THE STATUS AND TRENDS IN THE VEGETATION TYPES AND THE EFFECTS OF PERIODIC FLOODING ON THESE TYPES

The most critical vegetation types in the Okavango Delta are those which are dependent on a varying annual period of inundation and a high water table, viz. the floodplain and riverine vegetation types. The regularity of inundation, the duration it occurs for and the pattern it assumes varies from year to year, being dependent on local Delta rainfall quantity, floodwater quantity from Angola, vegetation friction and obstruction to water flow (and thus burning of aquatic and floodplain vegetation types) and any alterations in local Delta base levels. The annual alteration and interaction of these above parameters almost assures that no two flood seasons produce the same regularity, duration or pattern of flooding over the Delta.

A massive alteration in water distribution down to the Delta will affect the distribution of the aquatic vegetation types, since these plant communities are dependent on water throughout the year. Some can however tolerate short periods of absence of surface water in dry seasons. The floodplain communities are determined to be the most sensitive to change in altering flood regimes, and as such are dealt with in more detail. The riverine vegetation types are somewhat less sensitive to change being able to endure poor flood seasons for a longer period than the floodplain vegetation types. The marginal vegetation types are even less sensitive to change than the riverine vegetation types, and appear to be expanding in distribution up the Delta. Similarly the dryland vegetation types are expanding in distribution, but their expansion is curtailed to some degree by years of excessive floods when old drainage courses and old floodplain systems, which due to the sustained absence of surface water, and a low water table, were colonised by dryland woody species, and then are suddenly reinundated.

Methods

No quantitative assessment of aquatic vegetation types' status or trend was attempted due to the lack of methodology, the difficult working conditions or the time being available to carry out such fieldwork. Some floodplain, riverine, marginal and dryland vegetation types are assessed for status using a joint combination of the "Point-centred quarter method" (Cottam, Curtis and Hale 1953), the "Step-point method" (Evans and Love, 1957) with modifications by Riney (1963) and the "Concentric-circle method" devised by Havenga (1967, In Grunow, 1971). In sampling woody vegetation strata a combination of all methods was used, whilst the "Concentric-circle method" (CCM) was omitted when sampling vegetation types comprising a herbaceous stratum only. In some instances of sampling herbaceous strata the "Point-centred quarter method" (PCQM) was also omitted due to the time factor involved. In the "Step-point method" 100 points were sampled at 1 m intervals for herbaceous and/or woody vegetation. Along this transect eight random points (selected from random number tables) were sampled via the P.C.Q.M. (for woody and herbaceous vegetation) and/or C.C.M. (for woody vegetation only). A series of such parallel transects were conducted 100 m apart, the total number depending on the extent of the vegetation community being sampled. The ratio of radii used for the CCM was 1 : 10 m. "Nearest species method" of density was calculated from the nearest individual to a strike on the "Step-point method", this being expressed as a percentage of the overall total of points sampled. Each point sampled was visually checked for grazing records of herbaceous plants. The number of grazed samples around a 0,5 m radius with sample point as centre were then expressed as a percentage of the total number of points sampled. Importance value is obtained from the average of relative percentage frequency, density and dominance.

Average densities were obtained by the following formulae for each method:

PCQM: Average density $= \frac{\text{No of square units of measure}}{M}$

where M = average distance from sampling point to nearest species in each quarter. (measured in cm for herbaceous vegetation and in m for woody vegetation)

m $= \frac{\text{sum of all distances}}{\text{number of nearest species sampled.}}$

CCM: $n = C(Y_2^{\frac{1}{2}} - Y_1^{\frac{1}{2}})^2$

where n = number of plants over area sampled

$C = d^2/_\pi (X_2 - X_1)^2$

Y_1 = number of plants contained in small circle

Y_2 = number of plants contained in large circle

X_1 = Radius of small circle

X_2 = Radius of large circle

where $\frac{X_2}{X_1} \geqslant 8$

$d^2 = \frac{\text{Total area}}{N}$

N = total number of sample points

From obtaining n convert by simple proportion to the unit of a hectare.

Quadrat method:

Average density = Total number of woody species in all large circles per total area of large circles and this converted to the unit of a hectare.

Conservation trend percentages (conservation trends) are based on Riney (1963), a somewhat subjective assessment based on amount of annual versus perennial grass cover, amount of bare ground, amount of litter, encroachment of undesirable plant species in that community, amount of erosion pedestal and the evolution pattern of the plot. The plot size chosen was approximately one two-thousandth of a hectare. All transects, with the exception of a series conducted on primary floodplain in the lower Delta, were conducted in the study area. However, visual comparisons are made with any of the numerous areas covered throughout the Delta during the course of other fieldwork.

Aquatic vegetation types

Thompson (1975) deals independently with the major aquatic vegetation species of the Okavango Delta, their physical and chemical water requirements and the possible effects of some alterations of flow or the introduction of some undesirable aquatic vegetation species can be deduced from his work. Since no quantitative work was conducted in aquatic vegetation types, this work will only give general status and possible trends of these communities.

Filter Communities

Filter Communities are all situated in the upper section of the Delta and as such are not subject to the extremes of flood conditions affecting the seasonal swamps. Water levels fluctuate to a small degree (0,12 m) in the adjacent river at gauge posts, but since levels appear to be lower away from the river (Jeffares, 1938), the fluctuation in water levels may be greater. The Filter Communities as such appear to be relatively stable and subject to little or no vegetation compositional change.

However, studying the aerial photographs of this section of the Delta shows a maze of ancient upper channels which have existed during the evolution of the Delta. This may well be tied up with the period of development of the Nqogha River according to haMbukushu native legend. Large scale faulting which is possible in this upper-Delta section (Scholtz *et al.* 1975) may well alter the position and distribution of present filter communities.

Middle Channel Communities

Middle Channel Communities are situated in the perennial swamps and are relatively stable to vegetation changes. However, during the Delta's evolution changes have occurred in some of these channels. Notably the Moanachira River has evolved from an upper channel to a middle channel (Wilson, 1974), and the M'borogha River carried a far greater discharge during the first half of this century as is evident from the high banks of islands adjacent to the M'borogha River channel and the major discharge of its distributaries. The consolidation of the Nqogha blockage is the primary reason for loss of discharge down the M'borogha River. The upper Boro River after the 1950's is carrying an increased discharge of water.

Continual evolution towards a decreased discharge down the M'borogha River will allow for the eventual domination of aquatic vegetation species leading to the formation of surface blockages and possibly consolidated blockages in this system. (Fig. 14). This could have far reaching effects on the ecology of southern Moremi Wildlife Reserve, Chitabe controlled hunting area and human habitation of the lower Santantadibe River.

