A DETAILED VEGETATION STUDY ON THE CHOBE RIVER IN NORTH-EAST BOTSWANA

by

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A detailed vegetation survey was carried out in the Chobe National Park, Botswana, as part of a population ecology project on the Zambezi bushbuck (*Tragelaphus scriptus ornatus* Pocock). The general study area was situated along the Chobe River west of Kasane township (approximately 17°50′S., 25°10′E.), between the Kalahari Sand Ridge in the south and the river flood plain. The survey covered about 20 miles (32 kilometres) of river frontage from the eastern boundary of the National Park at the park headquarters, west to the Ihaha tourist loop road (fig. 1). In the general survey, vegetation types were broadly defined for the area and these habitats have been related to wildlife use and distribution elsewhere (Simpson, 1974*a*).

An intensive study area of 243 acres (98,3 hectares) was established near the Old Dip Tank, some two miles (3,2 km) east of Serondellas (fig. 2). The habitats occurring in this area were mapped in detail, and various vegetative parameters were measured in order to quantify some of the physiognomy of the vegetation. In addition, monthly assessments were made of vegetation change within the intensive study area.

I am most grateful to the Botswana Department of Wildlife and National Parks for permission to work in the National Park. Mr. R. B. Drummond of the Rhodesian National Herbarium, Salisbury, was most helpful in the identification and preparation of plant specimens collected in the area, and without his help this survey would have been impossible. Messrs. J. Hepburn, A. Moore, G. Mahundu and D. Ntukwa were invaluable field assistants. Finally, I am indebted to the Ceasar Kleberg Research Program in Wildlife Ecology who sponsored and provided the financing for the Botswana Bushbuck Project between 1969 and 1971.

PART I—VEGETATION ANALYSIS

Throughout the duration of the project, plant specimens were collected and sent to the National Herbarium in Salisbury (SRGH)

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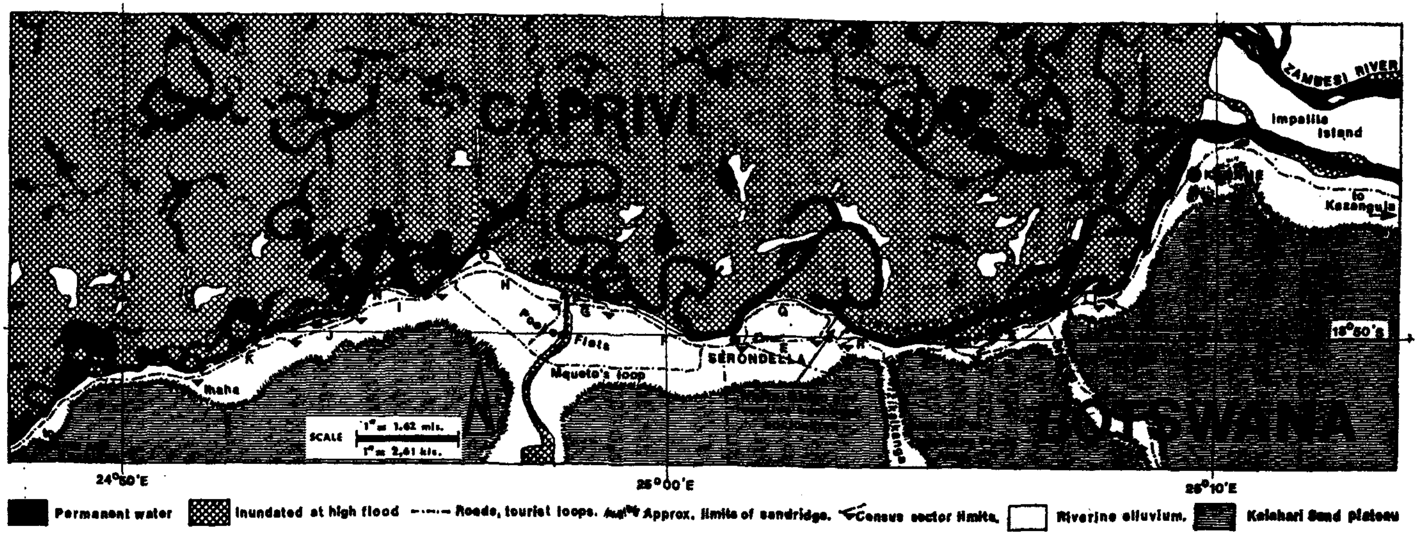

Fig. 1. General study area along the Chobe River in north-east Botswana to show topographical and physical features.

for identification. These form the nucleus of the plant collection presently being assembled for the Chobe National Park. A species list of plants collected along the river habitats of the Chobe in the course of this research is given in Appendix A.

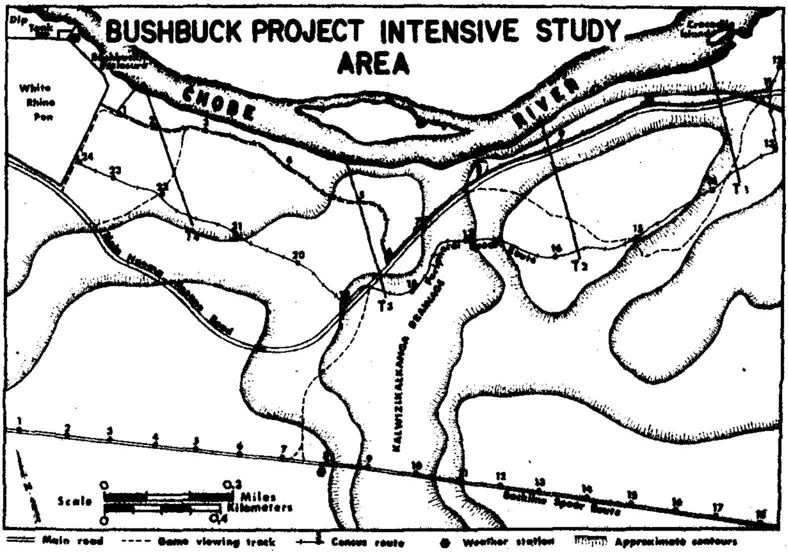

Fig. 2. Topographical and physical features of the intensive study area of the detailed survey. The census route with sampling substations and the transect lines are also indicated.

Eight vegetation types were distinguishable along the Chobe, of which three could be classified as being similar to the original climax vegetation in this area. The remainder appear to be either secondary or subclimax vegetation resulting from destruction of the original climax on that site. These eight vegetation types are broadly described below.

The intensive study area did not contain all the vegetation types represented in the general area, the Kalahari Sand Woodland and the *Colophospermum* Tree/Bush Savanna being absent. The distribution of the remaining six habitats in the intensive study area is shown in fig. 3.

The demarkation between adjacent habitats was seldom well defined and there was often a continuum of vegetation which was difficult to separate for purposes of mapping. In these cases, the criteria used were whether or not a distinction could be picked out on aerial photographs covering the intensive study area—taken in

1967—and once the boundaries of each vegetation type had been established, whether these limits were determinable on the ground. For the most part, this technique worked well, but in those areas where separation was between subclimax and climax type vegetation a degree of subjectivity had to be applied, based on ground survey.

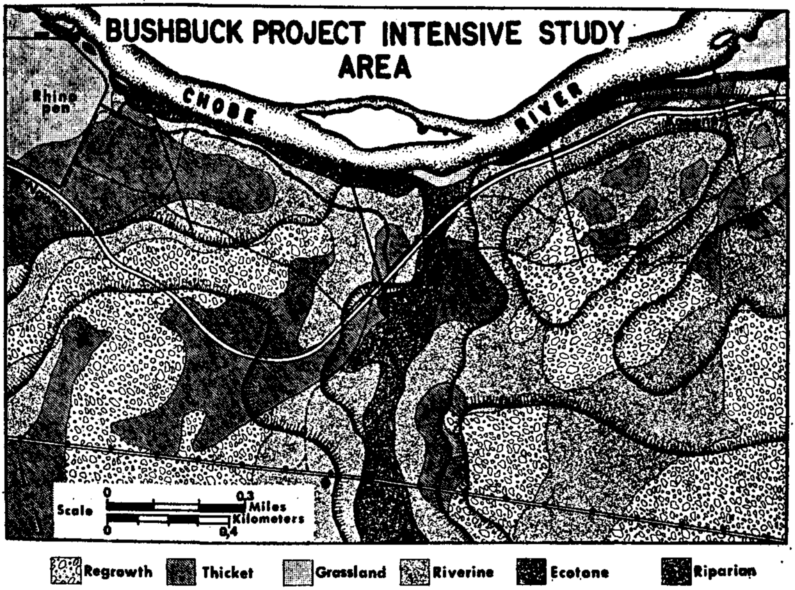

Fig. 3. Detailed distribution of the six major habitats in the intensive study area related to sampling stations and transect lines.

Flood plain grassland

The extent of this habitat is limited by the annual floods, covers most of the Caprivi shown in fig. 1 and that area of Botswana between the Chobe River and the high-flood ridge. The vegetation is probably close to climax, although heavy use in the days of the cattle-posts and repeated burning by Caprivi Africans has had its effect on some drier areas and caused a change in the species composition of the grasses. Annual inundation to varying depths results in the deposition of fresh silt, and keeps the grassland wet through the growing season; the moist conditions also make much of this habitat inaccessable to wildlife use until the dry season. The intensive over-burning reported by Child (1968) has been largely controlled within the boundaries of the National Park, and it seems that the downgrading of this habitat has been arrested to some extent.

Vegetation on the flats comprises many genera of sedges and grasses—*Cyperus*, *Brachiaria*, *Dactyloctenium*, *Digitaria*, *Echinochloa*, *Eragrostis*, *Panicum*, *Paspalum* and *Setaria* are among the more common—with numerous small herbs. Along the higher banks of the river a fringe of *Syzygium guineense* trees indicate the course of the main river-bed, and *Phragmites* and *Sesbania* spp. may also form local areas of dense vegetation along the banks. Most of the flood-plain is flat but small depressions form pools of water which may last late into the dry season, attracting wildlife which feed on the floating and submerged aquatic plants.

In the intensive study area this habitat covered approximately 2,1 acres (0,84 ha), representing about 1 per cent. The small strip of flood-plain grassland opposite Crocodile Island was used throughout the year by animals coming down to the water to drink, as well as by animals using a natural mineral lick, resulting in some breakdown of the typical flood-plain species. A similar situation applied to the small patch of grassland where Kalwizikalkanga opened out into the Chobe (fig. 3).

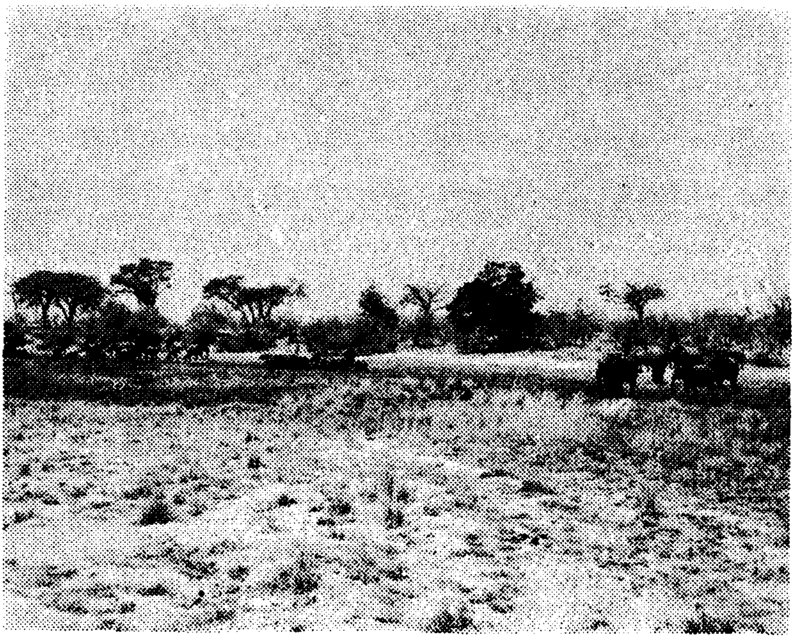

Fig. 4. Typical view of flood-plain grassland showing heavy use on raised ground and change in vegetation cover. Note how the riparian fringe in the background has been destroyed and replaced by thicket.

