinaceae
Commelina benghalensis
Cyanotis foecunda

Convolvulaceae
Ipomoea cairiea
I. eriocarpa
I. wightii

Cucurbitaceae
Momordica foetida

Cyperaceae
Cyperaus digitatus
C. rotundus

Ebenaceae
Diospyros kirkii
D. quiloensis
D. senensis
D. truncatifolea

Euphorbiaceae
Antidesma venosum
Bridelia cathartica
Croton gratissimus
C. megalobotrys
Euphorbia ingens
E. tirucalli
Phylanthus reticulatus
Pseudolachnostylus maprouniefolia
Ricinus communis
Securinega virosa

Fabaceae
Acysicarpus rugosus
Crotalaria laburnifolia
Dalbergia arbutifolia

D. boehmii
D. melanoxylon
Erythrina abyssinica
Indigofera schimperi
Lonchocarpus capassa
Melletia usaramensis
Neonotonia wightii
Omocarpum trichocarpum
Pericopsis angolensis
Tephrosia noctiflora
T. villosa

Flacourtiaceae
Oncoba spinosa

Lamiaceae
Leonotis nepetifolia
Leucas martinicensis

Liliaceae
Protasparagus africanus
P. racemosus
Urginea altissima

Loganiaceae
Strychnos decussata

Malvaceae
Azanza garckeana
Hibiscus vitifolius
Pavonia burchellii

Meliaceae
Trichilia emetica

Mimosaceae
Acacia ataxacantha
A. gerrardi
A. latistipulata

A. mellifera
A. nigrescens
A. nilotica
A. polycantha
A. sieberiana
A. tortilis
A. xanthophloea
Albizia anthelmintica
A. harveyi
A. petersiana
Faidherrbia albida
Dichrostachys cinerea africana

Olacaceae
Ximenia caffra

Oleaceae
Jasminum fluminense

Poaceae
Bothriochloa insculpta
Cynodon dactylon
Dactyloctenium aegyptium
Panicum maximum
Setaria pallide-fusca
S. sphacelata
Sporobolus pyramidalis
S. robustus
Themeda triandra

Polygonaceae
Polygonums ?salicifolium

Portulacaceae
Portulaca oleracea
Talinum portulacifolium

Rhamnaceae
Ziziphus mucronata

Rubiaceae
Canthium frangula
Crossopteryx febrifuga
Fretia aeruginescens

Hymenodictyon parvifolium
Xeromphis obovata

Salvadoraceae
Azima tetracantha
Salvadora persica

Sapindaceae
Allophylus africanus
Lecaniodiscus fraxinifolius

Solanceae
Solanum incanum

Sterculiaceae
Sterculia africana

Tiliaceae
Grewia bicolor
G. forbesii
G. monticola
G. stolzii

Verbenaceae
Clerodendrum myricoides
C. glabrum
Lippia javanica
Vitex ?payos

Vitaceae
Cissus quadrangularis

APPENDIX 2

TERMS OF REFERENCE

ECOLOGICAL EVALUATION AND DEVELOPMENT OF GUIDELINES FOR FUTURE MANAGEMENT OF BLACK RHINOS AT LIWONDE NP, MALAWI
SADC RPRC Task 1.2-4.1

Component: Ecological Evaluation

1. Use existing information, including field visits and ground truthing, to update and prepare a vegetation map of Liwonde National Park, redefining vegetation boundaries and highlighting the vegetation and critical habitat types important for black rhino.

2. Work closely with the WWF-SARPO GIS Section in the production of the vegetation maps which incorporate the available geomorphic and soil survey information.

3. With the use of an updated vegetation map and identified critical vegetation components important for rhino survival, estimate the potential carrying capacity for black rhino within the existing sanctuaries as well as and the entire park. The Adcock Model for estimating black rhino carrying capacity may be a useful aid in the estimation of the carrying capacity.

4. Provide recommendations for long term integrated ecological guidelines for monitoring and evaluation of black rhino conservation in the park, taking into account the habitat/vegetation components and interaction with other browsing herbivores such as kudu and elephant. Highlight the implications of extending the management of the park to the Mangochi Forest Reserve.

5. Coordinate with WWF-SARPO and SADC consultants to produce a consolidated evaluation report containing all elements of an integrated management plan for future rhino conservation in Liwonde.

6. Collaborate and work closely with Dr Roy Bhima, and ensure that his terms of reference are fully implemented.