Outlet Channel Communities

Outlet Channel Communities are located in the seasonal swamps and are subject to large scale discharge and thus vegetational changes. Ever since some form of discharge documentation has been recorded the main outlet channel discharge has varied. During the 1920's and 1930's the Gomoti River provided the bulk discharge from the Delta. Round about the 1950's the Santantadibe River filled this role, whilst from the late 1960's and till the

FIGURE 14 – Surface blockage of floating debris with sedges established further back along blocked Outlet Channel Community. Headwaters of Xudum River in the Xho Flats vicinity, Okavango Delta, Botswana.

present day the Boro River now delivers the bulk of the Delta's discharge. The redistribution of discharge water is thus a characteristic function of the Delta caused by natural phenomena and human factors occurring either independently or in conjunction with one another.

The result is that in the absence of man-manipulated control certain outlet channels are evolving towards closure, consolidation and eventual dying of those systems. However, the instability of the whole system allows for reflooding of any of these systems but invariably in an altered flooding pattern.

Madiba Communities

Madiba Communities seem relatively stable and are well represented in the upper-Delta and reasonably well in the northeastern central and lower-Delta sectors. The reason for the maintenance of these open surface water bodies is tied up with water depth and large animal utilisation. In the absence of the above two factors the madiba should evolve towards aquatic vegetation closure and thus the death of madiba as they exist today. Hippopotamus are considered to play a significant role in maintaining madiba; especially those madiba of more critical shallower depth. This will explain the persistence of madiba where hippopotamus are more stringently protected, or are less accessible to be destroyed and where water depth is a critical factor, viz. Dombo lediba on the Khwai River.

Flats Communities

Flats Communities appear to be relatively stable but those flats located in the seasonal swamps or at the junction of seasonal and perennial swamps have total or marginal areas subject to dessication for parts of poor flood years. This enables establishment of termitaria to occur leading to a higher ratio of localised, high, dry levels at the expense of the flooded flats. These termitaria are part of flats habitat which combined form a parkland vegetation type; the termitaria being significantly important areas utilised by both sitatunga *(Tragelaphus spekei)* and red lechwe.

Large-scale establishment of termitaria and their subsequent erosion and "linking up" leads to small island formation which if continuously in operation will lead to the change of this vegetation community.

Shallow Backwater Communities

Shallow Backwater Communities are well represented in the middle and lower perennial swamps. Their continued existence is dependent on surface inundation for the greater portion of any year. Since surface drying-out occurs during part of poor flood years, these areas are also subject to termitaria establishment and termitaria evolution. Being the first of the aquatic communities to dry out, termitaria play their largest role in Shallow Backwater Communities. These termitaria, whether colonised by woody vegetation or whether forming only a slightly elevated disc covered by lawn-like grass, are important to the ecology of sitatunga and red lechwe, and though ultimately the termitaria may play a role in the alteration of inundation patterns, they must be considered as part of the natural evolution of the Delta system.

Sump Communities

Sump Communities are well represented in the perennial swamps mainly as a mosaic in the depressed areas of the Shallow Backwater Communities. (Fig. 15). Since they are lower-lying areas surface water seldom dries up except undet extremely dry conditions. Provided no large scale change of flooding pattern takes place these communities are subject to little change. If localised inundation patterns change these areas are likely to develop to pan depressions surrounded by dryland vegetation types if island closure takes place around them.

Floodplain vegetation types

Primary Floodplain Communities

Insufficient sampling was conducted in this community due to the extreme flood conditions experienced from early 1974 till the termination of field work (November 1974) in this area of the Delta. Primary Floodplain Communities of the mid-Delta are dominated by sedges of *Scirpus inclinatus* and *Cyperus* spp. and the forb *Alternanthera sessilis* (Table 5, Fig. 16). Relative densities obtained from the "Point-centred quarter method" and "nearest species" are in good agreement. Herbaceous plant density for this community from the "step-point method" gave 70,26 plants/m^2 in the lower-Delta and 247,03 plants/m^2 in the mid-Delta areas (Table 6). The lower-Delta Primary Floodplain Community which was sampled had probably been receiving a below average period of flooding for the previous three years, whereas the mid-Delta community was inundated for more regular periods annually.

FIGURE 15 – Sump Community adjacent to Shallow Backwater Community, Boro floodplains, Okavango Delta, Botswana.

Table 5 – Importance values and Density Comparisons from the "Poincentred quarter Method" and the "Nearest species Method" for Herbaceous Vegetation in a primary floodplain situated off the lower Boro River, Okavango Delta, Botswana, 1973.

SPECIES	RELATIVE PERCENTAGE FREQUENCY	RELATIVE PERCENTAGE DENSITY	RELATIVE PERCENTAGE DENSITY FROM NEAREST SPP.	RELATIVE PERCENTAGE DOMINANCE	IMPORTANCE VALUE
Scirpus inclinatus	37,50	45,31	40,0	64,74	49,18
Alternanthera sessilis	25,00	23,44	17,0	8,96	19,13
Cyperus articulatus	21,87	20,31	26,0	8,96	17,05
Ludwigia octovalis	6,24	4,69	9,0	5,18	5,38
Cyperus denudatus	3,13	1,56	1,0	8,96	4,55
Unidentifie forb.	3,13	3,12	4,0	2,56	2,94
Unidentified grass	3,13	1,57	1,0	0,64	1,77
Echinocloa stagnina	0,0	0,0	2,0	0,0	0,0

FIGURE 16 – Dry Primary Floodplain Community with Closed Riverine Woodland in background, the former heavily utilised by red lechwe, Khwai River floodplain, Okavango Delta, Botswana.

Table 6 – Comparison of REGULARLY INUNDATED MID-DELTA and POORLY INUNDATED LOWER DELTA Primary Floodplain Communities (for some Riney 1963 conservation trend criteria) of the Boro River Floodplain system, Okavango Delta, Botswana 1973/74.

LOCALITY	FLOODING PATTERN	HERBACEOUS VEGETATION DENSITY	BARE GROUND PERCENTAGE		LITTER STRIKE PERCENTAGE	CANOPY PERCENTAGE	PLANT STRIKE PERCENTAGE	CONSERVATION TREND PERCENTAGE		
			Riney	Actual				Downgrading	Stable	Upgrading
Mid-Delta	Regular and good	247,03	84	21	63	74	16	0	80	20
Lower-Delta	Irregular and poor	70,26	97	86	11	48	3	25,0	56,25	18,75