A typical view of the flood plain grassland is shown in fig. 4, taken on "Q" sector of the general area census route, and the denudation of the semi-aquatic grass species by excess animal use mentioned by Child (1968) as occurring on higher ground shows up well in the foreground.

Riparian forest fringe

Philips (1965) refers this vegetation type to the derived savanna group and places the Chobe area in the subarid wooded savanna bioclimatic region, while Rattray (1961) would classify it as the *Trichilia* type of riparian forest. The riparian fringe varies considerably within the area surveyed, ranging from well-developed closed canopy forest with a good understory and little ground cover, through open canopy woodland, to relic trees in stands of dense heliophytic brush.

In the least damaged parts of the riparian fringe, large trees up to 80 feet (24,38 m) tall form a dense continuous canopy over a sparse understory and little ground cover. The dominant species typical for the Chobe are *Acacia albida*, *Garcinia livingstonei*, *Combretum imberbe* and *Diospyros mespiliformis* close to the river-bank where they are subject to seasonal flooding, with *Acacia nigrescens*, *A. tortilis*, *Trichilia emetica*, *Kigelia pinnata*, *Conopharyngia elegans*, *Ostryoderris stuhmanni* and *Lonchocarpus* ranging from the river to higher ground. *Croton megalobotrys*, *Phoenix reclinata*, *Gardenia jovis-tonantis* and *Rhus tenuinervis* form much of the woody understory, with occasional shrubs of *Grewia* spp., *Acalpha ornata*, *Ximenia americana* and *Securinega virosa*. Lianas and climbers such as *Tacazzea apiculata*, *Artabotrys brachypetalus* and *Capparis tomentosa* grow up into the lower canopy and form dense masses of tangled vegetation.

In those areas where damage has been heavy in the riparian fringe, many of the typical trees have disappeared and a few *Acacia nigescens*, *A. tortilis* and *Lonchocarpus capassa* may remain as relics of the former riparian forest. More hardy understory species such as *Ziziphus mucronata*, *Gardenia jovis-tonantis*, *Ximenia americana* and *Rhus tenuinervis* thicken their growth forms, and *Acacia ataxacantha* and *Capparis tomentosa* may spread across other vegetation to form impenetrable thickets. Further breakdown in this vegetation type leads to more open thickets of *Dichrostachys cinerea*, *Combretum elaeagnoides*, *C. mossambicense*, *Grewia bicolor*, *Maytenus senegalensis* and *Acacia* spp. with a good grass cover of *Digitaria*, *Panlcum*, *Setaria* and *Andropogon* spp.

Wherever the peripheral scrub of the riparian forest was still well formed, the inner riparian trees were relatively evenly spaced, the canopy was continuous, and regeneration well represented in the understory. In those areas where there were no well-defined fringe of peripheral shrubs, the riparian trees were more sparsely distributed, forming an open canopy, and few regenerating seedlings were in evidence. The role played by this protective fringe of fire-resistant shrubs along the outer edge of the riparian forest has long been understood (Swynnerton 1918, Pillans 1924, Trapnell 1959, Ramsey and Rose-Innes 1963), and the disappearance of this maintaining fringe from riparian forest areas under heavy animal use is a matter of considerable concern to habitat conservationists and game managers alike.

Fig. 5. Riparian habitat along the river in the intensive study area. Damage to this habitat can be seen in the fallen trees and in the opened up area above the high-flood ridge in the background.

The riparian forest fringe extended over 14,8 acres (5,99 ha) and represented 5,9 per cent. of the intensive study area. It was typical for this vegetation type all along the Chobe (fig. 5), being representative of all stages from well developed forest canopy to the heavily used, open brush type of vegetation seen in the background of fig. 4. Much of the riparian vegetation still relatively intact in the intensive study area was on the banks of the high-flood ridge above the river but it did occur up on the alluvial flats for a small area adjacent to the Old Dip Tank.

Riverine Acacia *tree savanna*

Selous (1881) described the riverine alluvial vegetation as an open wooded savanna with scattered brush patches and fine wide-branched thorn-trees, and called the area around Serondellas "Pookoo Flats". Old African residents also recall this vegetation as having been open country under a tall-tree discontinuous canopy, but its present status is more toward a tree savanna as defined by Rattray (1961), with a well-developed brush ground cover. The width of this habitat varies along the river, but it is more or less continuous between the riparian fringe and the sand ridge from Kasane to about 6,5 miles (10,5 km) west of Serondellas.

The larger species of trees in this habitat are *Acacia nigrescens*, *A. tortilis*, *Phyllogeiton discolor*, *Combretum imberbe*, *C. apiculatum* and *Lonchocarpus capassa*, many being relics of the past riparian nature of the flats. The brush consists mainly of *Dichrostachys cinerea*, with locally dominant areas of *Combretum elaeagnoides*, *C. mossambicense*, *Terminalia sericea*, *Ziziphus mucronata* and *Acacia* spp. In the more open areas the grass cover dominants are *Aristida*, *Hyparrhenia*, *Eragrostis*, *Digitaria* and *Setaria* spp., associated with *Dactyloctenium*, *Panicum*, *Andropogon*, *Heteropogon* and *Urochloa* spp.

Fig. 6. Riverine *Acacia* tree savanna in the intensive study area in February. Grass is *Panicum maximum* and averages about 6 foot (1,83 m) in height.

The riverine *Acacia* tree savanna covered most of the alluvial flats of the intensive study area, comprising 49,6 per cent. (106,4 acres or 43,06 ha) of the total area. It was well formed, with many mature *A. tortilis* and little ground cover other than good stands of *Panicum maximum* during the rainy season (fig. 6).

Dichrostachys *thicket*

This vegetation type is secondary, developed most commonly on alluvial soils or old cultivation patches (Rattray 1961). The best examples of this habitat can be seen around Serondellas where the cattle-post overgrazing effects were heaviest, but it occurs all along the Chobe flats south of the river. The thicket occurs either as pure stands of *Dichrostachys cinerea*, or this species associated with *Combretum elaeagnoides*, *C. mossambicense*, *C. apiculatum*, *Terminalia prunioides*, *Ziziphus mucronata* and *Acacia* spp. Stands vary in density and heights range from 6 to 15 feet (1,8 to 4,6 m). This vegetation is fire-sensitive and *Dichrostachys* represents one of the most persistent invaders in overgrazed areas where the reduced grass cover precludes fire. Grass cover is generally absent in this habitat,

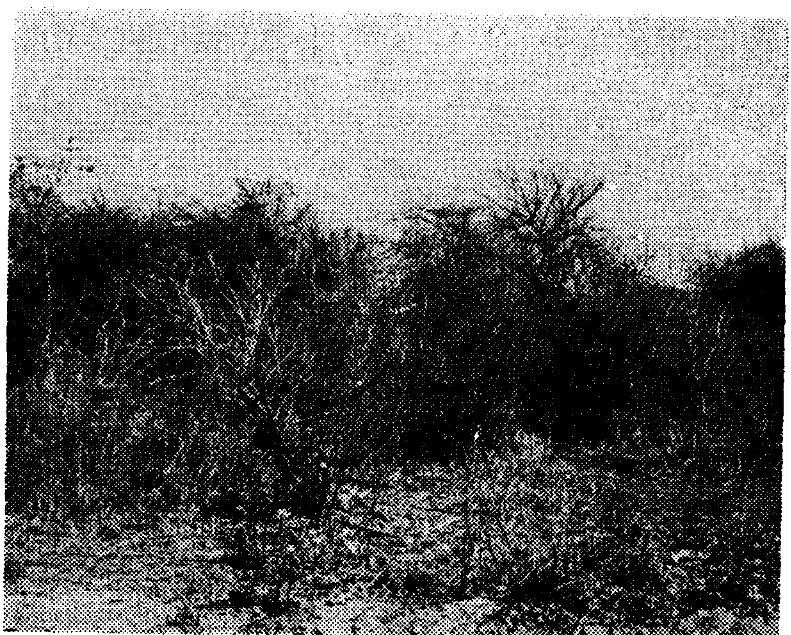

Fig. 7. Pure stand of *Dichrostachys cinerea* in the intensive study area, heavily grazed in the past by cattle held over at Serondellas before shipment to northern markets.

but occasionally a few scattered annuals such as *Aristida, Setaria* and *Panicum* spp. may establish themselves in the more open aspects.

One small area close to the Old Dip Tank had a pure stand of *Dichrostachys cinerea* (fig. 7), but most of the vegetation classified in this category was a mixture of thicket species with *Dichrostachys* predominating. In all instances where there was a mixture of thicket species, the density of vegetation was such as to class the area under this category; in cases of some doubt—as for example, in some of the thicker parts of the regrowth *Combretum/Baphia* scrub—the deciding criterion as to which habitat occupied the area lay in the proportion and growth-form of the *Dichrostachys* plants. This habitat covered 64,8 acres (26,22 ha), 30,0 per cent. of the intensive study area.

Kalahari sand or Baikiaea *woodland*

Rattray (1961), Mitchell (1961) and Child (1968) have all given detailed descriptions of this woodland type, considered to be climax in the existing climatic and edaphic conditions. Dominant trees are *Baikiaea plurijuga, Guibourtia coleosperma* and *Pterocarpus angolensis* with *Brachystegia* and *Julbernardia* spp. in association with these dominants. The understory usually comprises *Bauhinia macrantha, Baphia obovata* and *Combretum* spp. In the more open aspects, dominance moves to *Julbernardia* and *Brachystegia* spp. with associated species such as *Pterocarpus angolensis, Afzelia quanzensis, Ricinodendron rautanenii, Kirkia acuminata, Burkia africana* and *Erythropleum africanum*. The grass cover is light with tall species of *Aristida, Hyparrhenia*, and *Digitaria* in the more open patches. In those areas which have a history of continuous severe burning, stands of *Loudetia simplex* and *Hyparrhenia* spp. cover much of the more open ground.

For the most part, only relic patches of *Baikiaea* woodland remain after the timber extraction operations, and these patches have been subject to burning to such an extent that they are probably altered from the original climax. *Baikiaea* woodland was not represented in the intensive study area.

Regrowth Combretum/Baphia *scrub*

Much of the cut-over *Baikiaea* woodland had most of the tall timber trees removed, and a scrub growth has developed from understory species. Stands vary from 5 to 8 feet (1,5 to 2,4 m) in height and may almost reach thicket density in local areas, but are usually more open with some grass cover. Frequent burning in the past has resulted in a bush/scrub savanna (Rattray 1961) in the eastern stretch along the sand ridge, but tends more toward an open tree/bush savanna in the western reaches of the study area beyond Pookoo Flats.

Dominant bush species are *Baphia obovata, Bauhinia macrantha, Combretum elaeagnoides, Terminalia sericea, Popowia obovata, Grewia* spp., with *Dichrostachys cinerea, Ziziphus mucronata* and *Piliostigma thonningii* in the richer soils and more open country to the west. Some regeneration of *Baikiaea plurijuga, Guibourtia coleosperma* and *Pterocarpus angolensis* was seen, but for the most part, coppicing of these and other species resulted in a bush rather than a tree savanna.

