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Classification and ordination of aquatic macrophytes in the Pongolo River Pans, Natal

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ABSTRACT

The physiography, soils and climate are briefly described for the Pongolo River flood plain pans situated in north-east Zululand (27° S, 32° E), Natal, South Africa. Quantitative vegetation data obtained from 60 stands distributed over 9 pans were summarized using a Braun-Blanquet procedure and a Principal Components Analysis (PCA). Both approaches indicated that the aquatic vegetation could be subdivided into two main groups of growth forms: the submerged and the floating and/or rooted-floating aquatic plants, each showing a distribution influenced primarily by physical factors such as exposure and depth of water. In the PCA, each of the above groups was defined by two stand noda, each nodum representing a plant community that could be observed in the field. The Braun-Blanquet analysis further subdivided the floating and/or rooted-floating aquatic plants into groups of species on the basis of chemical and substrate factors.

INTRODUCTION

The Pongolo River flood plain pans are situated in north-east Zululand near the co-ordinates 27° S and 32° E.

In this study, only the (macrophytic) higher aquatic plants were considered, that is, from the order Charales in the phylum Alga upwards. Owing to numerous often conflicting definitions of the term "aquatic plant" (Inversen, 1936; Raunkiaer, 1934), no strict definition was adhered to. For the purposes of this study, only those plants found growing in the water during sampling were considered aquatic.

The Braun-Blanquet system can be defined as a phytosociological technique which aims at a description and classification of vegetation, while Principal Components Analysis (PCA) can be regarded as a technique of axis construction in order to achieve an efficient ordination of stands (Seal, 1964). Ordination is defined as the uni- or multidimensional arrangement of stands so that a statement of stand position, relative to other stands or to the axis or axes of the model, conveys the maximum amount of information about its composition. Although it is true that most ordinations are constructed on the basis of compositional information, the arrangement of stands should also follow environmental gradients of some sort.

In this study, the aim of both approaches was the same: to investigate the possible relationships of any floristic differences to selected environmental factors.

PHYSIOGRAPHY AND SOILS

The Pongolo Pans lie on Cretaceous and Tertiary sediments (Du Preez, 1967), and extend along the flood plain from Otobotini Drift in the south, where the Pongolo River emerges from the Lebombo mountains, northwards to the confluence of the Pongolo and Usutu Rivers (Fig. 1). The entire flood plain lies below the 75 m contour and is on the average between 0,8 and 4,8 km wide. The system of pans comprises some 25 major bodies of water and a mass of smaller pans which total some 2 600 ha under normal summer conditions. During peak summer floods, 10 000 ha may be under water. The largest pans are between 80 and 280 ha in extent and average 1,5 m in depth, the depths varying according to the extent of seasonal flooding or drought. The pans previously relied for their water supply on the annual summer flooding of the Pongolo River but, since closure of the J. G. Strijdom Dam in March 1970, depend on irregular excessive discharges from the dam (Coke, 1970).

A general description of the soils was given by Tinley (1958). Hensley (1968) studied the soils in detail and recognizes two principal soil types, terrace and sandy soils. The terrace soils are derived from alluvium deposited by the Usutu, Pongolo and Ingwavuma Rivers. These range from leached red sandy clay loams and clays, — oxisols of the Msinga, Shorrocks and Makatini Series on well drained sites, to saline calcareous black clay vertisols, such as those of the Rensburg Series, as drainage deteriorates. The sandy soils lie adjacent to the terrace soils of the Pongolo River. The aeolian sandy soils are of marine origin resulting from successive decreases in sea level since the late Pleistocene.

CLIMATE

Two main seasons are experienced in the flood plain area (Fig. 2 and 3).

From May to mid-September, the dry winter season, temperatures vary from 12° C at night to 25° C in the day. Strong winds are experienced in this season, especially during August.

The summer rainy season is from the middle or latter part of September to April, with temperatures rising to 32°C and higher. The annual rainfall is ca. 580 mm.