The conservation trend percentages show the majority of plots assessed as stable for both mid (80 per cent) and lower-Delta (56,25 per cent) areas. However, the lower-Delta area showed 25 per cent of plots downgrading as against none downgrading in the mid-Delta communities where more sustained flooding is evident (Table 6). During 1972/73 (a very dry season) mid-Delta Primary Floodplain Communities were dry for seven months of the season, whereas during 1974/75 (an extremely wet season) these same floodplains were inundated throughout the season. The lower-Delta Primary Floodplain Communities by comparison were dry for nine to ten months of the 1972/73 season and inundated for ten to 12 months during 1974/75. The average duration of flooding in Primary Floodplain Communities should be from eight to ten months per season, during which time they serve primarily as lechwe habitat in the seasonal swamps. As Primary Floodplain Communities dry out after the winter floods they are utilised extremely heavily by a variety of large mammals. At this period they form the only non aquatic vegetation type green grazing available until the summer rains commence and fresh growth appears in the riverine, marginal and dryland herbaceous layers. If these summer rains are well below average (510 mm) following a poor flood season, the Primary Floodplain Communities are subjected to a long, dry period. In such instances these Primary Floodplain Communities are over-utilised. As dessication proceeds, the feed value of this community becomes very low and the main utilisation is from the subsurface component, viz. bulbs, tubers and rhizomes being rooted up and utilised by warthog *(Phacochoerus aethiopicus sundevalli).* Baboon *(Papio ursinus ngamiensis)* follow up the warthog, often feeding in close unison with the latter also utilising this uprooted subsurface vegetation component. When the water table has dropped sufficiently, Damara mole-rats *(Cryptomys damarensis)* move into these Primary Floodplain Communities, establish their burrows and feed on the subsurface vegetation component.

No marked erosion pedestal was detected on any of these Primary Floodplain Communities. The average depth of inundation is about 1,2 m at the lowest point in a Primary Floodplain Community but the range varies from 0,6 to 1,8 m at this lowest point and from 0,01 to 0,4 m at the verges.

Secondary Floodplain Communities

Twenty four transects were conducted in the Secondary Floodplain Communities during 1973. These were divided into three groups according to their flooding pattern and water table position during 1973. The first group was partially flooded, the second group not flooded but with a high water table and the third group not flooded and with a lower water table (Table 7, Figs. 17 and 18). All the Secondary Floodplain Communities sampled were in the mid-Boro River seasonal swamps to the west of Chief's Island and in the study area.

All the Secondary Floodplain Communities support an open grassland, but the herbaceous plant density and composition vary in accordance with flooding frequency, flooding duration and mammalian utilisation (Tables 7 and 8). The factors of prime importance are the lower local base levels and the position of the Secondary Floodplain Communities in relation to receiving inundation in poor flood seasons; or the maintenance of a relatively high or low water table. Secondary Floodplain Communities favourably located with regard to regular surface inundation or high water table show a healthier status and trend, whereas those not regularly inundated and with a low water table show a series of degrading trends (Table 7).

The density of herbaceous vegetation in the Secondary Floodplain Communities under different floodwater and water table regimes (Table 7) are different. Those Secondary Floodplain Communities showing the higher density are either located higher up in the mid-Boro River floodplains; or those lower down, closer to the Boro River itself when compared with the Secondary Floodplain Communities of lower density. The secondary Floodplain Communities of lowest herbaceous plant density are in general closest to the southwestern margins of Chief's Island; and it is in these communities that more forbs (both species and individual plants) are present, (Table 7); overutilisation is taking place and the beginning stages of bush encroachment from the verges are evident.

Table 8 compares the herbaceous vegetation components in order of relative density and importance value for the more regularly inundated Secondary Floodplain Communities with high water table. The herbaceous species composition was impossible to determine in the badly degraded floodplain as these areas were held in a short-cropped state by mammalian overutilisation.but comparative percentage composition of herbaceous species is provided in Table 7. The composition of the two Secondary Floodplain Communities under different flood regime and water table shows good comparison except that the two sub-dominant grasses differ and that forbs are starting to appear in the mid study area. Table 7 shows the increase in forb composition for non flooded, low water table Secondary Floodplain Community.

Table 7 – Comparison of three classes of Secondary Floodplain Communities (based on flooding conditions and available water) for utilisation, herbaceous plant density, herbaceous plant growth form composition and conservation trend percentage and situated in the mid-Boro River floodplains, Okavango Delta, Botswana, 1973.

1973 FLOOD CONDITIONS	GRAZING PERCENTAGE FROM SAMPLE PLOTS	DENSITY OF HERBACEOUS PLANTS PER SQUARE METRE	HERBACEOUS PLANT GROWTH FORM COMPOSITION			GRASS CONPOSITION		CONSERVATION TREND PERCENTAGE		
			Grasses	Sedges	Forbs	Annual	Perennial	Downgrading	Stable	Upgrading
Flooded some parially	77,33	220,00	85,17	14,	0,00	18,17	81,83	3,33	70,00	26,67
None flooded high water table	95,00	84,03	80,65	18,18	1,17	20,33	79,67	6,67	76,67	16,
Flooded none low water table	99,33	46,25	68,33	5,00	26,67	43,17	56,83	40,00	46,67	13,33

FIGURE 17 – Secondary Floodplain Community well inundated during 1974, but not inundated during 1973, Mid-Boro River floodplain, Okavango Delta, Botswana.

FIGURE 18 – Dry, downgraded, overutilised Secondary Floodplain Community, not receiving sufficient annual surface inundation, lower Boro River floodplain, Okavango Delta, Botswana.

Table 8 – Comparison of two Secondary Floodplain Communities from the Mid-Boro River floodplain, (the mid-study area Secondary Floodplain Community receiving less regular flooding and having a slightly lower water table than the upper-study area Secondary Floodplain Community) Okavango Delta, Botswana, 1973, for herbaceous species composition, relative density and importance value.

HERBACEOUS SPECIES	RELATIVE DENSITY		IMPORTANCE VALUE	
	Mid study area	Upper study area	Mid study area	Upper study area
Eragrostis lappula var. *divaricata*	32,50	45,00	34,88	45,12
Brachiaria humidicola	26,88	0,00	24,18	0,00
Cynodon dactylon	0,00	21,88	0,00	17,49
Eragrostis lappula var. *lappula*	10,63	10,00	12,24	11,96
Cyperus denudatus var. *sphacrospermus*	14,38	5,00	11,39	4,79
Setaria woodii	1,25	4,38	1,77	6,65
Panicum repens	0,63	5,63	0,73	5,86
Trachypogon spicatus	1,25	0,00	3,26	0,00
Eragrostis lehmanniana	3,13	3,13	3,23	2,83
Nicolasia costata	3,13	0,00	2,44	0,00
Bulbostylis burchelli	2,50	1,25	2,27	1,30
Cyperus longus	1,88	1,88	1,86	1,65
Panicum aphononeurum	1,25	0,63	1,19	1,04
Imperata cylindrica	0,00	0,63	0,00	0,65
Setaria sphacelata	0,00	0,63	0,00	0,65
Sphaeranthus humilis	0,63	0,00	0,57	0,00

Frequency and duration of flooding in conjunction with the dry time period which Secondary Floodplain Communities are available for animal utilisation, play an important role in their vegetation composition and trend. (Table 7).