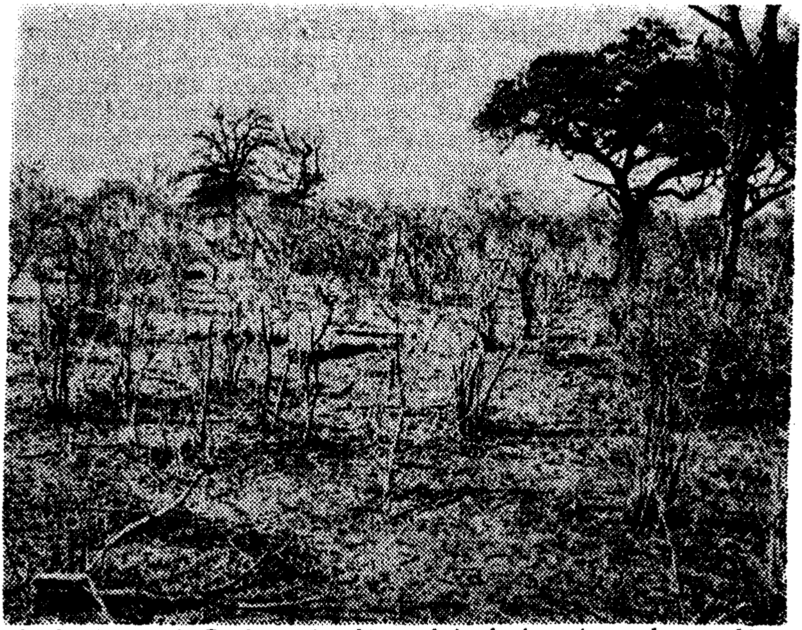

Fig. 8. Regrowth *Combretum/Baphia* scrub in the intensive study area. Note manner in which the *Combretum* spp. have been "poled" by elephant use.

The regrowth *Combretum/Baphia* scrub was not very well represented along the census routes of the intensive study area, only covering 16,1 acres (6,52 ha) (7,5 per cent.), and generally occurred further back from the river (fig. 7). In this particular part of the Chobe, the dominants were *C. elaeagnoides, Acacia tortilis, Commiphora angolensis* and *Baphia obovata*, with some *Combretum engleri, C. mossambicense, Bauhinia macrantha* and *Dichrostachys cinerea* as the main associated species. *Combretum elaeagnoides* and *Baphia obovata* were heavily used by elephant in small patches so that their growth-form was "poled"—all lateral branches were stripped off and all that remained in the dry season were one or two main stems on each plant (fig. 8). The *Commiphora angolensis* and *Acacia tortilis* also showed heavy use, most noticeable toward the end of the dry season.

Mixed tree/bush ecotone complex

This vegetation is difficult to categorize according to the Yangambi Conference classification (1956) as it represents a series of different successional stages along the ecotones of various habitats; its distribution is confined to the principal drainage lines in the area.

The vegetation varies from mature trees of differing species which have survived both the logging operations and the depredations of the high elephant population, through partly damaged habitats in various stages of breakdown, to almost completely denuded areas where the effects of the heavy concentrations of elephant and buffalo have set the vegetation back to an early successional stage. Local areas of tall trees occur which may be dominants from the *Baikiaea* woodland, the riverine *Acacia* tree savanna, or even the riparian fringe vegetation types, interspersed with patches of vegetation which would fall into the thicket or even the regrowth habitat categories described above.

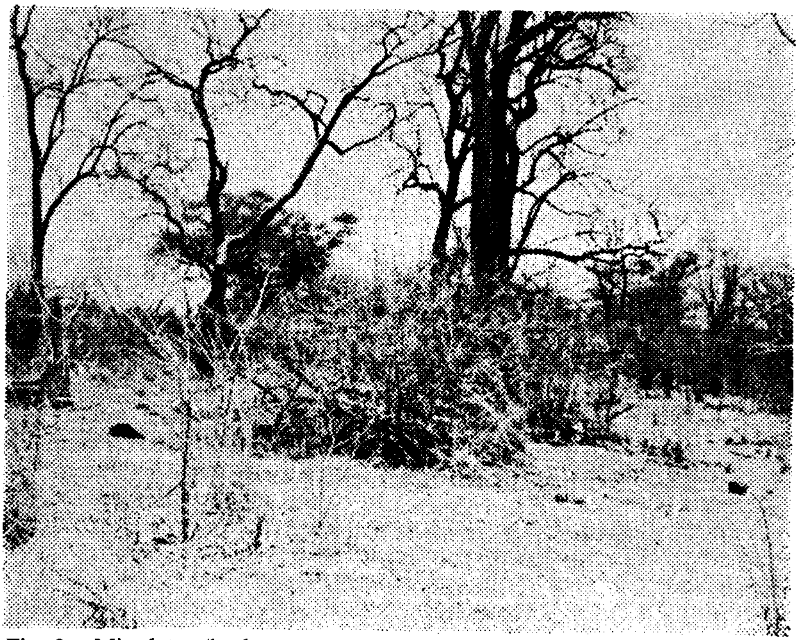

Fig. 9. Mixed tree/bush ecotone complex vegetation in the Kalwizikalkanga drainage line of the intensive study area. The photograph is typical for this habitat.

The mixed tree/bush ecotone complex in the intensive study area (9,8 acres/3,97 ha, 4,6 per cent.) was confined to the Kalwizikalkange drainage and was typical of this vegetation type for the whole Chobe area. As the drainage lines are used as a main thoroughfare to the river for many animals occupying the woodland on the sand ridge, the vegetation has suffered heavy damage with their passage to and from water. Some larger trees remain, principally *Acacia tortilis, Lonchocarpus capassa, Guibourtia coleosperma* and *Piliostigma thonningii*, but even these show signs of elephant damage and are slowly being removed. The ground cover is mainly low-growing scrub, coppicing thicket species and coarse annual grasses (fig. 9). Some of the commoner plants in this vegetation type in the intensive study area were *Ziziphus mucronata, Acacia hexacantha, Ximenia americana, Capparis tomentosa* and *Dichrostachys cinerea*, with *Aristida* spp. as the major grass cover.

Colophospermum *tree/bush savanna*

Confined to the western end of the general study area, this habitat starts about 7 miles (11 km) west of Serondellas and was not represented in the intensive study area. Trees range in height up to 25 feet (7,6 m) in an open tree/bush savanna, with *Colophospermum mopane* locally dominant or co-dominant with a number of other genera—*Combretum, Commiphora, Sclerocarya, Kirkia* and *Terminalia*—and a sparse grass cover of hardy annuals. The habitat stretches from the riparian fringe south to the sand ridge, replacing the riverine *Acacia* tree savanna of the alluvail flats found further east. The status of this habitat is uncertain; it may be original climax vegetation, or it may represent a secondary climax on heavily eroded and rocky soils. There are signs of heavy animal use in some areas, but generally this habitat does not seem to be as attractive to wildlife as do other areas along the Chobe.

METHODS USED TO EVALUATE VEGETATIVE PARAMETERS

Belt transects

The vegetation in the intensive study area was examined in more detail using various established techniques to measure required parameters. Four vegetation transects were made through the intensive study area in August, 1969, to evaluate the structure and composition of the different habitats. These were oriented on a north/south bearing, started at the peripheral spoor trace-line and extended down to the water's edge at the river, and were 6 feet (1,82 m) wide. All woody plants growing within the belt were identified by species where possible, their height and canopy spread measured, the number of stems over 1 inch (2,5 cm) thick at ground-level recorded, and the degree of animal use on each plant was assessed. The four belts totalled 7 710 feet (2 350,0 m) in extent, and showed 834 individual plants in 31 woody species. These species have been included in Appendix A.

Wildlife use was classified for all plants assessed: individuals were placed in the "no use" (*a*) category when no sign of damage or browsing was found; the "light use" (*b*) group when only terminal twigs had been eaten or damaged was confined to the current season's growth; "moderate use" (*c*) when plants showed some damage to previous season's growth—either through brooming of the lateral stems from constant destruction of the terminal buds, or by breakage of the smaller limbs of the plant. Plants which had been completely destroyed by wildlife, resulting in death of the individual or its survival only through ground-level coppicing, were classified as showing "heavy use" (*d*).

The ground cover along the midline of the belt transect was evaluated every 5 feet (1,52 m) using point readings, and classified as to whether it was bare, litter, grass/herb or woody. In this last class only living wood was considered, and any dead woody material on the ground was put in with litter data.

Quadrat analysis

Seventy-nine 10-foot (3,05-m) square quadrats were evaluated over all habitats in the intensive study area in December, 1970. These were located at the substations on the census routes indicated in fig. 2, and were spaced one-twentieth of a mile (0,08 km) apart. Each quadrat was identified by the census station number and a suffix (*a*, *b*, *c*, etc.), and its habitat was determined on the site, or in cases of doubt, with the aid of aerial photographs and the vegetation map (fig. 3). In order to negate any effects of the road/cutline, all quadrats were sited at a 90° angle to the north of the station and 25 feet (7,62 m) off into the bush.

Data collected in each quadrat comprised the status and species of plants, the number of stems greater than 1 inch (2,5 cm) at ground-level, and the approximate canopy cover. Wildlife use was also evaluated on a "no use", "moderate use" and "heavy use" rating; it was impractical to attempt a "light use" classification at this time of year—by definition this involves the current season's growth, and December is in the middle of the growing season for woody plants at Chobe. Ground cover was not evaluated as it had already been made elsewhere on the elephant utilization plots and this was thought to be representative enough for the rainy season.

Lateral visibility assessment

In order to measure vegetation from the wildlife standpoint, it was considered necessary to obtain some gauge of the lateral density within the study area. To achieve a measure of this, lateral visibility was evaluated on each side of the peripheral and internal census routes. A checkered board 24"×36" (0,61 m×0,91 m) was carried away at 90° from the substation marker on the road, the board being held about 15" (0,38 m) above the ground. When the outline of the board disappeared, or when less than one-eighth of the surface was clearly visible from the recording point, a measurement was made of the distance from the observer to the board, and this was considered to be the lateral visibility for that substation. Evaluations were made every two months from all stations and substations on the census routes through the intensive study area. Data from these assessments were grouped by habitat, and the mean visibility distance over the year was obtained for each vegetation type.

Ground cover evaluations

Ground cover was assessed at three different months—during August when the belt transects were run, at the height of the dry season in October using a line transect, and in December, during the analysis of the elephant utilization plots in the mid-rainy season. All measurements were made on a point basis, where each point was classified as having either a bare, litter, grass/herb or woody ground cover. On the belt transects the ground cover was evaluated every 5 feet (1,52 m) along the midline of the assessed strip. The October sample of 2 000 points was obtained along a straight line approximately following transects 2 and 3 with points recorded every 2 feet (0,61 m) along the tape, and ground cover assessment in the elephant utilization plots was on a 5-foot (1,52-m) square grid system. With the three ground cover evaluations made at different times of the year—at the end of the winter, at the peak of the dry season, and in the middle of the rainy season—it was felt that a good picture was obtained for the intensive study area from these data.

RESULTS OF VEGETATION ASSESSMENT

Species frequency and abundance

If each 100 foot (30,48 m) sector of the transect lines was taken as representing a single sample plot, it was possible to calculate the frequency of the eight most common plants on a presence/absence basis. Due to the difficulty in separating the *Combretum* spp., all the *Combretums* have been evaluated together in Table 1 which summarizes frequency data. This combined group showed the highest frequency over the sampled area, followed by *Dichrostachys cinerea* and *Baphia obovata* respectively. However, *Baphia obovata* was the most abundant plant along the transects, averaging 0,50 plants per 100 square feet (9,29 sq. m).

A total of 26 plant species were recorded in the quadrats sampled, and the eight most common of these are evaluated in Table 2. The *Combretum* spp. have all been combined again so that the data from the two sources can be compared.

The *Combretum* spp. showed the highest percentage frequency in both samples, with *Dichrostachys cinerea* second, and *Baphia obovata* third in order of rank. The percentage frequency values for five out of the six species recorded in both assessments are highly comparable, indicating that the two sampling techniques, although completely different in location and methodology, were probably close to obtaining a true picture of the vegetation in the intensive study area. The high ranking of *Erythroxylum zambesiacum* in the frequency ratings of the census route quadrats was surprising. The species was recorded in the belt transects, but did not occur in any numbers. However, this species is heavily used by wildlife, and its apparently poor representation in the vegetation assessments could be due to its rapid destruction in wildlife pressure areas. In the transects it would have been difficult to identify during the dry season, while it may be greatly reduced in the wildlife utilization plots through persistent use.

