

Vegetation of channels of the northeastern Okavango Delta,
Botswana

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Summary

Plant assemblages rooted within channels, as well as in peat deposits flanking channels, in the northeastern Okavango Delta have been classified and their distribution related to environmental conditions. Within-channel assemblages appeared to be related to the introduction of sediments from source areas and to differences in channel dimensions (particularly water depth) and current velocity. Channel margin assemblages appeared to be related to seasonal and longer-term water level fluctuations, as well as the extent to which water, introduced from either the catchment or from local rainfall, contributed to the water budget. These two classifications have been combined in a functionally based classification of channels in the study area in which five channel types were recognized; long-term and short-term aggradational, primary filter and confined and unconfined outlet channels. Comparison of these channel types with an earlier classification by Wilson (1973) has indicated some degree of correspondence. A number of changes in the spatial distribution of similar channel types have, however, taken place since the earlier study, mainly in the upper reaches of the study area. The reasons for these and possible short-term future change have been inferred based on the findings in the present study.

Résumé

Les groupements de plantes enracinées dans les chenaux ainsi que dans les dépôts de tourbe bordant les chenaux dans le nord-est du delta de l'Okavango ont été classés et leur distribution a été mise en rapport avec les conditions du milieu. Les groupements à l'intérieur des chenaux semblent être liés à l'introduction de sédiments provenant de la zone des sources et aux différences de dimension des chenaux (en particulier la profondeur de l'eau) et à la vitesse du courant. Les groupements des rives des chenaux semblent être liés aux fluctuations tout saisonnières qu'à plus long terme du niveau d'eau, de même qu'à la mesure dans laquelle l'eau—qu'elle provienne du bassin hydrographique ou des chutes de pluies—contribue au bilan hydrique. Ces deux classifications ont été combinées en une seule classification fonctionnelle basée sur les cinq types de chenaux identifiés dans la zone d'étude: les aggradationnels de court ou de long termes, les filtres primaires et les chenaux à exutoire libre ou bouché.

La comparaison de ces types de chenaux avec la classification antérieure de Wilson (1973) montre un certain degré de correspondance. Un certain nombre de

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changements dans la distribution spatiale de types similaires de chenaux ont cependant eu lieu depuis cette étude précédente, principalement dans la partie supérieure de la zone d'étude. Les raisons des changements et ceux qui pourraient survenir sous peu ont été prévues sur base des découvertes de la présente étude.

Key words: Botswana, Okavango, vegetation, water level

Introduction

The perennial swamps of the upper reaches of the Okavango Delta are characterized by numerous sandy-bottomed distributary channels which dissect a range of shallow-rooted plant communities growing on thick (1–4 m) peat deposits (Wilson, 1973; Gibbs-Russel & Biegel, 1973; Smith, 1976; Ellery, K., 1987). The peat banks lining the channels are almost vertical, with an abrupt transition to well-sorted fine sand of aeolian origin on the channel bed (McCarthy *et al.*, 1988). This sand moves by traction and saltation along the channel floor, and is therefore confined to in-channel areas (McCarthy *et al.*, 1986). For this reason there is no lateral fining of sediments, and the transition to peat remains abrupt throughout the life of a channel. Hydrological changes at the peat bank–water interface are equally sharp, with water filtering very slowly through the peat and emergent vegetation, even when flow in the channel less than a metre away can approach 1 ms^{-1} (W. N. Ellery, unpubl.). These differences in hydrological conditions and in the nature of the substratum give rise to spatially distinct plant communities within and flanking channels in the perennial swamps of the Okavango Delta. In addition, downstream changes in hydrological and sedimentation processes, which are the result of increasing distance from the source of water and sediment supply (Wilson, 1973; Smith, 1976; Ellery, 1988), give rise to floristic differences in both the in-channel and channel margin flora.

Temporal changes in these communities can arise as a result of the switch in flow from one channel system to another (avulsion) over time spans of 50 to 200 years (Wilson, 1973; McCarthy *et al.*, 1986). The accompanying changes in hydrology and sediment distribution have important consequences for the structure and distribution of vegetation within the Okavango Delta ecosystem, the response to drying as a result of channel avulsion having been described by Ellery *et al.* (1989), and the response to inundation of new areas by Ellery, K. (1987):

A number of studies have described aspects of the form and vegetation of channels in the Okavango Delta (Wilson, 1973; Gibbs-Russel & Biegel, 1973; Smith, 1976), but these have been subjective and qualitative. One of these studies (Wilson, 1973) distinguished three main channel types:

- 'Upper' channels, which linked directly to the inflowing Okavango River, were recognized as being the main systems distributing water and sediment. They were described as being 15–30 m wide, 5–7 m deep, with current velocities in the region of 0.6 ms^{-1} , with a low abundance of in-channel plant species, and fringed by the giant sedge *Cyperus papyrus*.
- 'Middle' channels were described as distributaries of the upper channels, but because of their origin they transported very little sediment. They were further described as being of variable width, depth and flow rate, having a small (less than 20 cm) seasonal change in water level, a diverse in-channel flora and lined by a combination of *C. papyrus* and *Miscanthus junceus*.

- 'Outlet' channels which carry water away from the perennial swamps were described as very variable in physical form and vegetation, but a distinguishing feature was the presence of the fringing swamp fig, *Ficus verruculosa*.

The aim of this investigation was to provide a quantitative description of vegetation within and flanking channels of the northeastern Okavango Delta, including examples of each of the channel types described by Wilson (1973), and to relate this to hydrology and substratum conditions. This provided a more detailed classification of channel types which allowed assessment of short-term changes in channels in the study area since the time that Wilson's (1973) study was completed.

The study area

The Okavango Delta forms part of the large, semi-arid, internal drainage basin known as the Kalahari Basin, and receives the bulk of its water from summer rainfall in the highlands in central Angola. Both the Cubango and Cuito Rivers arise in these highlands and unite to form the Okavango River which flows into Botswana from the north-west at the town of Mohebo. Downstream of Mohebo, the Okavango River is confined in a rifted graben in the region known as the 'panhandle' (Fig. 1). The Okavango Delta itself is confined in a second, larger rifted graben which runs at right angles to the panhandle, being defined by the Gomare fault in the north, and by the Thamalakane and Kunyere faults in the south.