The conservation trends in Secondary Floodplain Communities show a marked downgrading tendency in those communities receiving insufficient water and the best upgrading tendency is in those most regularly inundated (Table 7). Clearly a series of Secondary Floodplain Communities exist which vary in vegetation composition, density, trend and mammalian utilisation, all as a function of available water. During consecutive years of poor flood regimes the higher lying Secondary Floodplain Communities are subject to overutilisation by mammals, establishment of termitaria occurs, annual grasses increase and woody vegetation encroaches from the adjacent islands and also establishes itself on dead termitaria. The higher base levels established by termitaria are semi-permanent and contribute to the formation of islands. When the flooding cycle peaks in high floods and substantially inundates these above dessicated areas, it serves to re-establish conditions in certain instances, viz. some encroaching woody and forb vegetation species sensitive to surface flooding or a high water table, are killed. Also a period of rest and sufficient moisture allow for some recovery of this overutilised Secondary Floodplain Community. In some instances the development and erosion of termitaria may close off surface flooding access, and here the evolution of the old Secondary Floodplain Community will lead to one of the dryland communities supported by a sandy substratum. If this closure to surface flooding also affects Primary Floodplain Communities and they no longer receive floodwater inundation the evolution is towards a woody vegetation type supported by clay soils, viz. *Colophospermum mopane* woodland or *Acacia tortilis* savanna woodland.

During the 1973/74 season Secondary Floodplain Communities were inundated for a period of up to 9 months, but more generally for about 7 months. This period of inundation is abnormally long for this community and if continued seasonally would alter the herbaceous composition more towards that of a Primary Floodplain Community. The 1974/75 flood levels were also excessively high. These two seasons have served to kill some water sensitive woody and herbaceous plant encroachers onto Secondary Floodplain Communities, and provide adequate rest from mammalian overutilisation. Consequently an improvement in their conservation trend should thus result. In some central Secondary Floodplain Communities of the eastern floodplains, these two successive high flood years did not produce this excessive flooding of these communities. (Fig. 19). The overall situation of a largely altered flood pattern on parts of this eastern sector assures the evolution of these Secondary Flood-

FIGURE 19 – Secondary Floodplain Communities in the mid-M'borogha River floodplains no longer receiving surface inundation even in years of excessive high water levels (1974), Okavango Delta, Botswana.

plain Communities towards one of the dryland sandveld communities, unless further water flow changes occur and proper flooding results. (Fig. 20). A slight erosion pedestal exists on some of the more downgraded Secondary Floodplain Communities. Under extreme flood conditions these Secondary Floodplain Communities are inundated to a depth of 1 m, but more average conditions produce an inundation depth of 0,2 to 0,3 m or less.

Sporobolus spicatus Island Grassland Communities

During 1974, five transects were conducted in the study area on *Sporobolus spicatus* Island Grassland Communities of the seasonal swamps on the Boro River floodplain. The average density of herbaceous plant species is 269,54 plants/m^2 for the areas sampled. Table 9 lists the herbaceous vegetation species in order of importance values and relative density.

The trends in conservation values show the highest proportion of plots sampled as stable, but with more plots showing a downgrading than an upgrading tendency. *Sporobolus spicatus* Island Grassland Community is another floodplain vegetation community which is subject to no surface flooding in poor flood years. Flooding of island grassland communities of the perennial swamps varies between 0,01 and 0,4 m but the water table associated here is high. In the seasonal swamp these communities flooding varies between 0,01 and 0,3 m with a much lower water table and an average tendency to only slight surface inundation. In poor flood years no surface inundation occurs.

Due to the *Sporobolus spicatus* Island Grassland Communities occurring adjacent to higher lying island soils the establishment of termitaria is a constant factor operating and causing the evolution of Island Grassland Communities to proceed towards marginal or dryland vegetation types. *Sporobolus spicatus* Island Grassland Communities occur initially and usually on the off channel margins of some islands where a gentle ground slope gradient exists and no sharp altern occurs between aquatic vegetation margins and Closed Riverine Woodland. As these islands enlarge by the linking up of adjacent termitaria via erosion the riverine woodland tends to encircle the *Sporobolus spicatus* Island Grassland Community leading to a process termed island closure. When this occurs the encircled Island Grassland Community is cut off from normal surface flooding and can only be inundated by excessive local rainfall or by a rising water table. Once complete island closure has occurred the