Abundance was calculated as the number occurring over the total number of plants recorded. Comparison of the abundance of the six species common to both assessments gave the number of plants of *Combretum* spp and *Dichrostachys cinerea* in close agreement between the two techniques. *Baphia obovata* and *Canthium frangula*, however, showed a big difference between the two sets of data. The reason for this disparity is uncertain, but may be associated with the differences in the sampling sites. While the transects sampled the whole spectrum of vegetation from the top of the catena to the river, the quadrats were running more or less parallel to the river, contouring the catena. *Baphia obovata* and *Canthium frangula* were noted on the upper slopes of the catena, becoming less frequent toward the river. While the quadrats assessed on the peripheral census route sampled the higher slopes of the catena, those sited on the census route closer to the river (fig. 2) were at the base of the catena or along the lower slopes where these two species were less common. This would effect the overall abundance values obtained in the quadrat analysis to the detriment of the two species. A similar explanation may serve for the disparity between the overall plant abundance figures in the two assessments. Wildlife use was also heaviest at the river, becoming less apparent toward the top of the catena.

In evaluating the sectors on the transects and the quadrats, the single numerically dominant species in each subsample was noted, and these results are shown in the frequency and abundance tables.

The picture obtained from each vegetation assessment is somewhat similar, although there is again a clear transposition of dominance between *Baphia obovata* and *Combretum* spp. The former was most dominant in the transect data, while the latter became the leading dominant species in the quadrat samples. Both assessments had some subsamples where there were equal numbers of two or more species. These have not been classified under the dominance column in the tables.

Species' density, height and canopy

Data on various vegetative parameters for 15 major plants recorded on the transects were summarized and are presented in Table 3, together with wildlife use for each species. The *Combretum* spp. listed in this table included all four of the species in this genus recorded in the intensive study area—viz. *C. elaeagnoides*, *C. mossambicense*, *C. apiculatum* and *C. collinum*. Separation at the specific level within this genus in the field was largely dependent on leaf form, which became an impossible task at the time when these transects were made. In August, there are few, if any, leaves left on the deciduous plants. Where definite identification was possible, plants were assigned to their species, but the ranking of the two specified species of *Combretum* in Table 3 should be viewed with caution.

Only four of the 31 species recorded on the transects occurred in any great numbers, the remainder each representing less than 1 per cent. of the total plants on all transects combined. Seven species occurred on all four transects, nine were recorded on three transects, nine on two, and six were represented on one transect only. The species with the greatest height—*Acacia nigrescens*, *A. tortilis*, *A. albida*, *Lonchocarpus capassa* and *Diospyros mespiliformis*—were not present in enough numbers to figure amoung the most common species, nor to influence the overall height of vegetation on the transects which was 9,1 feet (2,77m).

Canopy spread data were obtained from woody vegetation, but is probably higher during that period when plants bear foliage. The high incidence of multiple stems at ground-level in the 15 most common plant species gives a clear indication of the thicketlike nature of much of the vegetation in the intensive study area. An overall average of 5,6 stems per plant was obtained. While the normal growth-form of some of these species shows multiple stemming, there can be no doubt that there is a high incidence of coppicing due to constant damage to plants from heavy wildlife use.

The results of the transects can be illustrated as a plan and profile of the woody vegetation sampled. Due to the considerable length of each transect, however, as well as the variability within each habitat type, this was considered to be a pointless exercise. Instead, typical 100-foot (30,48-m) sections of each of the five habitats found in the intensive study area have been extracted from the transects and these are detailed in plan (fig. 10) and in profile (fig. 11) to show vegetation characteristics. All transects had a varying slope from south to north down the catena, but as the project did not have the equipment to measure the slope accurately, it has been ignored and profiles are illustrated as if they were on level ground.

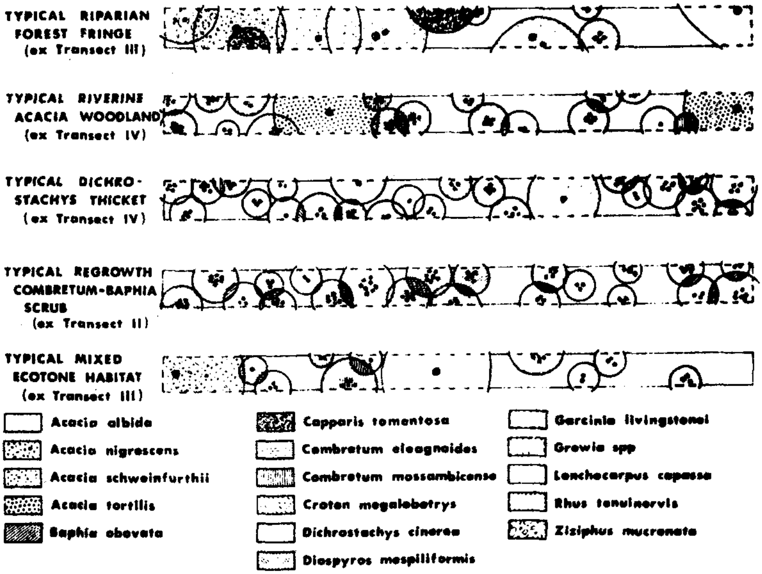

Fig. 10. Five major habitats occurring in the intensive study area shown in plan by typical 100-foot (30,48-m) sections taken from the belt transects.

The densities for the various habitats were determined for different parameters—the number of individual plants, the spread of the canopy, and the number of stems—based on a 100 square foot (9,29 sq. m) unit area. These pertinent data for the five habitats from the belt transects are given in Table 4, and a density value can be calculated for each. *The Dichrostachys thicket showed the highest* values for all three assessments, and the regrowth *Combretum/Baphia* scrub came next in the mean density ranking, followed by the riverine *Acacia* tree savanna. The riparian forest fringe, ranking fifth in plant and stem density and second in canopy density, probably has a much higher value in its pristine state. Due to the heavy continued use by wildlife, this habitat in the intensive study area was decimated of the smaller woody plants, particularly so toward the water's edge.

Thomson (1972) found the riparian habitat in his study area as having the highest canopy density of all local habitats, but wildlife damage in his research area was considerably less than at Chobe.

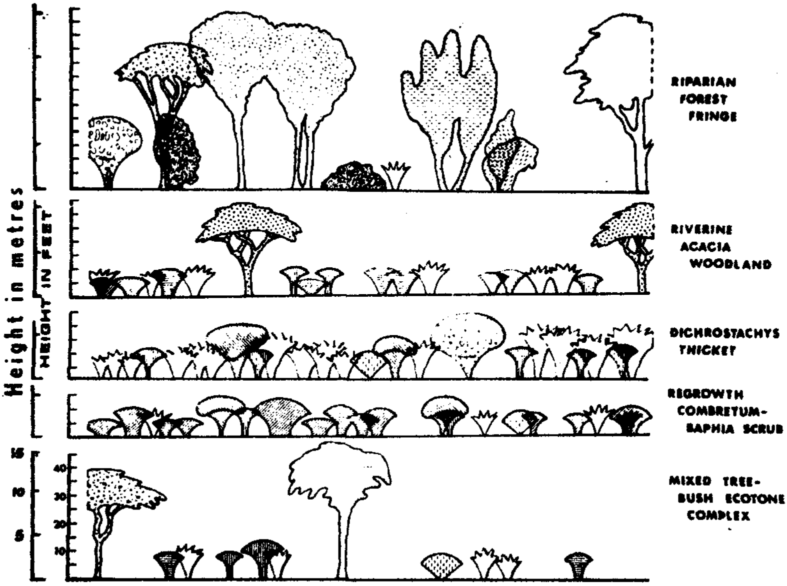

Fig. 11. The five major habitats in the intensive study area shown in fig. 10, illustrated in profile.

Comparison of the data from the belt transects with data obtained in the quadrat analysis and from evaluation of the wildlife utilization plots shows much the same patterns of plant distribution, although there are variations in densities of the vegetation. These results serve to further emphasize the considerable variation and intermingling of the main habitats along the river. Compounded by prolonged and heavy use by wildlife, this diversity has now reached the stage where there is little evidence of climax vegetation in the intensive study area and most of the habitats represent secondary successional development.

Lateral visibility

The overall lateral visibility for all habitats in the intensive study area was 42,52 feet (12,95 m) as an average throughout the year. Due to seasonal changes in vegetation and the concentration of elephant and buffalo at the river during the dry months, there was considerable variation in the lateral cover through the year; maximum densities were found in the mid-rainy season, while visibility opened up with leaf fall and animal use to a maximum in October. A Chi-square analysis of the differences between the visibility data from the five habitats indicated that they were significantly different from the overall visibility distance value for the whole intensive study area at the normally acceptable P = 0,05 level.

The lateral cover density was considered to be inversely related to visibility, when the latter was calculated on a relative scale. The calculated inversed lateral cover densities for each habitat (Table 5) show considerably higher values than found in analysis of the transect data, but this is to be expected and when these figures are corrected to a relative density, they show closer compatibility to the transect values. As found previously, the *Dichrostachys* thicket had the greatest lateral cover density, followed by the regrowth *Combretum/Baphia* scrub. The mixed ecotone complex ranked third, ahead of both the riverine *Acacia* tree savanna and the riparian forest fringe, but this was due to the relatively higher canopy levels found in the latter two habitats placing most of the vegetation above the normal height at which the lateral visibility measurements were made.

Ground cover

Child (1968) made ground cover assessments in various habitats in 1965 on and around the Chobe flood-plain following the step-point method of sampling described by Evans and Love (1957). While the technique used in this study was different to the above, the data from 1965 can be adjusted to be comparable to the present findings, and these have also been shown in Table 6 for comparison. The progressive change in ground cover from grass/herbs to litter, to bare ground is well shown by monthly sample averages both in the increased percentage of bare ground from the rainy months through the dry season, as well as the sequential change in dominance of the ground cover. Data obtained by Child (1968) for September fall into the bare ground data sequence, although they are somewhat at odds with the other data. This is probably due to the area where the sample was taken, but would also have been influenced by the game concentrations and the vegetation growth during the 1964–65 growing season. An overall average ground cover for the Chobe area shows 30,0 per cent. bare ground, 36,8 per cent. litter, 23,2 per cent. grass/herb cover, and 10,0 per cent. woody vegetation.

Analysis of the ground cover data in relation to habitat (Table 7) showed that in October the habitat with the highest recording of bare ground was the riparian forest fringe, closely followed by the mixed ecotone complex, while *Dichrostachys* thicket ranked last in this category. The *Dichrostachys* thicket ranked first in the litter cover which is not surprising as this habitat showed less wildlife use than the others, and litter accumulations would build up without being trampled as much as in surrounding vegetation types. The grass/herb cover was noticeably higher in the *Combretum/Baphia* scrub than in the other habitats, despite heavy wildlife use in this vegetation, while the maximum woody ground cover was recorded from the *Dichrostachys* thicket, which is in accord with the density values for woody plants mentioned earlier (fig. 12). In evaluating these data, it should be remembered that they represent the ground cover in the intensive study area at the peak of the dry season when animals are most concentrated at the Chobe River. They are important, however, as they show the status of exposed ground at the onset of the rains and the high potential erodibility of the area under a different soil regime.