Downstream of the town Seronga, the Okavango River flows into the Nqoga River which was classified as an 'upper' channel by Wilson (1973). Overspill from this channel system gives rise to a number of distributary channels, of which the Thaoge, Jao-Boro and Maunachira are the most important. The upper reaches of these channels were classified as 'middle' channels, and where they carried water away from the perennial swamps they were classified as 'outlet'. Most of these channels unite at the southern end to form the Thamalakane River, which flows into the Boteti River, the only river to flow out of the Okavango basin.

The major distributary channels of the Okavango Delta are subject to avulsion on a time scale of 50–200 years (Wilson, 1973; McCarthy *et al.*, 1986). These events involve the progressive deterioration, abandonment and desiccation of one channel system, with a new area becoming inundated and a new channel system forming. Two such events have been recorded in historic time. Progressive desiccation of the Thaoge River during the latter part of the last century (Thaoge Blockages, Fig. 1) was accompanied by an increase in flow along the Nqoga River, which is presently the major distributary channel of the Okavango Delta (Wilson & Dincer, 1976). It is also the main sediment transporting channel (Wilson, 1973; McCarthy *et al.*, 1986). The lower reaches of the Nqoga River have, however, become progressively desiccated (Nqoga Blockage, Fig. 1) since the 1920s (Wilson, 1973), a process which has been accompanied by an increase in flow along the more northerly Maunachira River, largely via the Letenetso Channel (Fig. 2). Sediment introduced into the Nqoga channel is similarly diverted into the Letenetso Channel and the upper Maunachira River between its confluence with the Letenetso Channel and Dxerega Lediba (Lake). The remaining channels in the study area do not receive sediments from source areas, but receive their water supply as overspill and via filter areas further upstream.

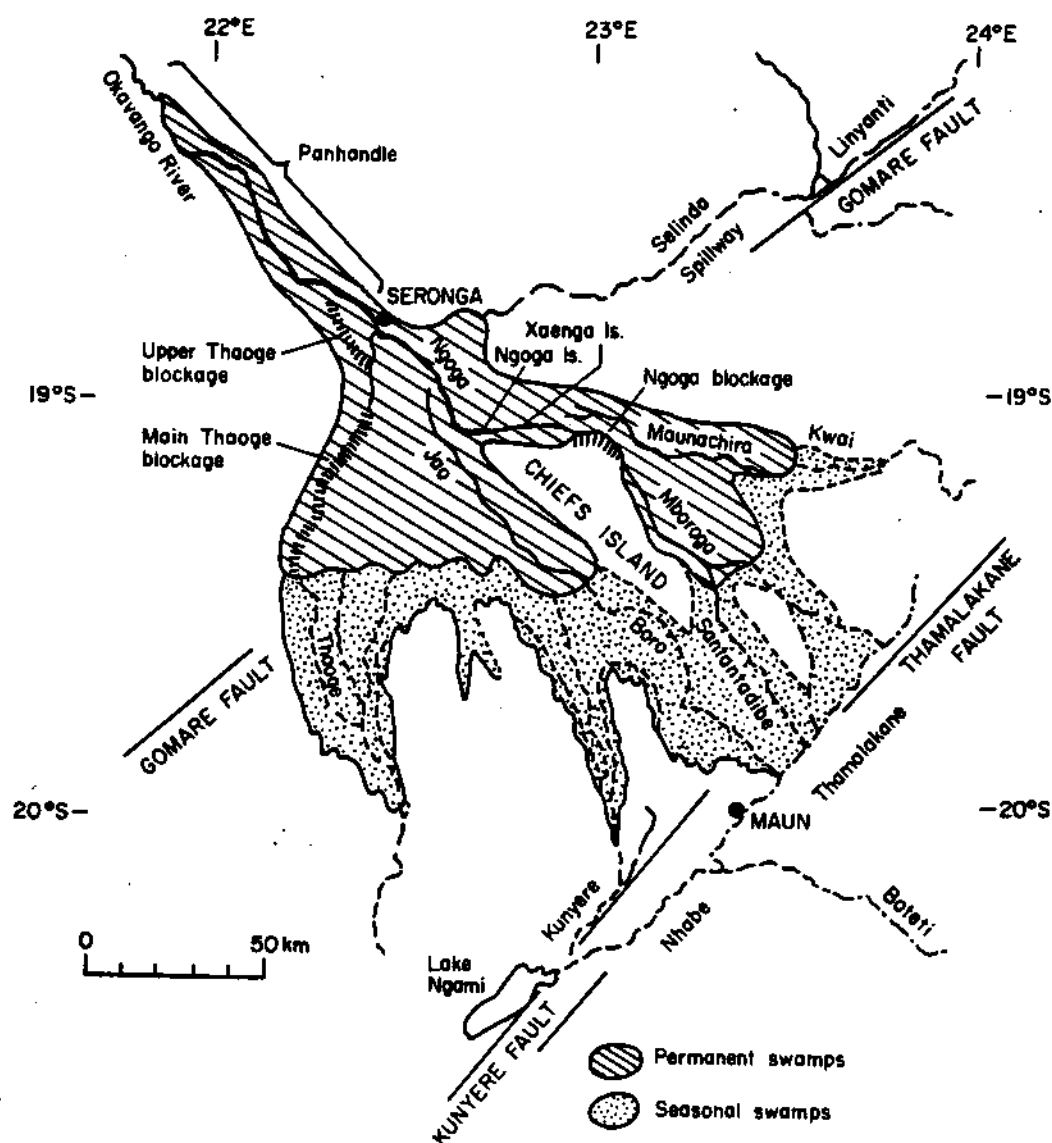


Fig. 1. Map of the Okavango Delta, Botswana, showing the major physiographical features and distributary channels.

Methods

In order to characterize the biotic and abiotic features of the presently active lower Nqoga and Maunachira Rivers, 59 stands were located in a stratified manner to cover a wide range of channel sizes and flow conditions. The Maunachira River is floristically relatively diverse by comparison with the relatively homogeneous lower Nqoga River and Letenetso Channel, so the majority of stands were placed along the former river system. Transects 3 m wide were placed across the channel at each sample site. An estimate of vegetation cover-abundance was made within and flanking the channel at each site using the Braun-Blanquet scale as presented in Mueller-Dombois & Ellenberg (1974). The data for bottom-rooted aquatic plant species and emergent plant species flanking the channel were analysed separately using a polythetic divisive cluster analysis (TWINSPAN; Hill, 1979).