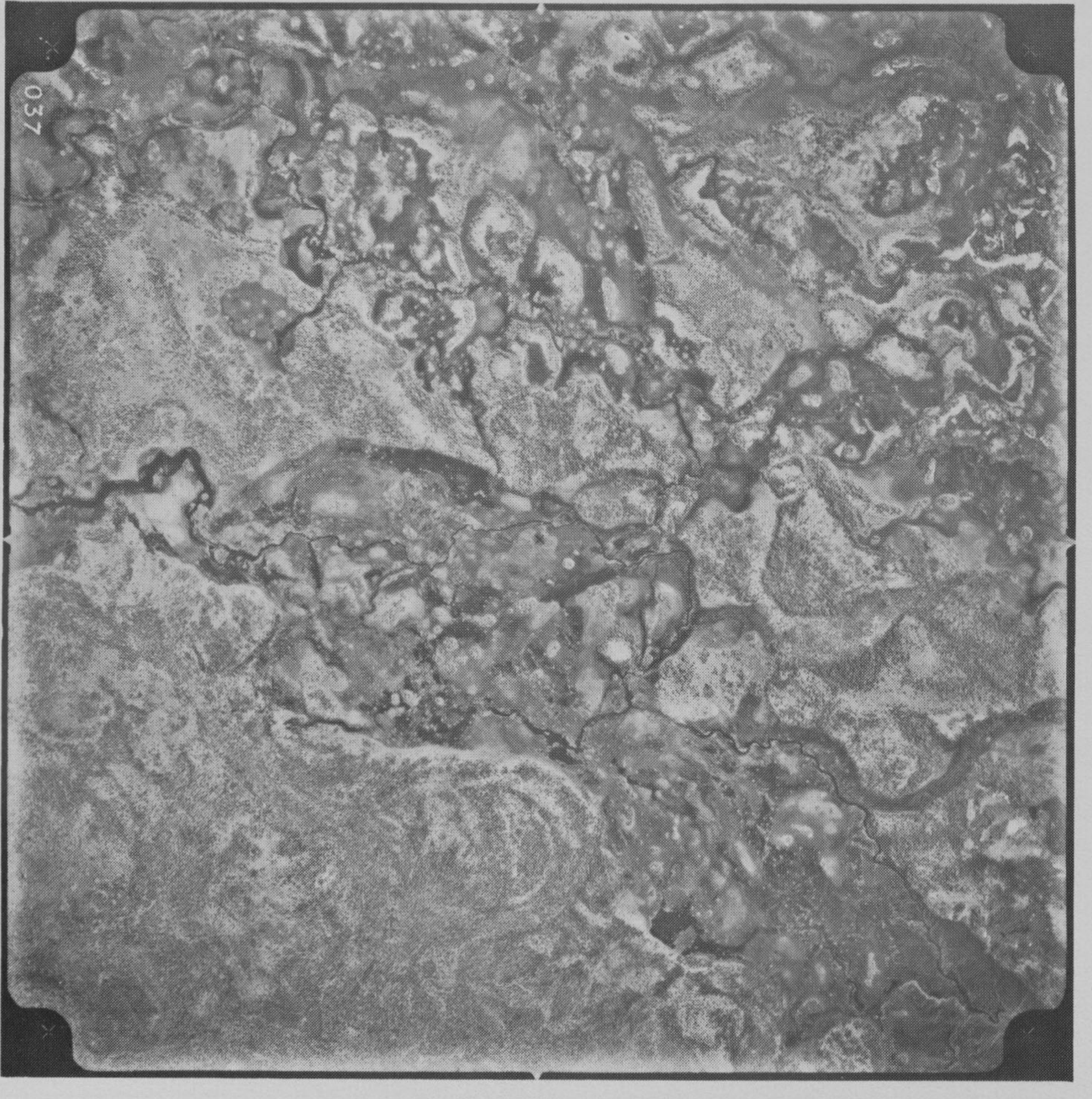

FIGURE 20 – Expansion of dryland vegetation types at the expense of floodplain vegetation types (to left and right of centre of figure) on remnants of the old Nambope River floodplain, Okavango Delta, Botswana. Note lower left hand corner of figure shows part of the north-eastern margin of Chief's Island.

Table 9 – List of herbacious plants species in order of importance value and giving relative density for *Sporobolus spicatus* Island Grassland Communities of the Mid-Boro River Floodplain, Okavango Delta, Botswana, 1974

HERBACEOUS PLANT SPECIES	RELATIVE DENSITY	IMPORTANCE VALUE
Sporobolus spicatus	29,38	28,24
Cynodon dactylon	24,38	24,30
Eragrostis cilianensis	17,50	19,35
Hermania modesta	5,00	4,91
Hirpicium gorteroides	5,00	4,48
Cyperus fulgens	3,13	4,18
Eragrostis viscosa	3,75	3,71
Chloris virgata	3,13	2,75
Cleome rubella	2,50	2,46
Pluchea leubnitziae	1,88	1,98
Aristida argentea	1,25	1,34
Unidentified forb	1,88	1,30
Setaria verticillata	1,25	1,01

central core of Island Grassland Community evolves towards a marginal or dryland vegetation type. All islands of the Delta are in varying stages of evolution, but they are all still subject to alteration and enlargement via termitaria. The encroachment of *Pluchea leubnitziae* from the verges centripitally is a manifestation of the drying-out conditions since from personal observation this herbaceous species cannot tolerate surface flooding or an extremely high water table. As base levels build up and dessication proceeds further, more forb and woody vegetation species encroach onto the Island Grassland Community changing the species composition. These Island Grassland Communities are important red lechwe habitat, whose numbers will probably diminish as this habitat type diminishes.

Riverine vegetation types

Closed Riverine Woodland

Where water tables are high and surface water is in close proximity the Closed Riverine Woodlands are best developed, viz. adjacent to some madiba and some perennial channels. Five transects conducted during May 1974 in this community gave an average tree density of 691,56 trees/ha from PCQM as against 751,56 trees/ha from the "Quadrat method". If shrubs and seedling trees are added the average woody vegetation density ranged from 1463,98 woody plants/ha from the "quadrat method" to 1584,95 woody plants/ha from CCM (Table 10). The average herbaceous plant on density from PCQM is 29,65 plants/m^2 below the tree canopies. (Table 11). Tables 12 and 13 list plant species in order of importance value for woody and herbaceous species respectively. The two sites sampled were along the Boro River verge.

Conservation trends in the Closed Riverine Woodland were either stable or upgrading but since all sampled sites were in favourable high water table conditions this is to be expected. Where water table conditions were not so high, the Closed Riverine Woodland was visually less well developed and was visually downgrading in the least favourable localities. The 1974 and 1975 flood patterns will improve these conditions due to the substantially raised water table during these years. Some woody species located on the lowest-lying areas of Closed Riverine Woodland have their stem bases inundated during parts of seasons of extreme high water levels, but remain unaffected except for isolated specimens of *Acacia erioloba* which die under waterlogged conditions. The well developed Closed Riverine Woodland along the islands adjacent to the M'borogha River is a function of the previous existing flow down this

Table 10 – Comparison of average densities (per hectare) based on the "Point-centred quarter method", "Quadrat method" and the "Concentric circle method" of various woody vegetation communities in the study area, Okavango Delta, Botswana, 1973/74.

VEGETATION COMMUNITY	POINT-CENTRED QUARTER METHOD	QUADRAT METHOD			CONCENTRIC CIRCLE METHOD
		Trees	Shrubs and tree seedlings	Total woody species	Woody species
Closed riverine woodland	691,56 trees	751,56	712,42	1463,98	1584,95
Hyphaene ventricosa - Croton megalobotrys palm woodland	973,71 woody species	600,86	716,34	1317,20	1326,60
Combretum inberbe - Croton megalobotrys woodland	202,92 woody species	84,55	90,81	175,36	163,96
Acacia erioloba woodland savanna woodland	48,65 trees	54,80	292,80	347,60	278,43
Colophospermum mopane woodland	462,75	549,97	80,25	630,22	649,88
Colophospermum mopane scrub savanna	2583,98 woody species	1753,65	1914,14	3667,79	3808,63
Grewia species - Croton megalobotrys scrub savanna	490,44 woody species	191,81	471,68	663,49	614,00

Note: Trees ⩾ 2 m   Shrubs < 2 m   Woody species = Trees plus shrub plus treeseedings

Table 11 – *Comparison of the herbaceous layer vegetation average densities (plants per square metre) using the "Point-centred Quarter Method",* and composition from "nearest species" for various plant communities sampled in the Okavango Delta Botswana 1973/74.