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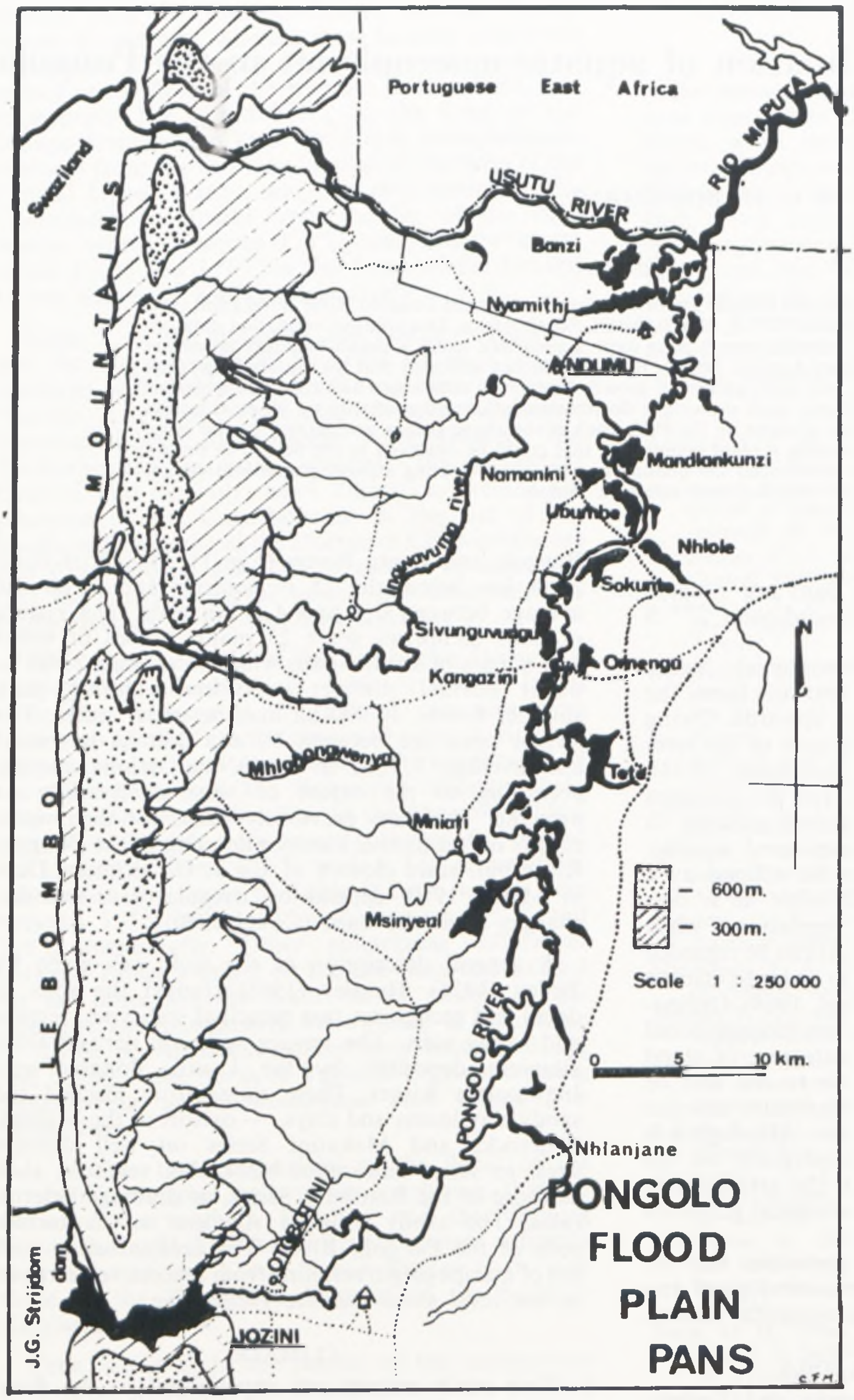

FIG. 1.—Pongolo River flood plain pans (partly after Tinley, 1958).

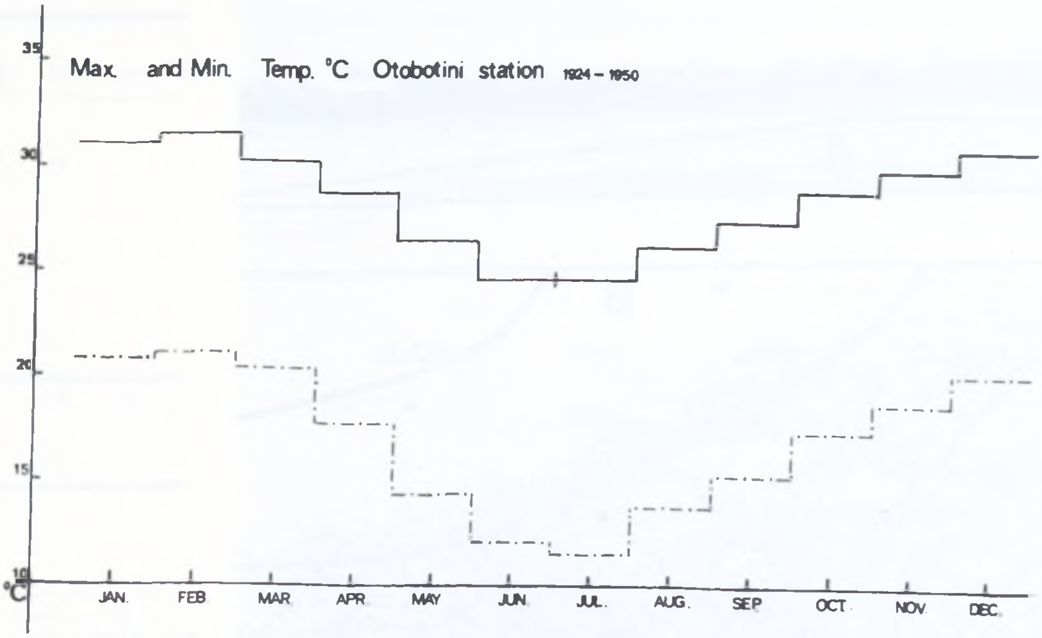

Fig. 2.—Monthly average max. and min. temperature in °C from Otobotini over 26 years.