Major groupings with the TWINSPAN cluster analysis are provided with diagnostic or indicator species as well as preferential species, which occur in a minimum

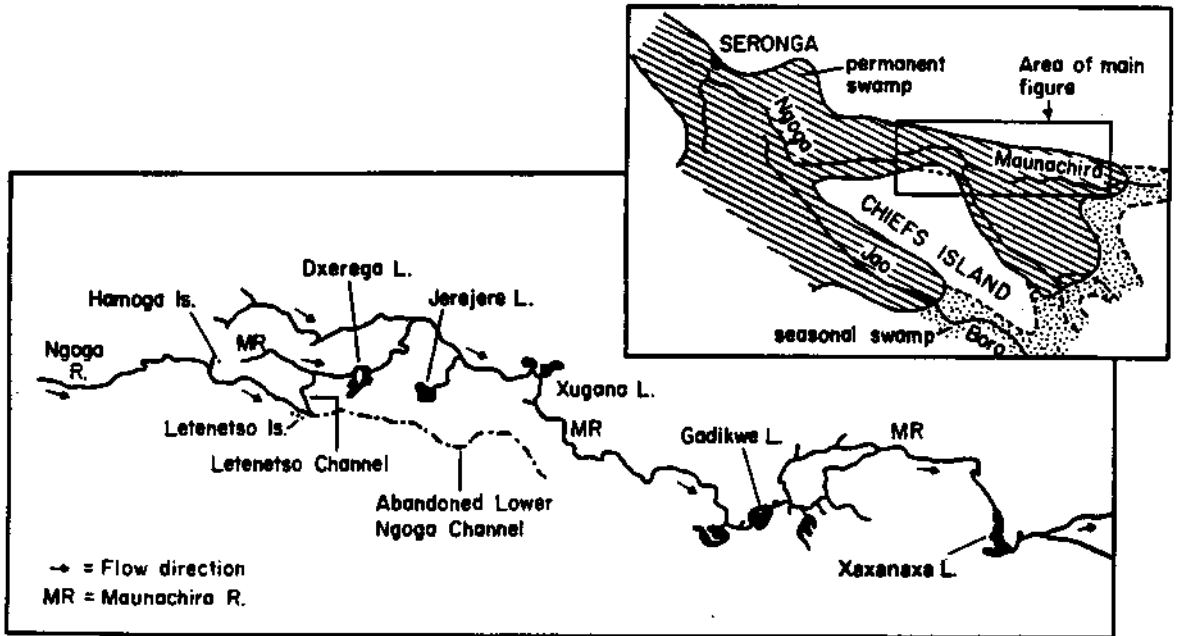


Fig. 2. Map of the study area in the perennial swamps of the northeastern Okavango Delta.

of 20% of the samples and are at least twice as likely to occur on one side of a dichotomy as the other (Hill, 1979).

Channel width, channel cross-sectional profile, and mean surface mid-channel flow rate were measured at each site. Within a stratified subsample ($n=16$), detailed measurements of flow conditions were made in which flow rate was measured using a calibrated flow meter at 2 m intervals across the channel at 20% and 80% of the total channel depth (British Standards Institution, 1964). The thickness of peat deposits in areas flanking the channel was also measured at these sites.

Results

Classification of within-channel vegetation

Within the 59 stands analysed in the TWINSPLAN cluster analysis of in-channel vegetation, five major groups were recognized (Fig. 3). A list of within-channel species, and the occurrence of each within each of the groups is given in Appendix 1. The first division was characterized by the indicator species *Vossia cuspidata*, an emergent grass which occurred in all of the stands in one of the groups (Group A, $n=9$), and was altogether absent from the remaining stands. *Vossia cuspidata* formed monospecific stands with a high cover-abundance on the convex side of channel bends, and low cover-abundance on the concave side and on straight channel sections. All of these stands occurred on the rivers receiving water and sediment directly from source areas (Fig. 4a)—on the lower Nqoga River, Letenetso Channel and upper Maunachira River downstream of its confluence with the Letenetso Channel as far as Dxerega Lediba. These stands were not divided further in the analysis.

At the second level of division the remaining 50 stands, which were dominated by submerged and floating leaved species, were divided into two groups based on the indicator species *Brasenia schreberi*, which was present in 22 stands, and was

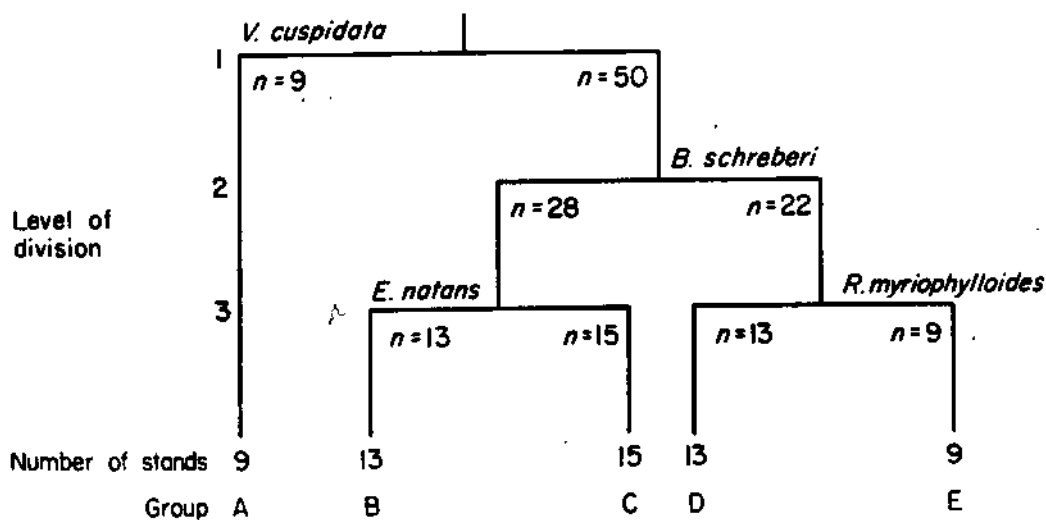


Fig. 3. Dendrogram illustrating the classification of stands based on the in-channel vegetation.