PLANT COMMUNITY	"POINT-CENTRED QUARTER METHOD" AVERAGE DENSITY	GROWTH FORM COMPOSITION FROM "NEAREST SPECIES"			
		Grass	Forb	Sedge	Woody Seedling or Shrub
Primary Floodplain	158,65	32,50	15,00	52,50	0,00
Secondary Floodplain	116,76	78,05	9,28	12,67	0,00
Sporobolus specatus Island Grassland	269,54	83,60	15,20	1,20	0,00
Closed Riverine Woodland	29,65	16,00	76,00	0,00	8,00
Hyphaene ventricosa - Croton megalobotrys Palm Woodland and Palm Savanne Woodland	43,45	66,00	31,00	0,00	3,00
Combretum imberbe - Croton megalobotrys Woodland and Savanna Woodland	0,00	71,00	28,00	0,00	1,00
Acacia erioloba Woodland and Savanna Woodland	18,54	82,00	6,20	10,80	1,00
Colophospermum mopane Woodland	16,88	46,30	53,10	0,00	0,60
Colophospermum mopane Pyrophytic Scrub Savanna	66,81	68,75	30,00	1,25	0,00
Grewia species - Croton megalobotrys Scrub Savanna	125,61	76,00	21,50	0,00	2,50

Table 12 – List of woody etc. species in order of importance value for Closed Riverine Woodland method by "Point-centred quarter method" and "Quadrat method" adjacent to the Boro River, Okavango Delta, Botswana 1974.

WOODY PLANT SPECIES	IMPORTANCE VALUE
Diospyros mespiliformis	*30,95*
Croton megalabotrys	*26,52*
Hyphaene ventricosa	*13,03*
Berchemia discolor	*9,71*
Euclea crispa	*5,06*
Kigelia africana	*5,00*
Garcinia livingstonei	*4,77*
Grewia schinzii	*2,48*
Lonchocarpus capassa	*2,47*

Table 13 – List of herbaceous etc. species in order of importance value for Closed Riverine Woodland by "Point-centred quarter method" and "Quadrat method." adjacent to the Boro River, Okavango Delta Botswana 1974.

HERBACEOUS SPECIES	IMPORTANCE VALUE
Achyranthus sicula	21,60
Setaria verticillata	17,40
Commicarpus africana	12,00
Celosia trigyna	12,00
Abutilon romosum	8,60
Sporobolus fimbriatus	7,50
Dicliptera micranthes	6,70
Cynodon dactylon	5,40
Seedling trees	5,40
Leptocarydion vulpiastrum	3,40

Middle Channel before the development of the Nqogha blockage when this channel still carried a greater water discharge. Should the discharge down the M'borogha River decrease further, degrading of this community can be expected. Conversely the Boro River is now carrying an increased discharge resulting in a higher water table in this area over earlier years and more luxuriant Closed Riverine Woodland is expected to develop there (See Past water regime 1849 – 1968 p. 224).

Phoenix reclinata – Syzygium spp. Termitaria

No quantitative work was conducted on *Phoenix reclinata – Syzygium* spp. Termitaria. Normally this community is well established on old termitaria surrounded by well-inundated lowerlying floodplains in Flats or Shallow Backwater Communities of the upper and mid-Delta. The almost complete absence of this community on the upper and middle M'borogha and Nambope floodplain systems remains a mystery, whilst the same community persists down parts of the dessicated ancient floodplains of the lower Thago River system (Smith **pers. comm.**). The occurrance of *Phoenix reclinata* and *Syzygium* spp. on the lower Thaoge River floodplain is a manifestation of earlier flood regimes when the bulk of water was flowing towards Lake Ngami (Stigand, 1923) and *Phoenix reclinata* thus seems able to resist sustained periods of dessication. The water table level is not known in this area, but possibly it is still relatively high and thus maintains this community; but not under optimum conditions. Under optimum conditions the water table is consistently high and surface water usually laps or floods the woody species stem bases during the high-flood months.

Marginal vegetation types

Acacia nigrescens – Croton megalobotrys
Woodland and Savanna Woodland

No quantitative work was conducted in the *Acacia nigrescens – Croton megalobotrys* Woodland and Savanna Woodland Communities. The stands of this community are common on most islands but the stands are not extensive and are nowhere developed in the study area to the extent found on the lower Khwai River margins.

The areas of occurrence of *Acacia nigrescens – Croton megalobotrys* Woodland or Savanna Woodland Communities appear to be on ancient floodplains, now raised above present flood levels and no longer subject to surface inundation. As island size increases so does this community and the *Hyphaene ventricosa – Croton megalobotrys* Palm Woodland and Palm Savanna Woodland are expected to increase slightly in extent and distribution.

Hyphaene ventricosa – Croton megalobotrys
Palm Woodland and Palm Savanna Woodland

Hyphaene ventricosa – Croton megalobotrys Palm Woodland and Palm Savanna Woodland Communities are common in the central and lower Islands of the study area as well as in general in the mid and lower areas of the Delta. Four transects conducted in these communities, during June 1974, using the "Point-centred quarter method", provided an average density in the woody stratum of 973,71 woody spp/ha (Table 10) and in the herbaceous stratum of 43,45 plants/m^2 (Table 11). The density sampling conducted via the "concentric circle method" provided much higher density estimates per unit area (Table 10), but these are not accepted since this sampling method is unsuitable in these woody vegetation strata of the Okavango Delta (*Grunow pers. comm.). The woody species in order of importance value are *Hyphaene ventricosa* (68,93), *Croton megalobotrys* (29,12) and *Ziziphus mucronata* (1,95) and in Table 14 the herbaceous species are represented in order of importance value for this community.

Table 14. List of herbaceous layer species in order of importance value and relative percentage density from "Nearest Species" for *Hyphaene ventricosa – Croton megalobotrys* Palm Woodland and Palm Savanna Woodland sampled adjacent to the Boro River Okavango Delta Botswana 1974

VEGETATION SPECIES	IMPORTANCE VALUE	"NEAREST SPECIES" RELATIVE DENSITY
Setaria verticillata	37,78	37,0
Sporobolus fimbriatus	14,93	14,0
Achyranthus sicula	13,78	15,0
Canodon dactylon	10,79	8,0
Unidentified forbs	8,11	7,0
Celosia trigyne	7,59	3,0
Commicarpus africanus	4,22	2,0
Abutilon ramosum	2,78	0,0
Leptocarydion vulpiastrum	0,00	6,0
Solanum spp.	0,00	4,0
Hyphaene ventricosa seedling	0,00	3,0
Aristida argentea	0,00	1,0

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The conservation trend in the *Hyphaene ventricosa – Croton megalobotrys* Palm Woodland Communities shows 81,25 per cent of plots stable and the remainder upgrading. The absence of downgrading plots shows this community to enjoy a healthy and probably expanding trend. Within the herbaceous layer 66 per cent of the plants are grasses (two-thirds of which were annual grasses), 31 per cent forbs and 3 per cent woody plant seedlings (from "Nearest Species"). This proportion of grass plants shows over 300 per cent increase when compared with that of Closed Riverine Woodland (Table 11).

This communtiy also appears to occur on ancient floodplains now raised above present flood levels and thus no longer subject to surface inundation. All three marginal vegetation communities' dominant woody vegetation species often occur as isolated individuals or small clusters on single termitaria, the erosion of which provides suitable higher base levels for their expansion. Some degree of mixing of *Hyphaene ventricosa* and *Acacia nigrescens* occurs in both above communities.