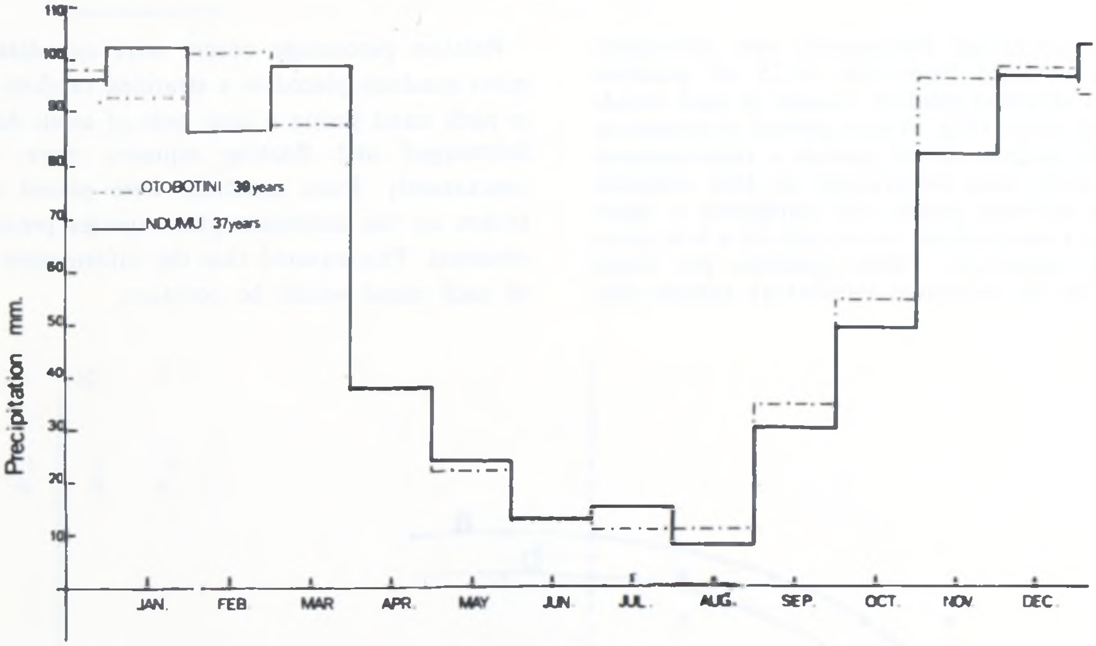

Fig. 3.—Average monthly rainfall in mm from Otobotini and Ndumu stations.

METHODS

Vegetation

Relative percentage frequencies and cover values of species were obtained in each of 60 stands distributed over 14 sampling sites on 9 pans. From south to north these pans were, Msinyeni, Mniati, Mhlabongwenya River, Tete, Omengu, Sivunguvungu, Sokunte, Nhlole and Mandlankuzi.

Sample sites were located at each pan following a subjective assessment of the overall species composition and habitat conditions. It was considered most important that each of these sites be uniform and this was subjectively assessed using all the properties of the vegetation and site that could be directly observed. Each sampling site was subdivided into stands (stand samples) along the depth contours 5, 20, 40, 60, 80 and 100 cm (depth permitting). Each stand, therefore, was a line following a chosen depth contour parallel to a uniform shore and on a uniform substrate (Fig. 4).