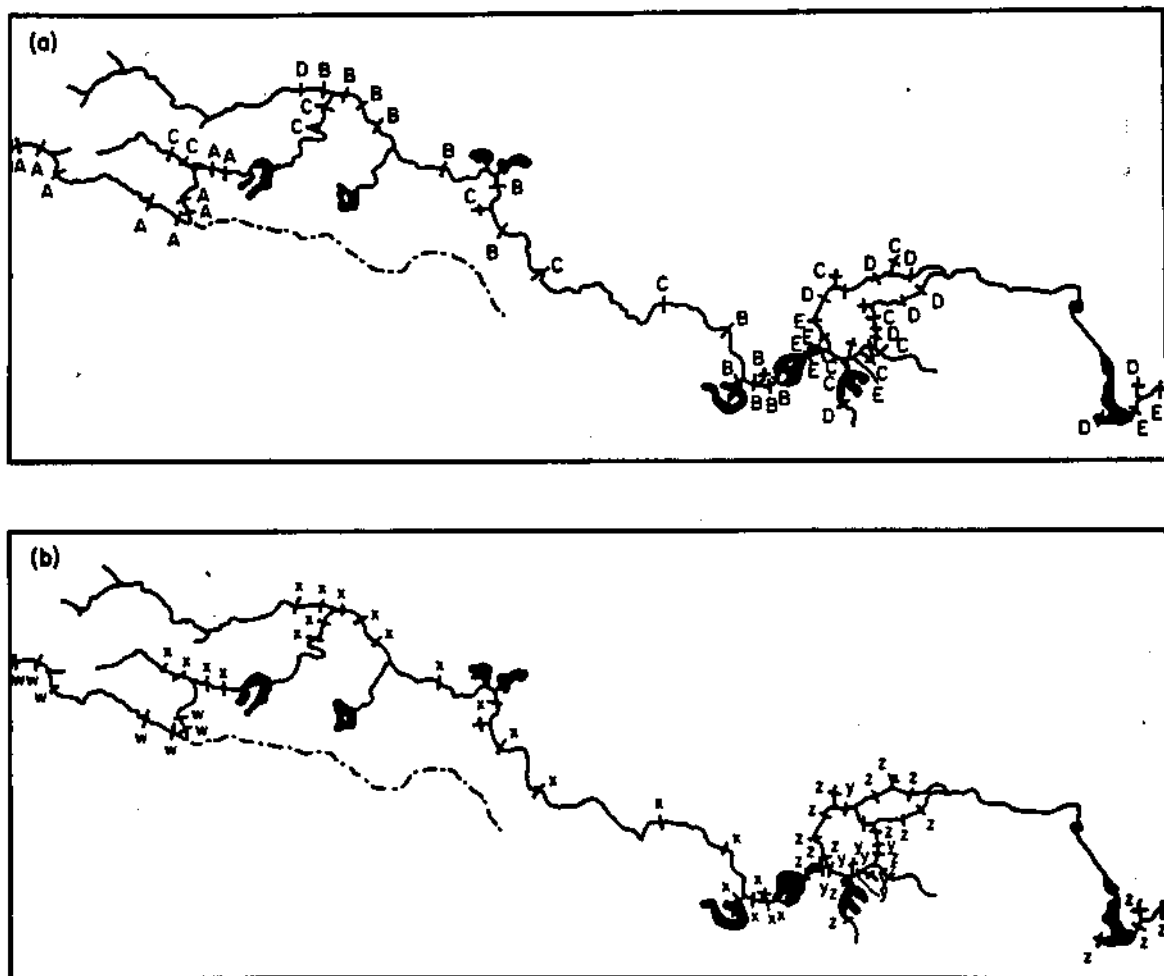


Fig. 4. The distribution of stands within the study area showing the stand group into which each was classified based on the in-channel (a) and channel margin (b) vegetation. Consult Fig. 1 for labelling of physiographic features.

largely absent from the remaining stands. The submerged species *Ceratophyllum demersum*, *Rotala myriophylloides* and *Nesaea crassicaulis* were preferentially associated with these stands. *Rotala myriophylloides* was the indicator species which determined the next level of division of these 22 stands. Nine stands (Group E), were characterized by a high cover-abundance of this species, as well as by the presence of preferential species *C. demersum*, *N. crassicaulis* and the floating leaved *Nymphoides indica*. This predominantly submerged assemblage occurred along wide reaches on the lower Maunachira River downstream of Gadikwe Lediba, which appear to be relatively diffusely disturbed by animal movement or boating activity. There were no indicator or preferential species associated with the remaining 13 stands (Group D) of this division. This mixed species assemblage had a low diversity of species, and was associated with narrow channels which result from the diurnal movement of *Hippopotamus amphibius* L. from areas close to the Maunachira River downstream of Gadikwe Lediba to terrestrial feeding sites.

The 28 stands identified at the second level of division were not indicated by any species, but the floating-leaved *Eichhornia natans* was preferentially associated with them. At the third level of division, however, these stands were further divided based on the indicator species *E. natans* which was present in 13 (Group B) of these 28 stands. The submerged species *Ottelia muricata* and the floating-leaved *Nymphaea caerulea* were associated preferentially with this group which characterized much of the Maunachira River between Dxerega and Gadikwe Madiba (Lakes). There were no indicator or preferential species associated with the remaining 15 stands (Group C) of this dichotomy which were relatively widespread in the study area, being mainly on channels downstream of Gadikwe Lediba on the lower Maunachira River, but with some stands on channels of the middle and upper Maunachira River (upstream of its confluence with the Letenetso Channel).

Divisions beyond those described above were based on minor species differences, and five groups of stands have therefore been retained, giving five recognizable species assemblages associated with distinct channel sections.