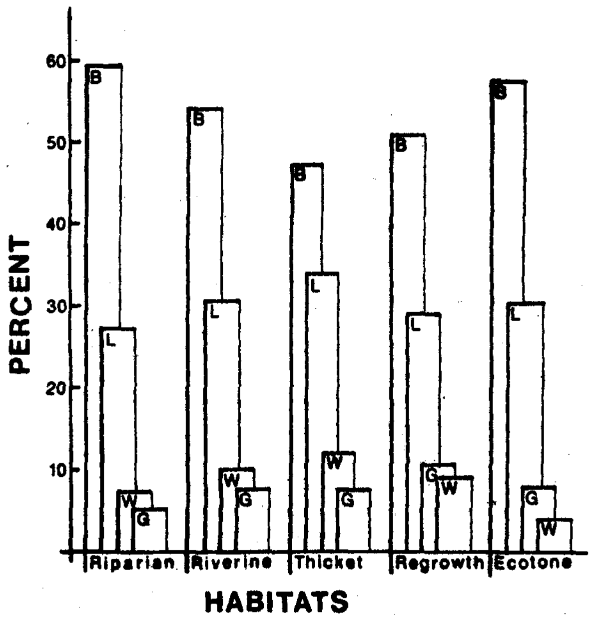

Fig. 12. Relative distribution of four major ground cover categories through five habitats in the intensive study area.
(B = bare, L = litter, G = grass/herb, W = woody.)

Wildlife use

The status of wildlife utilization in each of the 15 plants given in Table 3 showed considerable variation both between and within species. While some species appeared to have the majority of their numbers heavily used by wildlife, others averaged out at moderate or even light use, and *Dichrostachys cinerea* showed the greatest percentage of individuals in the "no use" category. Interpretation of these use data is too speculative to be worthwhile, especially in the face of small samples which have obvious inconsistencies. In those species where the sample size is larger, however, comparison can be made to similar data presented by Child (1968), based on transects run in the same general area in 1965. *Baphia obovata* showed a trend toward heavier wildlife use in 1969 than in 1965, and if *Combretum mossambicense* and *C. elaeagnoides*—as representing the collective *Combretum* spp. group—are examined, there is also a tendency toward heavier use in 1969. *Dichrostachys cinerea* appears to have been more heavily used in the earlier sampling; this may be due to the plants being younger at that time and so more readily available to wildlife. The remainder of the species that overlap between the 1965 and the 1969 transect surveys were recorded in such small numbers in 1969 as to make valid comparisons of trends impracticable.

The status of wildlife utilization in the five habitats (Table 8) shows an overall moderate use by game. While these data give an indication of animal use in the sample quadrats, it should be realized that the assessment of vegetation damage at this time of year (December) is most difficult due to the heavy development of foliage and the active growth of lateral stems and buds. As a consequence, there would be a tendency toward an underestimation of the actual use of plants by wildlife, and these figures must thus represent a very conservative evaluation of this parameter.

The habitat with the most wildlife use was the riparian forest fringe, followed by the regrowth *Combretum/Baphia* scrub and then the riverine *Acacia* tree savanna (Simpson 1974*b*). This is in accord with the field observations made on elephant by Child (1968) and during the present study. Elephant, the major factor in habitat damage and responsible for probably most of the utilization assessed in the vegetation, feed between the riparian strip at the river and the regenerating woodland on the sand ridge during their annual concentrations at the river in the dry season. The relatively low number of plant species recorded in the sample riparian quadrats also probably reflects this heavy use by elephant (see Child 1968).

A summary of the assessed vegetation parameters for the five habitats in the intensive study area is given in Table 9.

PART II—SEASONAL VARIATION IN VEGETATION

In any study involving ecology, the seasonal effects of climate on the environment, and especially on the vegetation, must be taken into consideration. Within the semi-arid zone of the tropics the annual temperature cycle does not exhibit the extreme fluctuations associated with higher latitudes, and consequently other factors, usually rainfall, become limiting to plant distribution. Factors such as daylight length, insolation, aspect, humidity and wind also have a considerable indirect bearing on plant ecology and effect the phenology of vegetation in an area.

The measurement of seasonal change in the environment is subject to many independent and dependent variables, as well as fluctuations between different years. An attempt to quantify some of the more obvious changes was made during the study period with a view to a clearer understanding of the year-round activity patterns of wildlife species utilization of vegetation (Simpson 1974*a*, *b*, *c*).

The maximum and minimum temperatures were recorded three times a week at two weather stations in the intensive study area, one on the banks of the river near the Old Dip Tank and the other on the sand ridge above the Kalwizikalkanga drainage (fig. 2). Daily maximum and minimum temperature readings were taken at a third weather station situated on the project headquarters near Kasane (fig. 1). Rainfall was recorded at both stations in the intensive study area over the duration of the research, and a monthly diary was maintained on the phenology of the major plant species in the area. Bi-monthly lateral visibility assessments along the internal and peripheral census route permitted an evaluation of the seasonal change in lateral cover, but no measurements were made on either the humidity or wind changes.

Temperature

The average monthly temperatures for Kasane are given by Child (1968), based on data collected over 24 years, and the monthly averages obtained at the project headquarters were very similar to these long-term averages. Temperatures recorded in the intensive study area (Table 10) were also similar to the district averages, but the lower weather station, sited to measure temperatures near the river showed an anomaly.

Generally, the maximum daily temperatures ranged a few degrees higher on top of the sand ridge than at the river station, and it seems probable that the Chobe was a regulating factor here. However, the mean minimum temperatures were lower at the river station than on the sand ridge for most months; this is contrary to the expected warmer minimum temperatures close to the slower-cooling large water mass. Similar results were obtained by Thomson (1972) some 60 miles east of the present study area. The mean daily temperature range at the upper station was maximal in October, after which there was a gradual decrease through the rains to a low in the winter months. The lower recording station showed its highest daily range in winter, decreasing to a low in the rainy season (fig. 13).

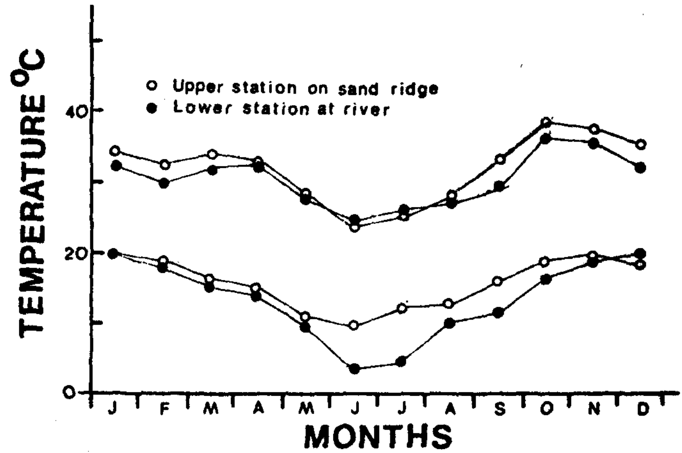

Fig. 13. Temperatures recorded through the year at two stations in the intensive study area with an approximate altitudinal difference of 300 feet (100 m).

Precipitation

The only measure of precipitation made in this study was for rainfall, and although condensation through cold air drainage and dew undoubtedly raises the annual precipitation, especially in the non-rainy months, their significance remain unknown. Rainfall was recorded at the two weather stations in the intensive study area as well as at the project headquarters from September, 1969, through January, 1971 (Table 11), and was found to be slightly lower than the overall average for Kasane (Child 1968). The first rain occurred in September at all recording points in both years, but these showers were usually light and could often only be recorded as a trace in the rain gauge. The main rains in 1969 and 1970 broke on the 10th and 16th October respectively, starting with short, heavy downpours spaced a week to 10 days apart, and increasing in frequency to a peak in December. The rainy season lasted through April, by which time showers were again light and widely spaced (fig. 14).

The rainfall figures from the upper sand ridge station showed the highest annual total with least rain recorded at the project headquarters station; however, a Chi-square test on these total annual figures showed no significant differences between the three recording stations. The functional start of the rains in November was clearly reflected in the numbers of animals recorded at the river, especially so with elephant (*Loxodonta africana*) and kudu (*Tragelaphus* *strepsiceros*), and by the time the rains had reached their peak in December, the concentration of animals along the river was at a minimum.

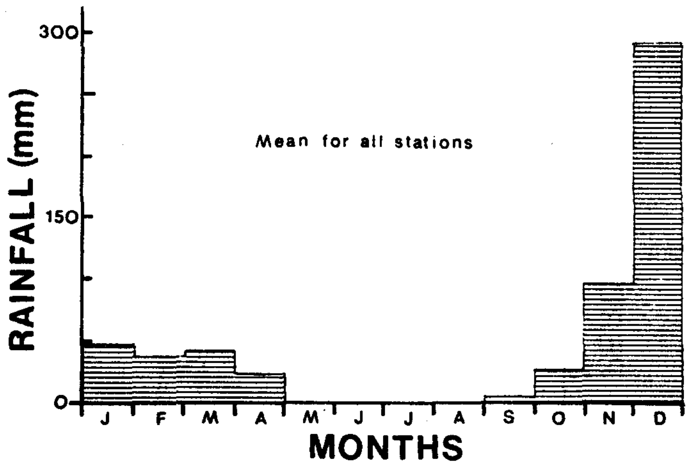

Fig. 14. Average for monthly rainfall recorded at three stations along the Chobe River during the study period.

Wind

No measurement was made of the wind conditions in the area along the Chobe River, but some qualitative notes are available that could be of pertinence. Wind was generally not a noticeable factor for most of the year, but became so in August and early September when the deciduous vegetation had shed its leaves.

SEASONAL CHANGES IN VEGETATION

Density

Comparison of canopy density in August and in December as recorded on the transects and the quadrat evaluations, showed a considerable variation between the end of winter and the peak of the rainy season.

The canopy spread was highest in thicket vegetation (Table 4), followed by the riparian and regrowth habitats, but there is no doubt that the shade value of the thicket to wildlife species is low during the dry season. Despite this, however, the thicket was used more during the dry season than at any other time. The canopy cover of the riparian and riverine habitats ranked second and fourth and their use in the dry season was high, but the regrowth habitat (ranked second in canopy density), showed a low use in the hot months. Examination of the lateral density of the different vegetation types shows the thicket to have the greatest density over the year, but especially so in the dry season.

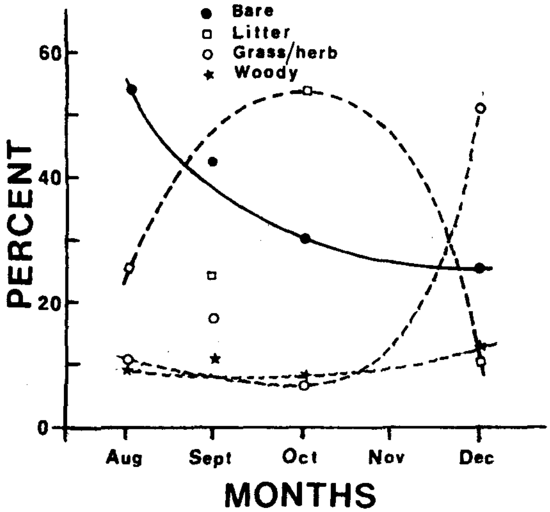

Fig. 15. Seasonal change in ground cover in the intensive study area. Data from Child (1968) are shown for September, 1965, for comparison.

Ground cover

Ground cover was not assessed in computing density values for the habitats in the intensive study area. For the study area as a whole, considerable changes were found in ground cover as the dry season progressed (Table 6), and these are shown graphically in fig. 15. Bare ground was maximal in late winter, but with the completion of leaf fall in the early dry season, litter predominated in the ground cover. This decreased rapidly with heavy animal use along the river in the late dry season and the advent of the rains. The grass/herb cover declined as animal use increased up to the arrival of the rains, whereafter it increased rapidly to become the principal ground cover by December, with a concomitant drop in the percentage of litter and bare ground. The woody cover remained more or less constant throughout the year at about 10 per cent. of the area. Ground cover values given by Child (1968) for September are also shown in fig. 15, but they have not been included in the curves.