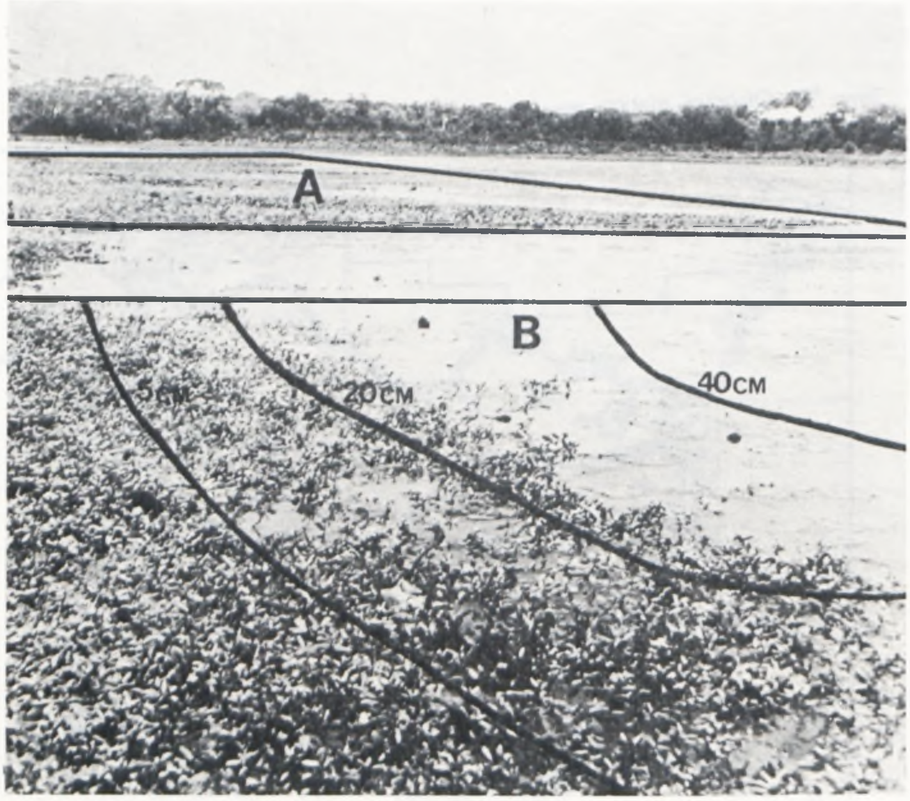

FIG. 4.—View southward of eastern shore of Omengu Pan with two sample sites A and B. Sample site B subdivided into stands at 5, 20 and 40 cm water-depths.

Relative percentage frequencies were calculated from data obtained from forty 0,25 m^2 quadrats placed in a stratified random manner in each stand. Species area curves (Fig. 5) were plotted to determine whether 40 quadrats would provide a representative sample. Curves were constructed on data obtained from three different stands: (a) containing a dense cover; (b) an intermediate cover; and (c) a low cover of aquatic vegetation. Thirty quadrats per stand proved to be the minimum satisfactory sample size.

Relative percentage covers were calculated from point quadrats placed in a stratified random manner in each stand (using a long pole of small diameter). Submerged and floating aquatics were sampled concurrently. Point quadrats were placed until 80 strikes on the dominant plant species present were obtained. This ensured that the information content of each stand would be constant.

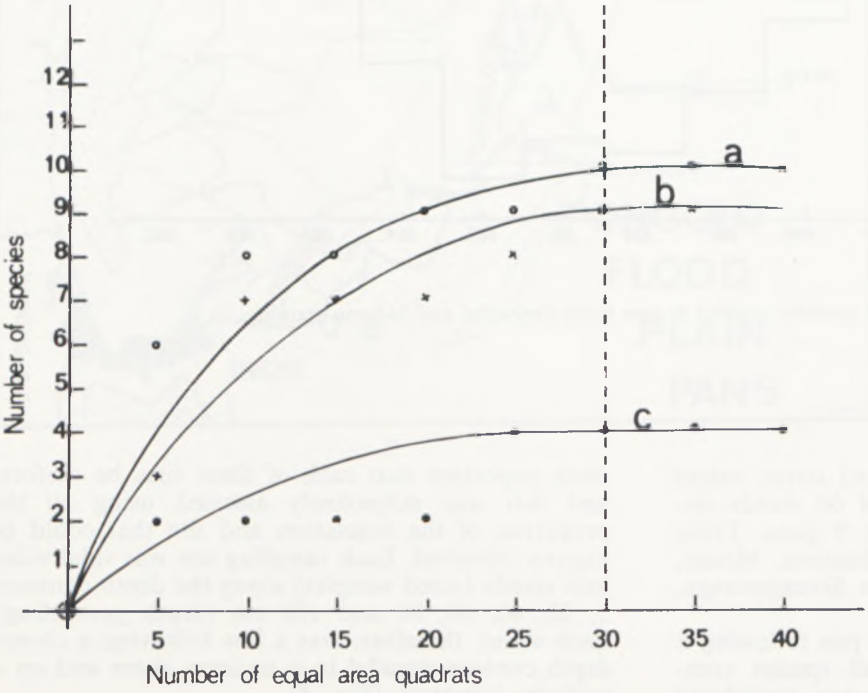

FIG. 5.—Species area curve from three localities to determine a satisfactory sample size.

TABLE 1.—Classification of the aquatic vegetation of the Pongolo pans according to the Braun-Blanquet method.