Studies of the hydrological conditions in the channel sections where these assemblages (A-E) occurred, gave some insight into the environmental conditions contributing to their distribution. The assemblages found in stand-groups A and B were associated with channel sections of similar mean flow rate, water depth and width, although the characteristics of group B channels were more variable (Fig. 5). The distinguishing characteristic of group A channel sections was undoubtedly the large quantity of bed-load sediment which would provide a highly unstable habitat for all but emergent plant species. In addition, suspended sediment of kaolin clay limits light penetration. The suggestion that sediments from source areas limit the growth of bottom rooted plants was supported by data on the relationship between overall plant cover of the channel bed and channel depth (Fig. 6a). There was a negative linear relationship ($P < 0.001$) indicating a general increase in plant cover with decreased water depth, presumably due to increased light availability as water depth decreases. The effect of high sediment load is evident in the distribution of stands receiving sediments from source areas being largely below the line of best fit. This suggests that for a given water depth, channel sections receiving sediments from the source area have a lower plant cover than those not receiving sediments from source areas. The suggestion that the introduction of sediments affects the ability of plants to colonize these channels is further supported by the negative

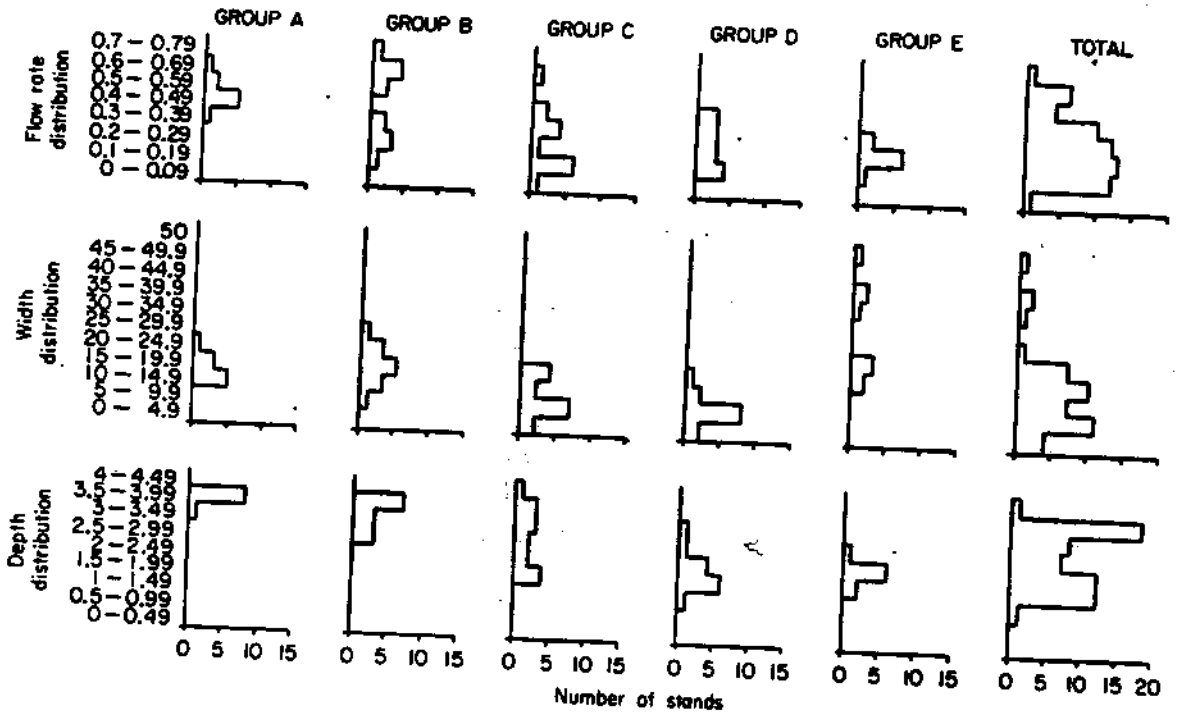


Fig. 5. Range of channel dimensions and mean mid-channel current velocities in each stand-group identified in the classification of stands based on in-channel vegetation.

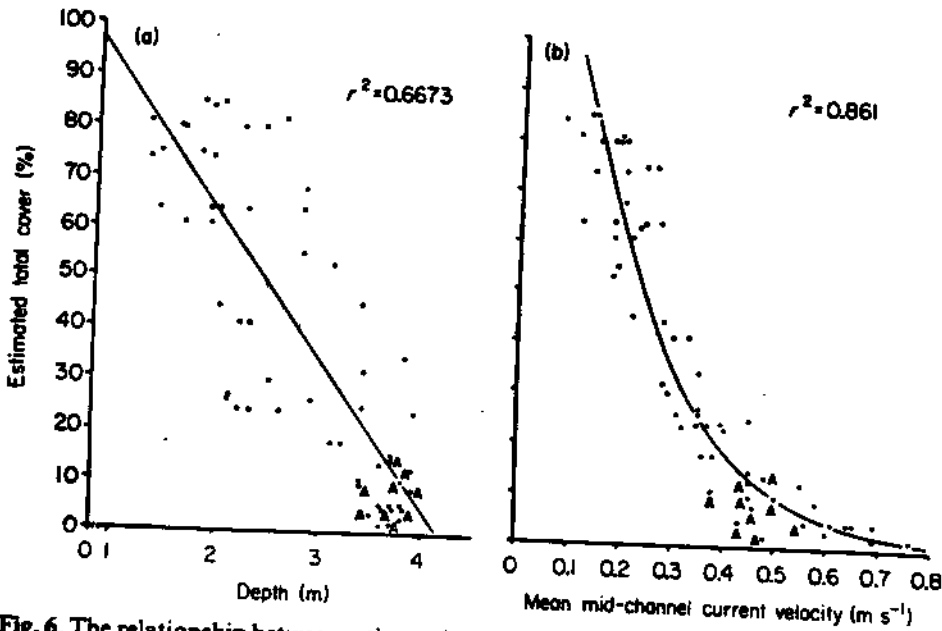


Fig. 6. The relationship between estimated total plant cover within channels and mean channel depth (a) and mean mid-channel current velocity (b). Stands on channels receiving sediments from source areas are indicated as belonging to stand-group A.