Combretum imberbe – Croton megalobotrys
Woodland and Savanna Woodland

Combretum imberbe – Croton megalobotrys Woodland and Savanna Woodland Communities occupy the lower-lying marginal areas and appear to have a higher sand content in the substrate. Five transects conducted in this community during June 1973 using the "Point-centred quarter method" provided an average density of 202,92 woody plants/ha in the woody stratum (Table 10). Average density from the "concentric circles method" provided the lower density estimate of 163,96 trees/ha but again this latter method was unacceptable (Grunow **pers. comm.**). Table 15 lists the woody species in order of importance value, and Table 16 lists the herbaceous species in order of relative density from nearest species for this community.

The conservation trend in the *Combretum imberbe – Croton megalobotrys* communities showed 56,25 per cent of plots stable 31,25 per cent downgrading and 12,50 per cent upgrading. From "Nearest species" this community's herbaceous layer composition comprised 71 per cent grasses, 28 per cent forbs and 1 per cent woody plant seedlings. Possibly the high proportion of down grading plots was caused by the previous low flood years, as some of these communities appear to occur on ancient Secondary Floodplain and the sandier soils seem more prone to rapid degradation.

Table 15. List of woody species in order of importance value for *Combretum imberbe – Croton megalobotrys* Woodland and Savanna Woodland from marginal island areas of the Boro river floodplain, Okavango Delta Botswana,1973

WOODY PLANT SPECIES	IMPORTANCE VALUE
Combretum imberbe	45,32
Croton megalobotrys	19,51
Lonchocarpus capassa	15,78
Acacia nigrescens	3,82
Grewia schinzii	2,56
Diospyros mespiliformis	2,34
Kigelia africana	1,91
Dichrostachys cinerea	1,75
Grewia flavescens	1,55
Ziziphus mucronata	1,50
Acacia tortilis	1,44
Maytenus senegalensis	1,41
Garcinia livingstonei	1,14

Table 16. List of herbaceous layer species in order of relative density from "Nearest Species" calculations for *Combretum imberbe – Croton megalobotrys* Woodland and Savanna Woodland of Marginal island areas of the Boro River Floodplain, Okavango Delta, Botswana,1973

PLANT SPECIES	RELATIVE DENSITY
Cenchrus ciliaris	20,80
Sporobolus fimbriatus	19,60
Cynodon dactylon	16,40
Digitaria pole-evansi	9,60
Blepharis diversispina	8,40
Monechma debile	6,40
Tephrosia lupinifolia	5,60
Celosia scabra	4,00
Chloris gayana	2,80
Oxygonum de lagoense	2,40
Panicum maximum	0,80
Enteropogon macrostachys	0,80
Hibiscus engleri	0,80
Asparagus sp	0,40
Lonchocarpus capassa seedling	0,40
Capparis tomentosa seedling	0,40
Ximenia americana seedling	0,40

The *Combretum imberbe – Croton megalobotrys* Woodlands and Savanna Woodland are Communities subject to some slight surface inundation in high flood years but no surface flooding in average seasons. This serves to substantiate their evolution from ancient Secondary Floodplain Communities which in the past have received progressively less and less surface inundation and eventually no surface inundation except when extreme flood conditions reoccur after their establishment.

Dryland vegetation types

Acacia tortilis Savanna Woodland

No quantitative field work was conducted in *Acacia tortilis* Savanna Woodland. The stands of this community are common in the central and upper parts of the study area adjacent to Chief's Island but are all subject to heavy mammalian utilisation.

Visually the trends seem to be downgrading due to overutilisation of both the woody stratum and the herbaceous stratum; but more especially the herbaceous stratum. *Acacia tortilis* Savanna Woodland occur on relatively recent old primary floodplains as well as ancient primary floodplains. Due to their situation such communities are subject to inundation in high flood years or in instances where flooding pattern changes and ancient floodplain is reflooded after sustained dry periods.

Acacia tortilis Savanna Woodland must provide probably the most palatable grazing and browsing available for most months of the year, after summer grazing areas have dried out. The largest concentrations of non-aquatic dependent large mammals were always present in these communities during dry periods and wet periods, and remained so until Primary Floodplain Communities became available for mammals to utilise. During excessively high flood periods, when these areas are shallowly inundated, red lechwe are forced to utilise *Acacia tortilis* Savanna Woodland as their prime habitat is excessively inundated and under such circumstances prefer this habitat although this is not normally utilised by lechwe under average flood conditions.

Acacia erioloba Woodland and Savanna Woodland

Acacia erioloba Woodland and Savanna Woodland are wide-spread throughout the study area but mainly occur on parts of Chief's Island. Five transects conducted during July 1973 in *Acacia erioloba* Savanna Woodland provided an average woody vegetation stratum density of 48,65 trees/ha from the "Point-centred quarter method" (Table 10). Using the "concentric circles method" and taking shrubs and seedling trees into account the density obtained is 278,84 woody plants/ha which again is considered too high and unacceptable. However, although only 1 per cent of strikes occurred, numerous seedling trees are sprouting in this community. The herbaceous species of this community is widely spaced, providing an average density of 18,54 plants/m^2 (Table 11). The woody species in this community in order of importance value are: *Acacia erioloba* (74,87) *A fleckii* (15,72), *Terminalia sericea* (7,85) and *Grewia subspathulata* (1,56). Table 17 lists the herbaceous species in order of importance value.

Table 17. List of herbaceous layer species in order of importance value and "Nearest Species" relative percentage density from *Acacia erioloba* Woodland and Savanna Woodland on Chief's Island, Okavango Delta, Botswana 1973

HERBACEOUS PLANT SPECIES	IMPORTANCE VALUE	"NEAREST SPECIES" RELATIVE DENSITY
Brachiaria brizantha	54,11	49,2
Tricholaena monachne	7,52	6,4
Eragrostis pallens	6,60	6,4
Digitaria eriantha	5,97	3,2
Bulbostylis burchelli	5,76	10,8
Pluchea leubnitziae	4,34	1,8
Cynodon dactylon	4,24	8,0
Borreria paludosa	2,90	1,6
Aristida stipitata	1,81	5,6
Commelina benghalensis	1,44	0,8
Blepharis diversispina	1,44	1,2
Pogonathria fleckii	1,29	0,4
Stipagrostis uniplumis	1,29	1,2
Cleome rubella	1,29	0,8
Acacia erioloba seedling	0,0	1,0
Sporobolus fimbriatus	0,0	0,8
Eragrostis lehmanniana	0,0	0,4
Enteropogon macrostachys	0,0	0,4

From "Nearest species" method grasses form 82 per cent of this community with 10,8 per cent sedges, 6,2 per cent forbs and 1 per cent woody plant seedlings (Table 17). Fifty per cent of the *Acacia erioloba* community plots sampled were determined to be stable with 25 per cent downgrading and 25 per cent upgrading. Heavy utilisation occurs below mature *Acacia erioloba* trees where *Tricholaene monachne* is dominant. In the open *Brachiaria brizantha* is heavily utilised and sample plots failing into these areas were often found to be downgrading. In general the communities seem to be evolving more towards a woodland as is evident from the presence of small trees, shrubs and seedlings of *Acacia erioloba.*

Acacia erioloba Woodland and Savanna Woodland are not subjected to flooding or an excessively high water table, and when extremely high floods or altered flooding patterns occur, *Acacia erioloba* is killed by water presence. The community is well utilised by large mammals but not as excessively as *Acacia tortilis* Savanna Woodland communities.