														C_1									
No.	Species names	50	51	52	61	62	59	49	56	57	58	45	46	29	30	33	34	47	48	44	41	42	43
18	Potamogeton crispus	+4	+4	+4	+1	+2	+2	+4				+4	+4	+2	+4	+4	+4	+4	+4	+3			−1
21	Najas pectinata								+4	+4	+4	−1	−1	−3	−3	+2	−2	−1	−1	−1	+2	−2	−2
36	Nitella tenella							−1							+2	+4	+4	−3	−1	+1	+3	+4	−3
5	Cynodon dactylon																	−3	−1	+1	+1	+1	
2	Cyperus sp ?																				+4	+4	+1
23	Rotala tenella																					−1	−1
24	Limosella capensis																					+1	
25	Phyla nodiflora																				−1		
7	Ludwigia stolonifera																				Y		
4	Echinochloa pyramidalis																						
9	Nymphaea lotus												−1										
10	Nymphaea caerulea																						
20	Limosella maior												−1										
11	Nymphaea capensis																						
8	Ipomoea aquatica																						
26	Scirpus litoralis																						
22	Ceratophyllum demersum											1											
12	Trapa bispinosa																			−1	−1		−1
16	Utricularia gibba subsp. exoleta																						
14	Azolla pinnata var. africana																						
13	Pistia stratiotes																						
1	Scirpus cubensis																						
27	Neptunia natans																						
6	Paspalum vaginatum																						
17	Utricularia inflexa var. stellaris																						
15	Wulffia arrhiza																						
28	Spirodela polyrhiza																						
3	Cyperus nudicaulis																						
29	Cyperus fastigiatus																						
19	Potamogeton schweinfurthii																						
32	Phragmites mauritianus																						
33	Marsilea macrocarpa																						
30	Potamogeton pectinatus				+4																		
31	Najas marina subsp. delilei				+1																		
34	Typha latifolia subsp. capensis																						
35	Ludwigia octovalvis subsp. sessilifera																						
	Total 36	1	1	1	3	1	1	2	1	1	1	2	4	2	3	3	3	4	4	5	6	6	6
	Water depth range cm				20—60									5—100								5—60	
	Water depth average cm				60									71								31	
	Exposure rating	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Bottom substrate class	A	A	B	C	C	A	A	B	B	B	B	B	D	D	D	D	A	A	B	B	B	B
	pH range				8,4–9,3									7,7–9,1								8,4–8,7	
	pH average				8,9									8,5								8,6	
	Specific conductance /umho's range				220–310–7 750									239–290–2 100								235–239	
	Specific conductance/umho's average				N/A									N/A								239	
	Na range mg/l				28,0–700,0									28,0–36,0–230								36,0	
	,, average ,,				N/A									N/A								36,0	
	K range mg/l				0,56–5,56–10,0									0,56–5,55								2,56	
	,, average ,,				2,96									3,66								2,56	
	Ca range mg/l				3,9–36,6									1,5–7,2–36,8								1,5	
	,, average ,,				N/A									N/A								1,5	
	Mg range mg/l				6,25–237,0									6,25–35,06								6,25	
	,, average ,,				N/A									N/A								6,25	
	$\frac{Na}{Ca+Mg}$ range				1,42–1,72									1,36–2,08								2,08	
	$\frac{Na}{Ca+Mg}$ average				1,62									1,75								2,08	
	SiO_3 range mg/l				3,05–3,46									1,25–4,20								4,2	
	,, average ,,				3,31									3,68								4,2	
	Cl range mg/l				60,02–1 180,0									23,7–482,3								23,7	
	,, average ,,				N/A									N/A								23,7	