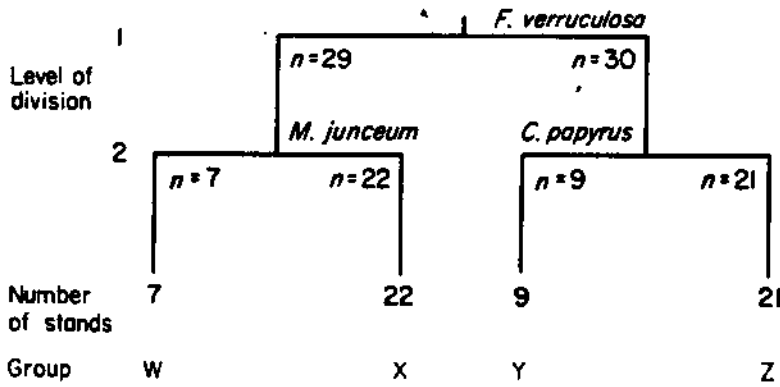


Fig. 7. Dendrogram illustrating the classification of stands based on the channel margin vegetation.

curvilinear relationship ($P < 0.001$) between plant cover and flow rate (Fig. 6b). Once again stands receiving sediments from source areas generally occurred below the line of best fit.

A general decrease in mean flow rate, water depth and channel width was evident for channels in stand-groups B to D (Fig. 5), but the variability in each factor was high and a larger sample size may be required to verify these trends statistically. Channel sections of stand-groups D and E of the lower Maunachira River exhibited similar flow and depth characteristics, but those of group E were much wider. It is unlikely that the difference in species composition of the associated plant assemblages could be directly attributed to differences in channel width alone. Indirect effects could arise from disturbance by hippopotamus and boats, which would be more dissipated in wider channels than narrower ones.

Classification of channel fringe vegetation

Four main groups of stands representing clearly recognizable species assemblages were delineated by the cluster analysis of vegetation in the channel margin (Fig. 7). A list of channel-margin species, and the occurrence of each within each of the groups is given in Appendix 2. The first division was based on the indicator species *F. verruculosa* which was present ($n = 30$) at a cover of greater than 5% (generally greater than 25%) along channels downstream of Gadikwe Lediba. In the stands upstream of this lake ($n = 29$) *F. verruculosa* was either absent, or present with low cover (less than 5%), and the giant sedge *C. papyrus*, with cover of greater than 25%, was associated preferentially with these stands.

At the second level of division the stands upstream of Gadikwe Lediba were further divided on the basis of the indicator species *M. junceus*, which was found with high cover (greater than 25%) in the stands on the Maunachira River itself (Group X, $n = 22$). This tall, shallow-rooted, emergent grass was, however, absent along the lower Nqoga and Letenetso channels (Group W, $n = 7$), which were dominated entirely by luxuriant stands of *C. papyrus*.

The channels downstream of Gadikwe Lediba were divided into two groups at the second level of division, this time based on the indicator species *C. papyrus*, which was generally present with a cover less than 25% in nine stands (Group Y), and was absent from the remaining 21 stands (Group Z).

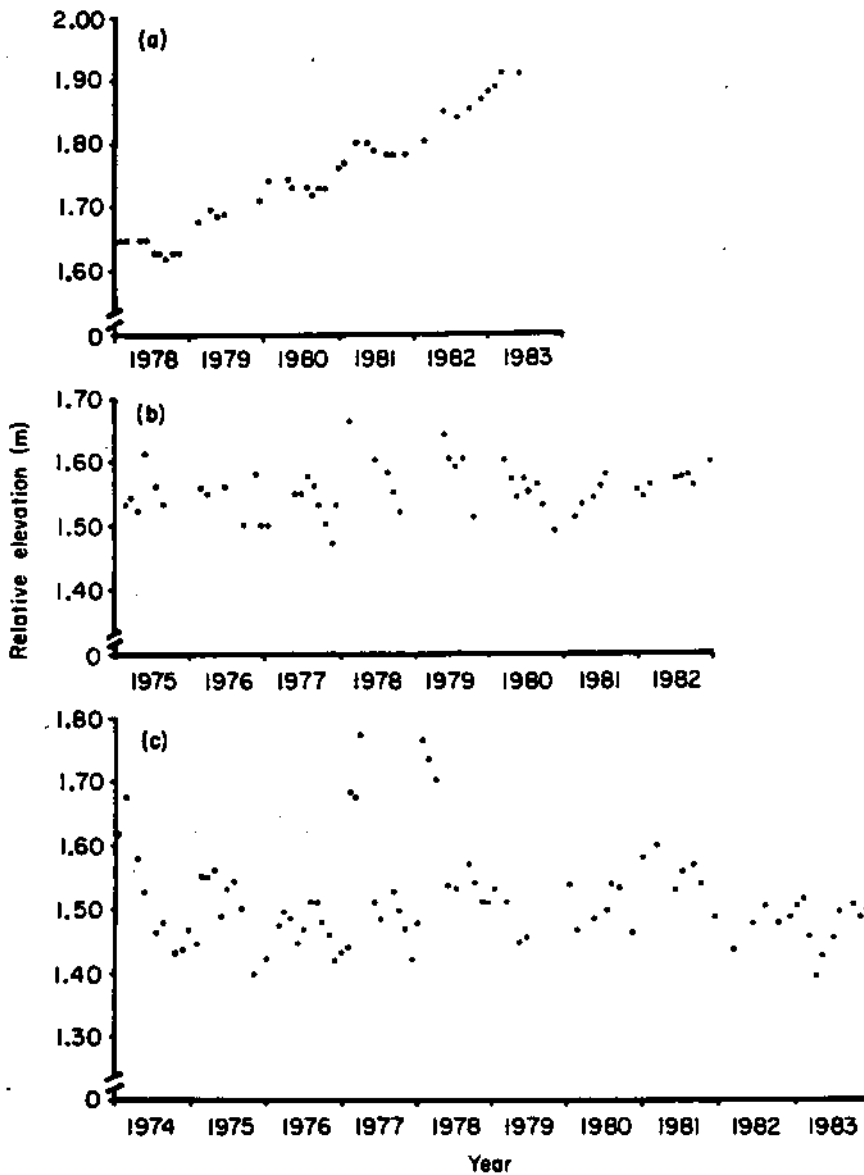


Fig. 8. The seasonal and longer term (several years) water level fluctuation along three channel sections corresponding to stand-groups identified in the classification of stands based on channel margin vegetation.