Terminalia sericea – Combretum collinum
Savanna Woodland and Scrub

No quantitative work was conducted in *Terminalia sericea – Combretum collinum* Savanna Woodland and Scrub. The communities are wide-spread on Chief's Island and mainly on the central sectors of large islands.

In parts of this community the woody plants are damaged by elephant but nowhere was this found to be serious. This community visually appears to be in a stable trend and is not subject to surface flooding except in extreme flood years or via altered flooding patterns. Excessively long periods of surface flooding (longer than two months) will kill most dryland woody species unadapted to such Flooding; viz. the dryland types and some woody species occurring in the marginal vegetation types eg. *Acacia tortilis* and *Dichrostachys cinerea.*

Colophospermum mopane

Woodland and Pyrophytic Scrub Savanna

Large stands of *Colophospermum mopane* Woodland and Pyrophytic Scrub Savanna occur from southern Chief's Island mainly up the southeastern side and as a central core to some of the larger islands in the study area. Ten transects conducted in these communities ud during September 1974 gave an average density of 462,75 trees/ha in woodland and 2583,98 shrubs/ha in scrub savanna from the "Point-centred quarter method" (Table 10). The corresponding figures from the "concentric circles method" are approximately 40 per cent higher in each case and are disregarded as before. The herbaceous layer provided an average density of 16,88 plants/m^2 in the Woodland and 66,81 plants/m^2 in the scrub savanna from the "Point-centred quarter method" (Table 11). Table 18 lists the woody vegetation species in order of importance values.

Table 18 – List of woody species in order of average importance value for *Colophospermum mopane* Woodland and Pyrophytic Scrub Savanna from Chief's Island, Okavango Delta, Botswana, 1974

WOODY VEGETATION SPECIES	IMPORTANCE VALUES
Colophospermum mopane	80,91
Croton megalobotrys	8,13
Grewia bicolor	3,76
Grewia flava	2,77
Acacia tortilis	1,65
Commiphora africanus	1,41
Grewia villosa	1,38

Values in conservation trends in the *Colophospermum mopane* communities were generally stable (79,17 per cent) with few downgrading (8,33 per cent) and a slightly higher percentage of plots upgrading (12,5 per cent). This community is fairly well utilised but mainly so during the summer months when herbaceous grazing is at its best and drinking water is available in pans. Elephant and fire (Fig. 21) do some slight damage to the mature *Colophospermum mopane* trees and elephant utilise this habitat more than other large mammal species, but nowhere was excessive elephant damage found.

Colophospermum mopane Woodland and Pyrophytic Scrub Savanna are not inundated by floodwaters except in extremely high flood years or altered flooding pattern, but in either case only small parts of this community are affected for a short duration.

Grewia spp – *Croton megalobotrys* Scrub Savanna

Grewia spp. – *Croton megalobotrys* Scrub Savanna is well-developed on the central sandy cores of medium to large islands. Five transects conducted in this community during July 1973 provided an average density of 490,44 woody plants/ha from the "Point-centred quarter method", with higher estimates from quadrates method and the "concentric circle method" being disregarded (Table 10). The herbaceous stratum provided an average density of 125,61 plants/m^2 from the "Point-centred quarter method" (Table 11). Table 19 lists the woody species in order of importance value and Table 20 lists the herbaceous species also in order of importance value in this community.

This community was being well-utilised but still showed very rank growth at the time it was sampled. Trends in conservation values showed no downgrading plots with 65,63 per cent of plots stable and 34,37 per cent of plots upgrading in this community. *Grewia* spp –*Croton megalobotrys* Scrub Savanna is not subject to surface inundation from floodwaters except under perhaps exceptional circumstances.

FIGURE 21 – Fire damage in *Colophospermum mopane* Woodland with commencement of Pyrophytic Scrub Savanna development, Chief's Island, Okavango Delta, Botswana.

Table 19 – List of woody species in order of importance value from *Grewia species* - *Croton megalobotrys* Scrub Savanna sampled from large sandy central islands on the Boro River Floodplain, Okavango Delta, Botswana 1974.

WOODY PLANT SPECIES	IMPORTANCE VALUE
Grewia flavescens	27,05
Grewia schinzii	19,52
Croton megalobotrys	19,02
Grewia retinervis	10,93
Acacia erioloba	6,65
Ziziphus mucronata	3,96
Acacia tortilis	3,77
Hyphane ventricosa	2,28
Lonchocarpus capassa	2,25
Commiphora africana	1,62
Diospyros lycioides	1,09
Ximenia americana	1,06
Gomphocarpus species	0,78

Table 20 – List of herbaceous layer species in order of importance value and "Nearest Species" relative percentage density from *Grewia species - Croton megalobotrys* Scrub Savanna sampled from large sandy central islands on the Boro Rivier Floodplain okavango Delta, Botswana,1974.

VEGETATION SPECIES	IMPORTANCE VALUE	"NEAREST SPECIES" RELATIVE DENSITY
Urochloa brachyura	26,67	26,50
Eragrostis rotifer	22,31	21,00
Eragrostis tricophora	7,76	3,00
Eragrostis biflora	6,67	7,50
Pluchea leubnitziae	5,42	4,00
Setaria verticillata	4,66	5,00
Schmidtia pappophoroides	3,94	1,50
Chloris virgata	3,11	3,00
Clerodendron uncinatum	5,61	5,50
Blepharis diversispina	3,27	2,50
Pseudobrachiaria deflexa	2,80	1,00
Unidentified grass	1,87	4,50
Ipomoea magnusiana	1,87	3,50
Hermania glandufigera	1,76	1,50
Cynodon dactylon	1,35	0,50
Gisekia africana	0,93	2,00
Eragrostis lappula	0,00	2,00
Grewia retinervis	0,00	1,50
Unidentified forb	0,00	1,50
Andropogon huillensis	0,00	0,50
Aristida meridionalis	0,00	0,50
Dactylotenium aegyptium	0,00	0,50
Achyranthus sicula	0,00	0,50
Leucas martinicensis	0,00	0,50