				Stand						*Numbers*																																
No.	Species names	28	32	31	27	26	2	3	11	13	12	24	22	21	20	17	16	15	14	23	25	18	19	39	4	5	6	7	8	9	10	60	35	36	37	38	40	1	54	53	55	Totals
18	Potamogeton crispus	−1	−4		−1		+1	1	+2	+3	−3	−1			−1						−3	−1								−1	−3											31
21	Najas pectinata																																						+1	−2	+3	20
36	Nitella tenella																																									12
5	Cynodon dactylon																				C_2																					5
2	Cyperus sp ?																																									3
23	Rotala tenella																																									2
24	Limosella capensis																																									1
25	Phyla nodiflora																																									1
7	Ludwigia stolonifera	+1	+1	+3	+4	+4			−1			+4	+4	+4	+4	+4	+4	+4	+4	+4	+3	+4	+4	+1	+4	+4	−1	−1	−1	+4	+4	−2	+4	+4	+4		−1	+4	+4	+4	−3	35
4	Echinochloa pyramidalis		−1	+1	−1	−1	+1	1							−1		−1	+1	−1	−1	+4	+4		+4								+4	+4	+4				+4	+4	+4	+4	21
9	Nymphaea lotus	−2	+2	−2	+1	+1		1	−1	−1	+4	−1									−3	−1	−1							+4	+3						−1					17
10	Nymphaea caerulea	+1	−1	−1	−1						+2	+1	−1	−1	−1	+1	−1				+3	+1	−1			−1				+2												16
																																										16
20	Limosella maior	+4	−1	−1	−3	−1																																				6
11	Nymphaea capensis	+4	+1	−1	+4	+2																																				5
8	Ipomoea aquatica		−1	−3	+1	+3												Y_1																						Z_1		4
26	Scirpus litoralis		+1	−1																																						2
22	Ceratophyllum demersum			X_1			−4	4	+4	+4	+4	−1	+1	−1	−1	+1	−1	−1	−1	−1	−2	+1	+1	+1	−3	−3	+1	+1	+4	+4	+4	+4	−4	+4	+4	+4	+2	+1				33
12	Trapa bispinosa						−1		+4	−1	+1	−1	−1	−1		+2	+1	−1	−1	−2	+2	+2	−3	−1	+4	−3	+4	+4	+4	−2	+1	+4		+4	−4	−4	+4					31
16	Utricularia gibba subsp. exoleta											−1	−2	+1	−1	−3	+3	+3	+2	−2		−3	−2	+1	+2	+2	−1	−1														16
14	Azolla pinnata var. africana											−4	+3	−3	−2	+2	+4	+4	+4	+4	−2	+3	−3																			12
13	Pistia stratiotes								W			−4	+4	+2	−2	+1	+2	+1	+2	+4	−2	+1	+2														−1					13
1	Scirpus cubensis															−3	−4	+4	−3		−1	+2	+3	−1																		8
27	Neptunia natans																	−1	−1	−1					−1	−1																5
6	Paspalum vaginatum															X									+4	+3	−2	−1	+1	+1	+1											7
17	Utricularia inflexa var. stellaris																							x_1								+4	−3	−3	−4	+4	+3					6
15	Wulffia arrhiza																											+2	−1	−2		+4		+4	+4	+4						7
28	Spirodela polyrhiza																																−1	−1								2
3	Cyperus nudicaulis																												y				+1	+1								2
29	Cyperus fastigiatus			−1	−2																														z							2
19	Potamogeton schweinfurthii						+4	+4																																		2
32	Phragmites mauritianus											−1								−1																						2
33	Marsilea macrocarpa																							−2																		1
30	Potamogeton pectinatus																																									1
31	Najas marina subsp. delilei																																									1
34	Typha latifolia subsp. capensis																							−2																		1
35	Ludwigia octovalvis subsp. sessilifera																							−2																		1
	Total 36	8	11	10	9	6	5	5	5	4	5	10	7	7	8	8	9	9	9	9	10	11	9	9	6	7	5	6	5	8	6	6	6	8	5	4	6	3	3	3	3	
	Water depth range cm			5—60					20—60									5—100										5—100							5—100					5—40		
	Water depth average cm			22					36									65										44							41					17		
	Exposure rating	2	4	3	2	2	4	4	3	4	3	2	2	2	2	1	1	1	1	2	3	1	1	2	3	3	3	3	4	4	3	2	2	2	2	2	1	4	4	4	4	
	Bottom substrate class	D	D	D	D	D	A	A	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	A	B	B	B	B	B	B	B	A	A	A	A	A	A	A	B	B	B	
	pH range			7,1–8,8					7,2–7,7									6,3–7,8										7,2–7,4							7,3–8,2					7,7–8,2		
	pH average			7,7					7,5									7,0										7,4							7,6					7,9		
	Specific conductance /umho's range			2 100					230–235									215–260–(630)										230–235							290–420					235–272		
	Specific conductance/umho's average			2 100					233									237										230							391					261		
	Na range mg/l			227–230					27,5									25,0–28,6–(62,5)										27,5							30,0–45,0					27,5–30,0		
	,, average ,,			229					27,5									26,8										27,5							42,0					29,2		
	K range mg/l			3,75–5,33					2,2									2,56–3,30–(7,3)										2,2–2,5							3,9–6,4					2,20–5,55		
	,, average ,,			4,69					2,2									2,93										2,45							4,4					4,7		
	Ca range mg/l			34,8–36,8					1,5–1,9									1,99–5,0–(9,2)										1,5–3,8							5,6–5,7					1,90–7,2		
	,, average ,,			36,0					1,7									3,50										3,47							5,6					3,6		
	Mg range mg/l			34,2–35,06					6,25–7,50									5,86–6,3–(22,5)										7,50–8,75							9,0–12,5					6,25–7,25		
	,, average ,,			34,5					7,0									6,08										8,57							9,7					7,0		
	$\frac{Na}{Ca+Mg}$ range			2,13–2,16					1,74–2,0									1,42–2,15–(1,18)										1,32–1,74							1,0–1,92					1,36–2,0		
	$\frac{Na}{Ca+Mg}$ average			2,14					1,84									1,78										1,38							1,73					1,84		
	SiO_3 range mg/l			3,7					3,4–3,65									3,4 (2,35)										3,4							2,35–7,4					1,25–3,65		
	,, average ,,			3,7					3,50									3,4										3,4							3,36					3,05		
	Cl range mg/l			482,3					22,0–29,8									21,27 (40,42)										22,0							22,69–36,17					29,8–31,2		
	,, average ,,			482,3					25,1									21,27										22,0							33,47					30,8		

To test for adequacy of sample size, appropriate statistical procedures were applied to point quadrat data obtained in a test stand with an intermediate cover prior to the start of the investigation. This revealed that the 80 strikes mentioned would ensure that the cover data for all species had a standard error of less that 10 per cent of the mean. To ensure that stands included in the data would be homogeneous, a Chi-square test for homogeneity (uniformity of distribution) of the plant species present was also conducted from point quadrat data obtained in each stand. For the same reason and in the same way as Curtis and McIntosh (1951), only the strikes contributed by species with a relative percentage cover of 25 per cent and above were tested for homogeneity at the 5 per cent level of significance. Point quadrat data taken sequentially were divided into four groups for the test. The Chi-square test, therefore, had three degrees of freedom corresponding to a tabular value of 7,815. If a calculated value for the observed data was equal to or smaller than this, it indicated homogeneity.