Further division of these groups at the third level of division was based on minor species differences, and these groups of stands have therefore been retained, giving four recognizable species assemblages of vegetation in the channel margin.

The distribution of plant assemblages rooted in the peat deposits in the channel margin appears to be related to seasonal and longer term water level fluctuations, as well as to the thickness of the peat deposits in which the plants were rooted. The *C. papyrus* assemblage with an understorey of *Thelypteris interrupta* (Group W) was present along the lower Nqoga and Letenetso Channels (Fig. 4b), rooted in peat deposits between 3 and 4 m thick. Water level recordings at Hamoga island showed a seasonal fluctuation of less than 10 cm, but a long term rise in the water level was apparent (Fig. 8a). This has been related to the deposition of bed-load sediment along the channel floor, and has been accompanied by a concomitant rise

in the peat level in areas flanking the channel (McCarthy *et al.*, 1986). The peak in water level occurs in approximately April, May and June, which is when the flood-water from rainfall in the catchment in Angola reaches this area. The hydrological conditions are therefore dominated by water flowing into the Delta from the catchment and it is evident that these channels are 'suppliers' of water from source areas to the channel types further downstream. Because these channels are aggradational, water level gradients slope away from them, and they do not receive any water from the surrounding swamp areas.

The *C. papyrus*/*M. junceus* assemblage (Group X) showed a very distinct distribution pattern along the Maunachira River upstream of Gadikwe Lediba. *Cyperus papyrus* was always dominant on the side of the channel where flow rates were slowest (convex banks), and *M. junceus* was dominant on the banks where flow rates were greatest (concave banks). Along straight channel sections these species occurred as mixed stands, with either of the species dominant.

The peat deposits flanking these channels were between 1.5 and 3.0 m thick. It is possible that the section of the Maunachira River between its confluence with the Letenetso Channel and Dxerega Lediba has been aggrading since approximately 1970 but the absence of an hydrological bench mark along this channel section makes it difficult to be certain.

The water level in the channels of the Maunachira River between Dxerega and Gadikwe Madiba however, fluctuated less than 20 cm, with two distinct peaks each year, one in summer as a result of local rainfall, the other in June and July, when the flood-waters from the catchment in Angola reach this area of the Delta (Fig. 8b). The water levels associated with these two annual peaks were similar, except in extremely wet years such as 1977/1978, when the summer flood was greater than the winter flood. There does not appear to be a significant ($P > 0.05$) long-term change in the water level.

The *M. junceus* and *F. verruculosa* assemblages with (Group Y) as well as without (Group Z) *C. papyrus* were present on the Maunachira River downstream of Gadikwe Lediba. The cover-abundance and stature of *C. papyrus* was markedly reduced compared to the previous channel margin assemblages, and decreased downstream, disappearing completely approximately mid-way between Gadikwe and Xaxanaxa Madiba. These assemblages were rooted in peat deposits between 1 and 2.5 m thick, and in areas that experienced seasonal water level fluctuations less than approximately 20 cm (Fig. 8c). Once again two peaks in the water level were evident each year. This illustrates the increasing importance of local rainfall to the hydrological regime in the lower reaches of the fan Delta.

Discussion

Quantitative description of the present day channel margin and in-channel vegetation of the permanently inundated areas of the northeastern Okavango Delta provides two distinct classifications of the channels, both of which differ from that of Wilson (1973). This is because Wilson's qualitative study was based on visually obvious plant species and not on the full complement of in-channel and channel margin species. It is also evident that several changes in vegetation distribution, hydrology and sediment movement characteristics, have taken place since the time of the earlier study.

Table 1. A functionally based classification of channels in the northeastern Okavango Delta indicating the basis for classification and the corresponding terminology used by Wilson (1973)

Predominant sedimentation process	Duration of sedimentation	Predominant source of water	Degree of confinement	Wilson's equivalent term	Suggested term
Aggradational	Non-recent (> 20 years)	Source areas	Confined	Upper	Long-term aggradational
	Recent (< 20 years)	Source areas	Confined		Short-term aggradational
Non-aggradational		Source + non-source	Confined	Middle	Primary filter
		Non-source	Confined	Outlet	Confined outlet
	Unconfined		Unconfined outlet		

A comparison of the three classifications

The Nqoga River and Letenteso Channel appear to correspond to Wilson's (1973) description of 'upper' channels but although they do occur in the upper reaches of the study area, a more meaningful term is 'long-term aggradational' (Table 1). Furthermore these channels are distinct from channels in the panhandle, which are not aggradational (T.S. McCarthy, unpubl.), have a different flora (Smith, 1976) and occur further upstream compared to Wilson's 'upper' channels.

The Maunachira River between its confluence with the Letenetso Channel and Dxerega Lediba has characteristics of both the 'upper' and 'middle' channels described by Wilson (1973). The in-channel vegetation, hydrology and sediment supply are typical of upper channels, while the channel margin vegetation is typical of middle channels. The term 'transitional' has been used to describe this section (Ellery, 1988) as it appears to be spatially and floristically transitional between Wilson's 'middle' and 'upper' channels. Once again a term with a greater degree of functional significance is suggested, this being 'short-term aggradational' (Table 1).

The remainder of the Maunachira River as far downstream as Gadikwe Lediba corresponds to Wilson's (1973) description of 'middle' channels. These channels arise from filter areas as water flows away from both short- and long-term aggradational channels, and the term 'primary filter' channels therefore seems appropriate (Table 1).

Downstream of Gadikwe Lediba the Maunachira River appears to correspond to Wilson's (1973) description of an 'outlet' channel, although two distinct types were recognized in the present study, one having flow relatively well confined between peat banks, the other with flow relatively unconfined and with extensive beds of *N. crassicaulis* and *R. myriophylloides*. The terms 'unconfined outlet' and

'confined outlet' are suggested to convey the distinction between these channels respectively (Table 1). Both of these channel types have *F. verruculosa* and *M. junceus* as important channel margin constituents, and they may or may not have *C. papyrus* in the channel margins.

Inferring short-term changes in the distribution of channel types

Long-term aggradational channels occurred as far downstream as Letenetso Island on the Nqoga River at the time of Wilson's earlier study, but the present study suggests that this type includes the Letenetso Channel. Furthermore, the short-term aggradational channels appear spatially and temporally transitional from a primary filter channel to a long-term aggradational channel. The remaining channels in the study area appear to have a similar distribution to that described by Wilson (1973).