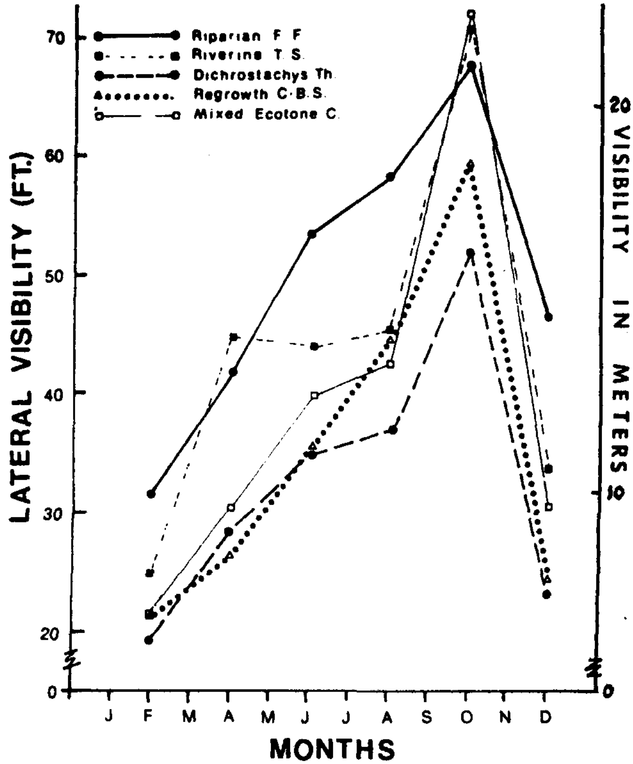

Fig. 16. Seasonal change in lateral visibility between five different habitats in the intensive study area.

Lateral visibility

The seasonal breakdown of the lateral visibility data (Table 12) again clearly show the effects of change in the five habitats examined in detail, and when these are plotted graphically (fig. 16), visibility as a function of seasonal variation is clearly apparent. To test the hypothesis that the dependence of lateral visibility on seasonal fluctuation was uniform throughout all habitats in the intensive study area, these data were compared by month in a contingency table. The statistic calculated inferred that there was no significant difference in lateral visibility between habitats due to seasonal change. Since, however, the data showed that there was a definite difference in visibility between habitats in any given sample month, some other parameter must influence this variation; it seems highly likely that this influencing parameter is the character and species composition of the individual habitats themselves.

The average width for the whole census route in the intensive study area was 42,5 feet (12,5 m) on either side of the census line, but this width varied from 23,1 feet (7,04 m) in February to 63,5 feet (19,35 m) in October when visibility was at its maximum. Evaluation of visibility in each habitat gave annual means as shown in Table 12. The greatest visibility was found in the riparian vegetation, while the lowest was recorded in the thicket habitat. This is in conflict with the results obtained by Thomson (1972) who found less than a 50 per cent. change in seasonal visibility in the riverine forest (i.e. riparian forest fringe) in the Victoria Falls National Park, Rhodesia.

The explanation for this disparity between the two geographically close evaluations of the same habitat lies in the degree of elephant damage. In Thomson's area, the total number of elephant recorded in the study area over 12 months was 84 animals, although he states that this is a minimal figure. In the Chobe study area over the same period of time, 5 631 elephant were counted during routine census trips; this figure is also minimal, as there was constant evidence to be seen along the census route of elephant herds crossing either at night or at other times when they would not have been seen in the intensive study area. To even the most casual observer it is apparent that the riparian vegetation along the Chobe is in an advanced stage of destruction by elephant, especially so when this habitat is compared to its equivalent further down the Zambezi River where elephant populations are considerably lower.

Plant phenology

A weekly diary of phenological events and interaction between the vegetation and wildlife was kept for the duration of the study period. Analysis of these notes produced considerable general descriptive information of seasonal change, but there was little data suited to quantitative evaluation. A brief summary of these notes for the intensive study area is given below to formulate a broad picture of the changing scene at Chobe. Detailed data on the phenology of four major plants species were available in this account, and these have been extracted to show the pattern of change in vegetation through the seasons. Further phenological data on many of the riparian species are shown by Wilson and Child (1964) and Thomson (1972) with special reference to the flowering and fruiting of some of the riverine trees.

In August there is an increase in the wind and this completes leaf fall for those plants which still have not shed their old leaves. Habitats away from the river are bare of foliage, especially in those areas where there has been heavy wildlife use. Some of the deep-rooted trees on the alluvial flats begin to bloom toward the end of the month, with the beginnings of the spring flush of growth seen in swollen terminal and lateral buds. A few of the winter-flowering plants (e.g. *Combretum mossambicense*) are still in bloom along the river habitats where soil moisture conditions may still be good, but there is no evidence of young shoots appearing. "Poleling" of the shrub species by elephant is most noticeable at this time, and elephant herds are beginning to appear at the river.

In September most of the larger *Acacia* spp. are in full bloom and the spring flush of new shoots can be seen on many of these trees by the end of the month. The early-flowering species are losing their blooms, but show few signs of leafing out. *Baphia* and *Bauhinia* both begin to flower here and there, and in the riparian habitat occasional trees and shrubs show evidence of the green spring growth, particularly *Combretum*, *Rhus* and *Croton*. The *Syzgium* and *Lonchocarpus* along the river have a profusion of flowers in the latter part of the month, and *Capparis* begins to bloom in the riparian habitat. Elephant are beginning to use the *Acacia* and *Dichrostachys* thickets heavily as they feed on seed-pods and twigs, and wildlife damage becomes noticeably more extensive each week. Some "trace" rain showers occur during the month, but these do not have any apparent effect on the vegetation.

In October, the cumulative effect of several "trace" showers bring many of the riverine and riparian habitat species into leaf, and once the main rains arrive, the vegetation greens up rapidly. The thickets are usually the last to develop new leaves, with the flush starting in areas of least damage and progressing to those areas where wildlife use has been heaviest. Those plants which have been poled by elephant were usually the last to produce new leaves, and even by the end of the month, many remain bare and apparently lifeless. October is the month of flowering for many of the brush species and those tree species which have not flowered earlier in the season. *Dichrostachys* is usually one of the last plants to flower and send out new shoots, while several early-flowering species—*Diospyros*, *Garcinia* and *Lonchocarpus*—are beginning to produce seed after prolific flowering earlier in the season. Elephant concentrations are very high along the river stretches at the beginning of the month, as are many other game species, but with the coming of the main rains in the latter part of the month, there is an emigration of wildlife into the woodland south of the river.

November through March, into April, are the main rainy months with frequent showers and overcast skies. All plants, except those that have suffered the severest damage by elephant, are in full foliage, and by January, even these latter individuals have sprouted green shoots and started the season's growth. Many of the plants that set seed at the end of the dry season germinate at the beginning of the rains, and seedlings are everywhere. By the end of December, the ground cover is well formed; grasses and herbs have established themselves in all previously bare areas, with grasses up to 5 foot (1,52 m) under the dense tree canopy, and lower growing herbaceous heliophytes in the more open areas where there is sufficient light. Many of the annuals complete their whole annual cycle during this period of the rains. Most of the woody legumes continue growth and seed formation until the dryer conditions of winter stop growth, when foliage dies on the twigs and seeds are either shed or carried on the plant. Wildlife use along the river is at its annual minimum during the early part of the rains, but toward April, some of the game species begin drifting back to the river strip.

April/May is an intermediate period so far as the vegetation is concerned. Soil moisture begins to diminish and temperatures cool down with the advent of winter. Most species show cessation of leaf growth, starting on the sand ridge and progressing down the catena toward the river habitats. The tall grasses that grew in the shade of the tree canopy have dried out and start to be trodden down by animal movement, while the herbaceous annuals that covered the open areas have dried and withered to a sparse, low cover that soon goes to litter with the combined effects of time and trampling. Perennial plants have built up their underground storage of food reserves and the above ground parts are dead. Wildlife use of the river strip has increased with animals moving to and from the river through the different habitats feeding on various drying leaves and fruits.

June/July are the two most severe winter months along the Chobe. Daily temperature ranges are high, cold air drainage becomes an important phenomenon at night and occasional frosts put a definite end to growth in all but the hardiest or most protected plants. Relatively little surface water is available except in a few permanent pans in the woodland away from the Chobe, and wildlife become more dependent on the river for their water requirements; game begins to concentrate along the river strip during the day, but severe night drops in temperature cause some daily movement of certain game species (Simpson 1972). Leaves and fruiting bodies are still quite plentiful but those species remaining green through the winter (*Capparis tomentosa*, *Rhus tenuinervis*) show indications of heavy browsing; wildlife also eat twigs, bark, dry leaves, seed-pods, and grass at this time of the year, and some of the older animals lose condition.

From the phenological diary of vegetation changes in the Chobe River strip it was possible to detail the annual cycle stages for four major plant species common to most habitats. These are represented graphically in fig. 17. Most plants begin their season's activity either

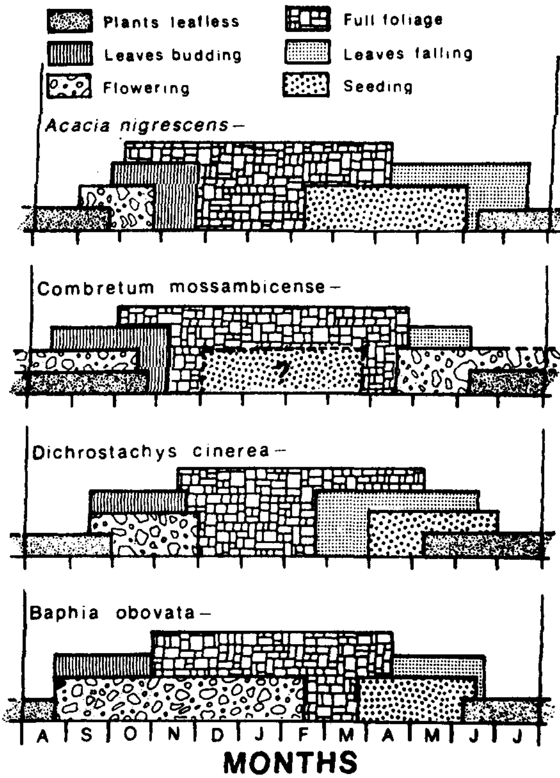

Fig. 17. Phenology of four representative woody plants from observational data collected in the intensive study area.

shortly before, or when the first "trace" rain showers occur, and the growing season lasts through to about the end of April when conditions begin to get unfavourable for further plant growth. Flowering is usually completed over a relatively short period, followed by a longer period of foliage and seed development. The notable exceptions to this pattern are *Combretum mossambicense* and *Baphia obovata*; the former is a species which blooms in winter, while the flowering of the latter is extended through the late dry season and the early rains. Both these species are widely distributed across the catena which might in part account for the prolonged flowering season (Simpson 1972). No data were recorded in the diary as to when *Combretum mossambicense* set seed, but two feeding records for bushbuck eating the fruits of this species in December and March have been tentatively included in fig. 17. It is considered that the phenology of these four plant species is probably representative of all woody plant forms in the intensive study area, thus, offering a realistic overview of the seasonal changes in vegetation along the Chobe River strip.

Comparison of the data collected during the first dry season with those for the following year showed a similar sequence of change, but a distinct difference in the timing of each event. The whole phenological series seemed to have been shifted forward by about three weeks in 1970 when viewed against the 1969 data, and there was a general impression of more foliage on plants than during the former dry season. No quantitative evaluation of this difference was directly possible after the event. Some degree of the variation between 1969 and 1970 is reflected in the lateral visibility assessments for the two dry seasons, despite a virtual chronologic duplication of the first trace rains and the beginning of the main rainy season. No cause was found for this phenomenon, but there is little doubt that it existed.

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APPENDIX A

List of plants collected within the general range of the bushbuck in the north-east Chobe National Park, Botswana, between August, 1969, and December, 1970. Identifications were made by Mr. R. B. Drummond of the Rhodesian National Herbarium and Botanic Garden, Salisbury.