Water and soils

To supplement the vegetation study, physico-chemical analyses were conducted on surface waters in each stand. The following factors were analysed: pH; specific conductance; temperature; O_2 concentration; turbidity; Na^+, K^+, Ca^{2+}, Mg^{2+}, and Fe^{2+} concentrations; total alkalinity as total CO_2 ($HCO_3^- + CO_3^-$); Si–SiO_3^-, Cl^- and PO_4^{-3} according to the method of Golterman (1969); and finally NO_3^- concentration according to the method of Muller & Widemann (1955).

In addition, each stand was assigned an exposure rating which was a subjective assessment of the degree to which the vegetation in a particular stand was exposed to the effects of wind and wave action. Four degrees of exposure were utilized, ranging from 1 in protected areas to 4 in exposed areas. Bottom substrate features such as colour and textures were also briefly assessed for each stand.

TREATMENT OF DATA

Braun-Blanquet Analysis

Frequency data obtained from some 2 480 quadrats, comprising 40×0,25 m² quadrats for 62 stands, were utilized. In this study two additional stands from the extreme east and western ends of Nyamithi Pan were included.

Stands and species were arranged into a comparison matrix. Braun-Blanquet indices of cover abundance and sociability were not used in this study. Each species in a stand was assigned a frequency index value according to the number of quadrats in which it occurred out of forty for each stand. An example of the frequency index values used is as follows:

Quadrat groups	*Frequency index values*
0 to 5..........	−1
6 to 10..........	+1
11 to 15..........	−2
16 to 20..........	+2
21 to 25..........	−3
26 to 30..........	+3
31 to 35..........	−4
36 to 40..........	+4

Entire columns and then rows were manipulated in the unordered matrix to give the best possible ordered matrix according to the method of Braun-Blanquet (Kuchler, 1967). Selected habitat factors measured in each stand were written in the table. For greater clarity in presentation, the range of variation and average values of each environmental factor rather than the individual stands, were recorded under each group of stands classified in the table.

Principal Components Analysis (PCA)

The basic technique of PCA has been described by Kendall (1957).

Quantitative data on presence-and-absence and cover obtained from 59 separate stands were utilized in this analysis. Only those stands which passed the Chi-square test for homogeneity were considered. Species and stands were arranged into a comparison matrix, each species in each stand being assigned an importance value (IV) which was calculated as

$$IV = \frac{2 \times \text{Relative \% Cover} + \text{Relative \% Frequency}}{3}$$

Species density was not measured in the stands as individuals could not be distinguished in some species of aquatic plants, particularly those exhibiting a stoloniferous habit. As the relative percentage covers were regarded as more important they were accordingly weighted appropriately.

Two separate PCA were conducted: one using seven species occurring in 20, that is, 30 per cent or more of the stands, and another using 12 species occurring in 12, that is, 20 per cent or more of the 59 stands. In each case, an analysis was performed utilizing untreated input data and again after normalizing the input data to a standard deviation of one and a mean of zero.

The behaviour of each species and selected environmental factors were obtained by, respectively, plotting their importance values and unmodified quantitative data within the various 3-dimensional stand ordinations constructed on information obtained in each PCA. The most interpretable ordination of stands was obtained in a PCA conducted on seven species utilizing unnormalized input data.

RESULTS

Braun-Blanquet Analysis

Two basic communities labelled C_1 and C_2 were delineated (Table 1).

Community C_1 contained predominantly submerged aquatic species, for example, *Potamogeton crispus*, *Najas pectinata* and *Nitella tenella* while, apart from *Ceratophyllum demersum*, Community C_2 contained a predominance of floating and rooted-floating aquatic species, for example *Trapa bispinosa*, *Ludwigia stolonifera* and *Echinochloa pyramidalis*.

Species belonging to Community C_1 were usually found in more exposed areas and in deeper and more alkaline water than those of Community C_2. For example all stands in Community C_1 were assigned exposure ratings of 4 and their water pH was generally above 8,4, with an average value of 8,6. Stands found in Community C_2, on the other hand, had exposure ratings ranging between 1 and 3 while their pH values were generally below 8,2 with an average value of 7,5. The water depth ranged from 5 to 100 cm in stands of both Communities; however, the average water depth in Community C was 54 cm while in C_2 it was 31 cm. There was considerable overlap in the other environmental factors recorded from stands of both communities.

Community C_1 was further subdivided into two sub-communities: a negatively defined bare Sub-community labelled X; and a Sub-community Y containing a number of rooted submerged or partially submerged marginal species, such as *Rotala tenella*, *Phyla nodiflora*, *Limosella capensis* and an unidentified *Cyperus* sp. These species were generally found in stands with shallower water whose depth ranged from 5 to 60 cm with an average value of 31 cm. In Sub-community X, the stands were found on an average in deeper water ranging from 5 to 100 cm, with an average value of 71 cm.