The changes in channels in the upper reaches of the study area appear to have accompanied the change in flow and increase in bed-load movement from the Nqoga River into the Maunachira River since approximately 1970. At the time of Wilson's study, Bokoro Lediba on the Letenetso Channel undoubtedly prevented the movement of sediment into the Maunachira River itself—much in the same way as Dxerega Lediba presently acts as a trap preventing the movement of sediment into the Maunachira River further downstream (McCarthy *et al.*, 1986). Today only remnants of this lake exist as backwaters isolated from the main channel by vegetation and peat banks. The Letenetso Channel, with *C. papyrus* dominated margins, flows directly through this former lake and carries sediments and vegetation debris directly into the Maunachira River. The continual movement of sand along the channel floor downstream of this former lake would prevent the establishment of seedlings, and would cover and smother the already established flora. It appears that only an emergent, supple, rhizomatous species such as *V. cuspidata* is able to withstand these conditions, and then only in selected areas close to the bank where the flow rate is substantially reduced.

In contrast to the rapid changes of in-channel vegetation to the introduction of bed-load sediments, the vegetation of the channel margins appears to respond more slowly. At the time of Wilson's (1973) study, the Letenetso Channel appears to have been dominated by a combination of *C. papyrus* and *M. junceus*. Today it is dominated by *C. papyrus*. One of the consequences of the deposition of bed-load sediments along the channel floor is a gradual rise in the water level over a period of years (McCarthy *et al.*, 1986). This is accompanied by aggradation of the peat banks flanking the channel. The ability of *C. papyrus* to exist as a floating mat at the waters edge has been well documented (Gaudet, 1976, 1978; Howard-Williams & Gaudet, 1985). In contrast, *M. junceus* appears to be deep rooted and unable to withstand the gradual rise in water level that accompanies the deposition of sediments along the channel floor. It may therefore be expected that the plant communities along the Maunachira River between the confluence of the Letenetso Channel and Dxerega Lediba will change from being dominated by a combination of *C. papyrus* and *M. junceus* to being dominated by tall dense stands of *C. papyrus* and *T. interrupta*, and that the recent aggradational channels are not only spatially, but also temporally transitional from primary filter to long-term aggradational channels.

The inlet to Dxerega Lediba is presently rapidly closing in as a result of sedimentation and the deposition of vegetation debris (Ellery, 1988), and it can be expected that within the next decade the lake will be replaced by a channel discharging sediment into the Maunachira River. In this event, marked changes in the in-channel vegetation along this channel can be expected as the substratum becomes unstable and much of the present submerged and floating leaved flora is smothered. A longer term change in the channel margin vegetation may also be expected.

Acknowledgments

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Appendix 1.

The occurrence and estimated cover ranges (1 = 0–2%, 2 = > 2–5%, 3 = > 5–10%, 4 = > 10–25%, 5 = > 25–50%, 6 = > 50–100%) of species that were recorded in 2 or more of the stands located within-channel areas

Stand-group Number of stands	A 9	B 13	C 15	D 13	E 9
<i>Brasenia schreberi</i>		1	1	9	5
J.F. Grmel.		(1)	(1)	(2,3)	(2,3)
<i>Ceratophyllum demersum</i> L.					5 (1–3)
<i>Eichhornia natans</i> (Beauv.) Solms-Laub.		13 (2–4)			
<i>Lagarosiphon ilicifolius</i> Oberm.		3 (2,3)	1 (1)		
<i>Najas pectinata</i> (Parl.) Magnus		3 (1–3)	5 (1–4)	1 (3)	4 (3)
<i>Nesaea crassicaulis</i> (Guill & Perr.) Koehne				2 (3)	7 (4,5)
<i>Nymphaea caerulea</i> Sav.		12 (1–3)	5 (2–4)	13 (2–4)	9 (2–4)
<i>Nymphoides indica</i> (L.) Kuntze		3 (1)	1 (2)	2 (1,2)	7 (2,3)
<i>Ottelia muricata</i> (C.H. Wr.) Dandy		5 (2,3)			
<i>Ottelia ulvifolia</i> (Planch.) Walp.		13 (2–4)	15 (2–5)	10 (2–5)	5 (1–5)
<i>Rotala myriophylloides</i> Welw. ex. Hiern				1 (2)	9 (5,6)
<i>Vossia cuspidata</i> (Roxb.) Griff.	9 (3,4)				

Appendix 2.

The occurrence and estimated cover ranges (1 = 0–2%, 2 = > 2–5%, 3 = > 5–10%, 4 = > 10–25%, 5 = > 25–50%, 6 = > 50–100%) of species that were recorded in 2 or more of the stands located in channel margin areas

Stand-group Number of stands	W 7	X 22	Y 9	Z 21
<i>Cyperus papyrus</i> L.	7 (6)	22 (5)	9 (3–5)	
<i>Ficus verruculosa</i> Warb.		4 (1,2)	9 (2,3)	21 (3–5)
<i>Ludwigia stolonifera</i> (Guill. & Perr.) Raven		2 (1)		
<i>Mikania sagittifera</i> B.L. Robinson	1 (1)	16 (1)	6 (1)	12 (1)
<i>Miscanthus junceus</i> (Stapf.) Pilg.		22 (5)	9 (5,6)	21 (5,6)
<i>Phragmites australis</i> (Cav.) Steud.	2 (1)	8 (1,2)		2 (1,2)
<i>Pycneus mundii</i> Nees	1 (1)			3 (1)
<i>Pycneus nitidus</i> (Lam.) J. Raynal		7 (1)	4 (1)	8 (1,2)
<i>Scirpus cubensis</i> Poeppig & Kunth ex Kunth			4 (1)	4 (1,2)
<i>Thelypteris interrupta</i> (Willd.) K. Iwats.	7 (1,2)	22 (1,2)	9 (2–4)	21 (1–3)
<i>Typha capensis</i> (Rohrb.) N.E. Br.			6 (1,2)	15 (1–3)
<i>Vigna luteola</i> (Jacq.) Benth.			1 (1)	1 (1)