Species	*Herbarium Reference*
Abutilon ramosum Guill. & Perr.	CNP 4/3
Abutilon sp.	CNP 4/72
Acacia albida Del.	CNP 1/1
A. galpinii Burtt Davy	CNP 1/37
A. giraffae Willd.	CNP 1/19
A. luederitzii Engl.	CNP 1/49
A. mellifera (Vahl) Benth. subsp. *detinens* (Burch.) Brenan	CNP 1/55
A. nigrescens Oliv.	CNP 1/9
A. nilotica (L.) Willd. ex Del. subsp. *kraussiana* (Benth.) Brenan	CNP 1/91
A. schweinfurthii Brenan & Exell	CNP 2/18
A. tortilis (Forsk.) Hayne	CNP 1/13
Acalypha indica L.	CNP 4/8
A. ornata Hochst. ex A. Rich.	CNP 4/6
Acalypha sp.	CNP 3/10
Acanthospermum hispidum DC.	CNP 2/78
Achyranthes aspera L.	CNP 2/27
Acrotome inflata Benth.	CNP 2/82
Aerva leucura Moq.	CNP 2/1
Afzelia quanzensis Welw.	CNP 2/59
Albizia anthelmintica Brongn.	CNP 1/21
Amaranthus spinosus L.	CNP 2/95
Amaranthus sp.	CNP 3/28
Andropogon gayanus Kunth	CNP 3/14
Artabotrys brachypetalus Benth.	CNP 4/41
Asparagus africanus Lam.	CNP 1/57
Asparagus sp.	CNP 2/64
Aspilia kotschyi (Schultz Bip.) Oliv. var. *kotschyi*	CNP 2/75
Azanza garckeana (F. Hoffm.) Exell & Hillcoat	CNP 4/12
Baikiaea plurijuga Harms	CNP 1/30
Baphia massaiensis Taub. subsp. *obovata* (Schinz) Brummitt	CNP 1/85
Barleria senensis Klotzsch	CNP 4/16
Bauhinia macrantha Oliv.	CNP 1/31
Berchemia discolor (Klotzsch) Herzog	CNP 1/86
Bergia prostrata Schinz	CNP 3/55
Blepharis caloneura S. Moore	CNP 4/14
Blumea gariepina DC.	CNP 1/53
Boscia albitrunca (Burch.) Gilg & Bened.	CNP 4/63
B. salicifolia Oliv.	CNP 1/40
Bridelia mollis Hutch.	CNP 2/52
Calostephane divaricata Benth.	CNP 4/68
Canthium burttii Bullock	CNP 1/47
C. frangula S. Moore	CNP 1/33
Capparis tomentosa Lam.	CNP 1/10
Carissa bispinosa (L.) Desf. ex Brenan	CNP 1/54
Cassia falcinella Oliv. var. *parviflora* Steyaert	CNP 4/13
C. obtusifolia L.	CNP 2/92
Cassine transvaalensis (Burtt Davy) Codd	CNP 1/58
Chloris virgata Swartz	CNP 3/64
Cissampelos mucronata A. Rich.	CNP 1/80

Species	*Herbarium Reference*
Cissus cornifolia (Bak.) Planch.	CNP 2/10
Citropsis daweana Swingle & Kellerm.	CNP 3/38
Citrullus lanatus (Thunb.) Mansf.	CNP 1/71
Cleome hirta (Klotzsch) Oliv.	CNP 3/17
Clerodendrum glabra E. Mey.	CNP 4/74
C. ternatum Schinz var. *lanceolatum* (Gürke) Moldenke	CNP 3/15
Coccinia adoensis (A. Rich.) Cogn.	CNP 1/99
Cocculus hirsutus (L.) Diels	CNP 4/43
Colophospermum mopane (Kirk ex Benth.) Kirk ex L. Léonard	CNP 1/92
Combretum collinum Fresen.	CNP 2/7
C. elaeagnoides Klotzsch	CNP 1/36
C. engleri Schinz	CNP 1/32
C. imberbe Wawra	CNP 1/20
C. mossambicense (Klotzsch) Engl.	CNP 1/38
Combretum sp.	CNP 1/35
Commelina sp.	CNP 3/33
Commicrapus plumbagineus (Cav.) Standl.	CNP 1/66
Commiphora angolensis Engl.	CNP 1/78
C. pyracanthoides Engl. subsp. *glandulosa* (Schinz) Wild	CNP 1/93
Commiphora sp.	CNP 3/58
Corchorus tridens L.	CNP 4/5
Corida pilossima Bak.	CNP 2/81
Crotalaria pisicarpa Welw. ex Bak.	CNP 1/65
Croton gratissimus Burch.	CNP 1/34
C. megalobotrys Muell. Arg.	CNP 1/7
Cucumis sp.	CNP 2/32
Cyathula orthacantha Schinz	CNP 4/70
Cymbopogon excavatus (Hochst.) Stapf	CNP 3/60
Cyperus compactus Lam. sens. lat.	CNP 2/41
C. digitatus Roxb. subsp. *auricomus* (Sieb. ex Spreng.) Kukenth.	CNP 1/83
Dactyloctenium giganteum Fisher & Schweikerdt	CNP 3/63
Dichrostachys cinerea (L.) Wight & Arn.	CNP 1/60
Dicliptera verticillata (Forsk.) C. Chr.	CNP 2/21
Digitaria setivalva Stent	CNP 3/61
Diospyros mespiliformis Hochst. ex A. DC.	CNP 1/17
D. lycioides Desf. subsp. *sericea* (Berh. ex Krauss) DeWinter	CNP 1/25
Dirichletia pubescens Klotzsch	CNP 3/40
Dregea macrantha Klotzsch	CNP 1/56
Ehretia coerulea Gürke	CNP 4/62
Enneapogon cenchroides (Licht. ex Roem. & Schult.) C. E. Hubbard	CNP 2/15
Eragrostis superba Peyr.	CNP 2/23
Erythrina sp. cf. *E. mendesii* Torre	CNP 1/45
Erythroxylum zambesiacum Robson	CNP 1/15
Euclea divinorum Hiern	CNP 4/65
Evolvulus alsinoides (L.) L.	CNP 3/25
Ficus burkei (Miq.) Miq.	CNP 1/52
F. sycomorus L.	CNP 1/26
Garcinia livingstonei T. Anders.	CNP 1/16
Gardenia jovis-tonantis (Welw.) Hiern	CNP 1/63
Glinus oppositifolius (L.) A. DC.	CNP 1/64
Gloriosa simplex L.	CNP 2/70
Grewia avellana Hiern	CNP 1/90
G. bicolor Juss.	CNP 4/36
G. cyclopetala Wawra	CNP 3/50
G. flavescens Juss.	CNP 3/27

Species	Herbarium Reference
G. retinervis Burret	CNP 4/35
G. schinzii K. Schum.	CNP 3/31
Hebenstretia holubii Rolfe	CNP 1/67
Helinus integrifolius (Lam.) Kuntze	CNP 2/39
Heliotropium baclei DC. var. *rostratum* Johnst.	CNP 1/61
H. indicum L.	CNP 3/19
H. ovalifolium Forsk.	CNP 1/72
Hibiscus caesius Garcke	CNP 2/74
H. cannabinus L.	CNP 2/96
H. dongolensis Del.	CNP 4/2
Hippocratea indica Willd.	CNP 4/37
H. parviflora N. E. Br.	CNP 2/38
Hoslundia opposita Vahl	CNP 1/100
Hyparrhenia filipendula (Hochst.) Stapf	CNP 3/62
Indigofera flavicans Bak.	CNP 1/73
I. hirsuta L.	CNP 2/91
Ipomoea arachnosperma Welw.	CNP 2/44
I. leucanthemum (Klotzsch) Hall f.	CNP 2/84
I. shirambensis Bak.	CNP 1/46
Jasminum stenolobum Rolfe	CNP 1/44
Justicia glabra Koen. ex Roxb.	CNP 4/71
J. heterocarpa T. Anders.	CNP 2/100
Kigelia pinnata (Jacq.) DC.	CNP 1/28
Lantana rugosa Thunb.	CNP 1/97
Lonchocarpus capassa Rolfe	CNP 1/4
Ludwigia stolonifera (Guill. & Perr.) Raven	CNP 1/81
Maerua angolensis DC.	CNP 4/64
Manilkara mochisia (Bak.) Dub.	CNP 2/8
Mariscus chersinus N. E. Br.	CNP 3/47
M. laxiflorus Turrill	CNP 2/65
Markhamia acuminata (Klotzsch) K. Schum.	CNP 1/42
M. obtusifolia (Bak.) Sprague	CNP 3/21
Maytenus heterophylla (Eckl. & Zeyh.) Robson	CNP 4/80
M. senegalensis (Lam.) Exell	CNP 1/18
Melanthera sp.	CNP 3/45
Melhania forbesii Mast.	CNP 3/37
Mimosa pigra L.	CNP 1/41
Momordica balsamina L.	CNP 3/54
M. cardiospermoides Klotzsch	CNP 2/71
Ochna pulchra Hook.	CNP 2/11
Ocimum canum Sims	CNP 2/24
Oncoba spinosa Forsk.	CNP 2/66
Panicum maximum Jacq.	CNP 3/57
Paspalum polystachyum R. Br.	CNP 2/72
Pavonia senegalensis (Cav.) Leistner	CNP 4/15
Pergularia sp.	CNP 2/22
Peristrophe bicalyculata (Retz.) Nees	CNP 2/89
Phoenix reclinata Jacq.	CNP 2/30
Phyllanthus pentandrus Schumach.	CNP 3/9
P. reticulatus Poir.	CNP 2/28
Phyllanthus sp.	CNP 3/42
Piliostigma thonningii (Schumach.) Milne-Redh.	CNP 2/85
Plumbago zeylanica L.	CNP 2/26
Pogonarthria fleckii (Hack.) Hack.	CNP 4/30
Polygonum limbatum Meisn.	CNP 1/70
Popowia obovata (Benth.) Engl. & Diels	CNP 1/94

Species	Herbarium Reference
Premna senensis Klotzsch	CNP 3/53
Pupalia lappacea (L.) Juss.	CNP 3/48
Rhus tenuinervis Engl.	CNP 1/27
Ricinus communis L.	CNP 1/22
Sclerocarya caffra Sond.	CNP 3/35
Securinega virosa (Roxb. ex Willd.) Pax & K. Hoffm.	CNP 1/3
Sehima ischaemoides Forsk.	CNP 1/2
Senecio ruderalis Harv.	CNP 3/18
Sesbania sp.	CNP 2/67
Setaria anceps Stapf ex Massey	CNP 2/69
S. verticillata (L.) Beauv.	CNP 2/14
Sida alba L.	CNP 3/11
S. cordifolia L.	CNP 1/62
Solanum panduriforme E. Mey.	CNP 2/12
S. renschii Vatke	CNP 1/43
Strychnos madagascariensis Poir.	CNP 2/57
S. potatorum L. f.	CNP 4/58
Syzgium guineense (Willd.) DC.	CNP 1/24
Tacazzea apiculata Oliv.	CNP 2/46
Tagetes minuta L.	CNP 4/66
Tephrosia purpurea (L.) Pers.	CNP 2/83
Terminalia sericea Burch. ex DC.	CNP 4/27
Tragia okanyua Pax	CNP 2/13
Tribulus terrestris L.	CNP 1/74
Tricalysia allenii (Stapf) Brenan	CNP 1/39
Trichilia emetica Vahl	CNP 3/26
Triumfetta pentandra A. Rich.	CNP 2/94
Urginea sanguinea Schinz	CNP 2/62
Urochloa pullulans Stapf	CNP 3/59
Vangueria lasioclados K. Schum.	CNP 1/89
Vernonia glabra (Steetz) Vatke	CNP 1/59
Vetiveria nigritana (Benth.) Stapf	CNP 3/49
Vigna unguiculata (L.) Walp.	CNP 3/56
Waltheria indica L.	CNP 4/11
Wissadula rostrata (Schumach.) Hook. f.	CNP 4/23
Withania somnifera (L.) Dunal	CNP 2/73
Xeroderris stuhlmannii (Taub.) Mendonça & Sousa	CNP 2/37
Ximenia americana L.	CNP 1/5
Ximenia caffra Sond.	CNP 4/31
Zaleya pentandra (L.) Jeffrey	CNP 4/69
Ziziphus mucronata Willd.	CNP 1/12

Table 1.—Frequency and abundance of eight most common plants recorded in 77 100-foot (30,48-metre) sectors of transect lines made in intensive study area in August, 1969

Species	Total # plants	# sectors present	% sample frequency	Relative frequency	Abundance	Sectors dominant
Baphia obovata	237	36	46,8	20,1	0,88	23
Combretum spp.	165	58	75,3	32,4	0,20	21
Dichrostachys cinerea	103	39	50,6	21,8	0,12	16
Canthium frangula	78	16	10,8	8,9	0,09	2
Acacia schweinfurthii	33	5	6,5	2,8	0,04	2
Bauhinia macrantha	28	10	13,0	5,6	0,03	3
Commiphora pyracanthoides	24	6	7,8	3,4	0,03	1
Ximenia americana	23	9	11,7	5,0	0,03	0
Total all species	834	77	—	100,0	1,00	68

Table 2.—Frequency and abundance of eight most common plants recorded in 79 100-foot (30,48-metre) square quadrats evaluated in intensive study area in December, 1970

Species	Total # plants	# quadrats present	% frequency in sample	Relative frequency	Abundance	Quadrats dominant
Combretum spp.*	127	53	67,1	28,8	0,33	24
Dichrostachys cinerea	86	40	50,6	21,7	0,22	13
Baphia obovata	73	38	48,1	20,7	0,19	19
Canthium frangula	18	10	12,8	5,4	0,05	2
Erythroxylum zambesiacum	18	15	19,0	8,2	0,05	1
Bauhinia macrantha	15	11	13,9	6,0	0,04	2
Acacia schweinfurthii	10	9	10,1	4,9	0,03	0
Canthium burttii	9	8	6,3	4,3	0,02	0
Total all species	385	79	—	100,0	4,87	61

* *Combretum* spp. assessed collectively to make data comparable to transect analysis

Table 3.—Vegetative and wildlife use data for 15 most common species recorded on four belt transects made in the intensive study area in August, 1969

Species	Total plants	Mean height (m)	Mean spread (sq. m)	Mean No. stems	% wildlife use a	b	c	d
Baphia obovata	237	1,80	2,26	7,4	8	11	28	53
Combretum spp.*	128	1,55	1,90	4,1	7	13	23	57
Dichrostachys cinerea	103	2,07	2,18	3,4	46	21	20	13
Canthium frangula	78	1,73	3,29	8,8	5	12	24	59
Acacia schweinfurthii	33	4,72	5,87	2,6	33	37	21	9
Bauhinia macrantha	28	1,07	1,59	7,6	18	39	29	14
Commiphora pyracanthoides	24	3,72	8,08	2,1	0	33	46	21
Combretum mossambicense	24	1,67	2,34	6,8	0	11	60	29
Ximenia americana	23	1,95	1,84	4,5	4	9	70	17
Croton megalobotrys	15	3,38	4,63	4,8	20	33	47	0
Securinega virosa	13	1,67	4,45	8,4	15	31	54	0
Combretum elaeagnoides	13	1,64	2,06	4,0	0	9	27	64
Rhus tenuinervis	12	1,67	2,73	3,2	8	17	50	25
Acacia nigrescens	11	4,63	5,91	2,3	0	36	55	9
Ziziphus mucronata	7	5,27	6,22	2,0	29	57	14	0
16 other species	85	3,51	3,07	1,7	13	24	38	25

* This group may include all four species of *Combretum* occurring in area—see text for further explanation.

Table 4.—Vegetation density calculated for five main habitats in intensive study area based on transect data. All species recorded in each habitat included in analysis with unit area taken as 100 square feet (9,29 sq. m.)

Habitat	Mean # plants/unit	Relative plant density	Mean # stems/unit	Relative stem density	Mean % canopy	Relative canopy density	Mean height (m)	# spp.	Mean density value
Riparian forest fringe	1,9	12,2	4,4	8,8	53,2	20,9	7,41	23	14,0
Riverine *Acacia* tree savanna	2,8	18,3	10,5	21,0	44,2	17,5	4,63	26	18,9
Dichrostachys thicket	4,4	28,7	13,4	26,7	75,3	29,6	2,93	14	28,3
Regrowth *Combretum*/*Baphia* scrub	3,7	24,1	15,5	31,0	52,0	20,5	2,04	19	25,2
Mixed tree/bush ecotone complex	2,5	16,7	6,3	12,5	29,3	11,5	3,57	18	13,6
Mean all habitats	1,8	11,8	10,0	20,0	40,6	16,0	2,77	20	15,9

Table 5.—Mean lateral vegetation cover of five habitats in the intensive study area based on bi-monthly sampling at 162 substations over 18 months

Habitat	Sample size	% of sample	Lateral visibility (m)	Relative visibility	Inversed density	Relative density
Riparian forest fringe	60	4,4	15,65	23,7	76,3	19,1
Riverine *Acacia* tree savanna . . .	660	41,6	13,96	21,1	78,9	19,7
Dichrostachys thicket	317	23,6	10,43	15,8	84,2	21,1
Regrowth *Combretum* /*Baphia* scrub . .	180	13,4	12,44	18,9	81,1	20,3
Mixed tree/bush ecotone complex . .	127	9,0	13,48	20,5	79,5	19,9
All habitats .	1 344	100,0	42,52	100,0	400,0	100,0

Table 6.—Ground cover point evaluations made on the Chobe flats in and near the intensive study area over three different seasons

Month	Sample method	Sample extent	Sample points	% ground cover: Bare	Litter	Grass/ Herb	Woody
August, 1969 . .	Transect	504,44 m	331	32,4	53,2	1,6	12,0
	Transect	670,56 m	440	20,2	62,3	9,3	8,2
	Transect	640,08 m	425	21,0	64,5	6,5	8,0
	Transect	534,92 m	351	33,4	38,7	19,7	8,2
October, 1970 .	Line	670,56 m	1 100	50,6	31,8	8,1	9,3
	Line	548,64 m	900	57,2	28,6	9,5	4,7
December, 1970 .	Grid	929,03 sq. m	121	12,3	19,5	55,9	12,3
	Grid	929,03 sq. m	121	8,6	30,9	47,6	12,9
August average .		2 350,00 m	1 547	25,6	54,9	10,4	9,1
October average .		1 219,20 m	2 000	53,9	30,2	7,3	8,5
December average		609,60 sq. m	242	10,5	25,2	51,8	12,5
September, 1965*	(Table 7)*		252	35,0	23,8	31,7	9,5
	(Table 8)*		183	54,1	26,2	5,4	14,3
	Average			43,0	24,0	18,3	11,5

* Data adapted from Child (1968).

Table 7.—Ground cover related to five major habitats based on point evaluations made in October, 1970, in the study area

Habitat	Sample size	% ground cover			
		Bare	Litter	Grass/ Herb	Woody
Riparian forest fringe	78	59,6	27,5	5,3	7,6
Riverine *Acacia* tree savanna . .	423	54,3	30,5	5,1	10,1
Dichrostachys thicket	631	47,3	33,4	7,5	11,8
Regrowth *Combretum/Baphia* scrub	690	51,0	29,2	10,7	9,1
Mixed tree/bush ecotone complex .	178	57,4	30,6	7,9	4,1
Average all habitats . . .	2 000	53,9	30,2	7,3	8,5

Table 8.—Wildlife utilization of five major habitats in the intensive study area based on data from 79 ten-foot square plots (9,29 sq. m). Mean canopy cover also shown for December, 1970

Habitat	Sample size	% sample	# spp.	% wildlife utilization			Mean % canopy
				Nil	Moderate	Heavy	
Riparian forest fringe	2	6,3	20	20	20	20	95,4
Riverine *Acacia* tree savanna . . .	34	43,1	21	3	50	47	63,7
Dichrostachys thicket	21	26,6	13	38	52	10	61,9
Regrowth *Combretum* /*Baphia* scrub . .	11	13,9	16	0	45	55	46,8
Mixed tree/bush ecotone complex . .	8	10,1	15	0	75	25	38,9
All habitats .	79	100,0	46	13	50	37	63,0

Table 9.—Summary of vegetation parameters assessed for five habitats in the intensive study area in August, 1969, based on a unit area of 600 square feet (55,47 sq. m)

Habitat	# plant spp.	Relative plant density	Relative stem density	Relative canopy density	Mean density value	Lateral relative density	Ground cover ranking	Wildlife utilization ranking
Riparian forest fringe	23	12,1	8,8	20,9	14,0	19,1	5	3
Riverine *Acacia* tree savanna . . .	26	18,3	21,0	17,5	18,9	19,7	3	2
Dichrostachys thicket	14	28,7	26,7	29,6	28,3	21,2	1	5
Regrowth *Combretum* /*Baphia* scrub . .	19	24,1	31,0	20,5	25,2	20,3	4	1
Mixed tree/bush ecotone complex . .	18	16,7	12,5	11,5	13,6	19,9	2	4
Mean all habitats .	20	11,8	20,0	16,0	15,9	19,2	3–4	4–5

Table 10.—Mean monthly temperatures (° C) for two weather stations in the intensive study area with an altitudinal difference of approximately 300 feet (100 m)

Month	*Maximum temperature*		*Minimum temperature*		*Daily range*	
	Upper station	Lower station	Upper station	Lower station	Upper station	Lower station
January	34,6	32,9	19,5	19,6	15,1	13,3
February	32,5	29,8	18,0	17,6	14,5	12;2
March	34,3	32,1	16,4	15,5	17,9	16,6
April	33,6	32,7	15,4	14,1	18,2	18,6
May	28,6	27,9	10,9	9,6	17,7	18,3
June	24,0	24,0	9,5	3,1	14,5	21,3
July	25,5	25,9	12,0	4,6	13,5	21,3
August	28,5	29,0	12,5	10,3	16,0	18,7
September . . .	34,4	31,1	16,1	11,7	18,3	19,4
October	39,2	36,4	18,8	16,8	20,4	19,6
November . . .	38,8	35,8	19,9	18,7	18,9	17,1
December . . .	36,2	32,8	18,1	19,8	18,1	13,0
Annual . .	32,5	30,9	15,6	13,5	16,9	17,5

Table 11.—Mean monthly rainfall (mm) for two weather stations in the intensive study area and at the project headquarters near Kasane

Month	Upper station	Lower station	Project headquarters camp	Study period average
January	53,3	53,2	40,6	49,0
February	58,4	48,3	12,7	39,9
March	45,7	50,8	30,0	42,1
April	17,8	22,9	30,5	23,7
May	0,0	0,0	0,0	0,0
June	0,0	0,0	0,0	0,0
July	0,0	0,0	0,0	0,0
August	0,0	0,0	0,0	0,0
September	Trace	10,2	5,1	5,1
October	30,5	22,7	30,0	27,7
November	132,1	99,1	65,0	98,7
December	256,5	280,2	342,9	293,2
Annual total	594,3	587,4	556,8	579,4

Table 12.—Seasonal changes in lateral cover of five major habitats based on bi-monthly visibility evaluations along the intensive study area census routes over 12 months. Mean distances in meters

Month	RFF	RATS	DTH	C/BS	MEC	Overall for I.S.A.
February	9,63	7,53	5,88	6,64	6,58	7,04
April	12,65	13,59	8,59	8,02	9,24	11,49
June	16,25	13,32	10,52	10,85	12,04	12,01
August	17,68	13,75	11,22	13,62	12,83	12,83
October	20,51	21,52	15,79	18,11	21,88	19,35
December	14,11	10,27	7,01	7,56	9,20	9,60
Annual average	15,64	13,96	10,42	12,44	13,53	12,95
Sample size	60	660	317	180	127	1 344