Community C_2, like C_1, was further subdivided, but into three sub-communities: a bare Sub-community Z_1; a Sub-community Y_1 characterized by the species *Trapa bispinosa* and *Ceratophyllum demersum*; and a Sub-community X_1 characterized by *Nymphaea capensis*, *Limosella maior*, *Ipomoea aquatica* and *Scirpus litoralis*.

The last mentioned Sub-community X_1 was distinguished from the other two on the basis of the considerably higher salinity of its water. The Na^+ concentration was 10× higher, that of Ca^{2+} and Mg^{2+} 5× higher, and that of Cl^- 15 to 20× higher, in its stands than for those composing sub-communities Z_1 and Y_1. In addition, the stands of X_1 all had substrates consisting of a firm black calcareous mud whereas those of Y_1 and Z_1 were found only on soft and firm brown muds.

Y_1 and Z_1 did not separate as two very distinct sub-communities as there was a considerable amount of overlap in the environmental data relating to each of their component stands. On an average, however, stands belonging to Sub-community Z_1 occurred in shallower water and in more exposed areas than those of Y_1, these being found in deeper water and in less exposed areas. For example, stands belonging to Sub-community Z_1 were all assigned exposure ratings of 4 and were found in water ranging in depth from 5 to 40 cm with an average depth of 17 cm. On the other hand, stands belonging to Sub-community Y_1 had exposure ratings generally ranging between 1 and 3 and were found in water ranging in depth from 5 to 100 cm with an average depth of 45 cm.

Sub-community Y_1 was further subdivided into five variants labelled w, x, x_1, y and z. Variant w was bare and negatively defined; x contained the species *Pistia stratiotes*, *Azolla pinnata* var. *africana*, *Utricularia gibba* subsp. *exoleta* and *Scirpus cubensis;* while z contained *Utricularia inflexa* var. *stellaris*, *Wolffia arrhiza* and *Spirodela polyrhiza*. Compositionally, Variant y was considered intermediate between x and z as it contained species from both, that is, *Utricularia gibba* subsp. *exoleta* and *Neptunia natans* from Variant x and *Wolffia arhiza* from Variant z. Variant y was, however, distinguished from the others by the fact that *Echinochloa pyramidalis* was replaced by *Paspalum vaginatum* in its stands. Finally, the fifth Variant x_1 was represented by a single stand (No. 39). It was characterized by the additional species *Marsilea macrocarpa*, *Typha latifolia* subsp. *capensis* and *Ludwigia octovalvis* subsp. *sessilifera*.

All five variants were separated on the different Mg^{2+} concentrations of their stands, which showed no overlap. For example, the highest Mg^{2+} concentrations were found in Variant x_1 with 22,5 mg/l (see x in Table 1), followed by z with a range of 12,5 to 9,0 mg/l, then Variant y with a range of 8,75 to 7,5 mg/l, Variant w with 7,5 to 6,25 mg/l and, finally, the lowest Variant x with 6,3 to 5,86 mg/l. In addition, stands composing Variant x_1 had the highest specific conductance and Na^+, K^+, Ca^{2+} and Cl^- concentrations (Table 1), followed by stands composing variant z. The remaining three variants had similar overlapping values. Moreover, stands included in Variants x_1 and z were found on soft brown muds, those in x and y occurred on firm brown muds, while those of Variant w were found on both soft and firm brown muds.

Principal Components Analysis

From the pattern of distribution of importance values of each species over the stands, five distinct groups of stands with similar floristic composition, termed noda and named after the species with the highest mean importance values in each group, were delineated. Noda were delimited by delineating those stands within the 3-dimensional ordination in which each of the species used in the PCA showed very little or no overlap with each other (Fig. 6). This was found in those stands where each species occurred with an importance value of 30,0 per cent or more.

The following noda were distinguished: the *Potamogeton crispus* Nodum, *Najas pectinata* Nodum, *Ceratophyllum demersum* Nodum, *Trapa bispinosa* Nodum and *Ludwigia stolonifera* Nodum. These noda were found to have meaning in the field where they could be identified as definite plant communities.

The floristic composition of an average stand within the areas occupied by each nodum are indicated in Tables 2 to 6. Mean importance and constancy values for each species occurring in more than two of the various stands comprising each nodum are included. Constancy is the frequency of occurrence of the species in the stands of the nodum expressed as a percentage of the total numbers of stands in nodum.

TABLE 2.—Vegetational characterization of *Potamogeton crispus* Nodum (14 stands)

Species	Mean IV	Constancy
	%	%
Potamogeton crispus	84,9	100,0
Najas pectinata	12,7	57,1
Cynodon dactylon	13,6	21,4
Trapa bispinosa	7,1	14,3
Nymphaea lotus	6,4	14,3
Ceratophyllum demersum	4,5	28,6
Total IV	128,2	

TABLE 3.—Vegetational characterization of *Najas pectinata* Nodum (6 stands)

Species	Mean IV	Constancy
	%	%
Najas pectinata	72,7	83,3
Potamogeton crispus	27,0	50,0
Echinochloa pyramidalis	11,8	33,3
Total IV	111,5	

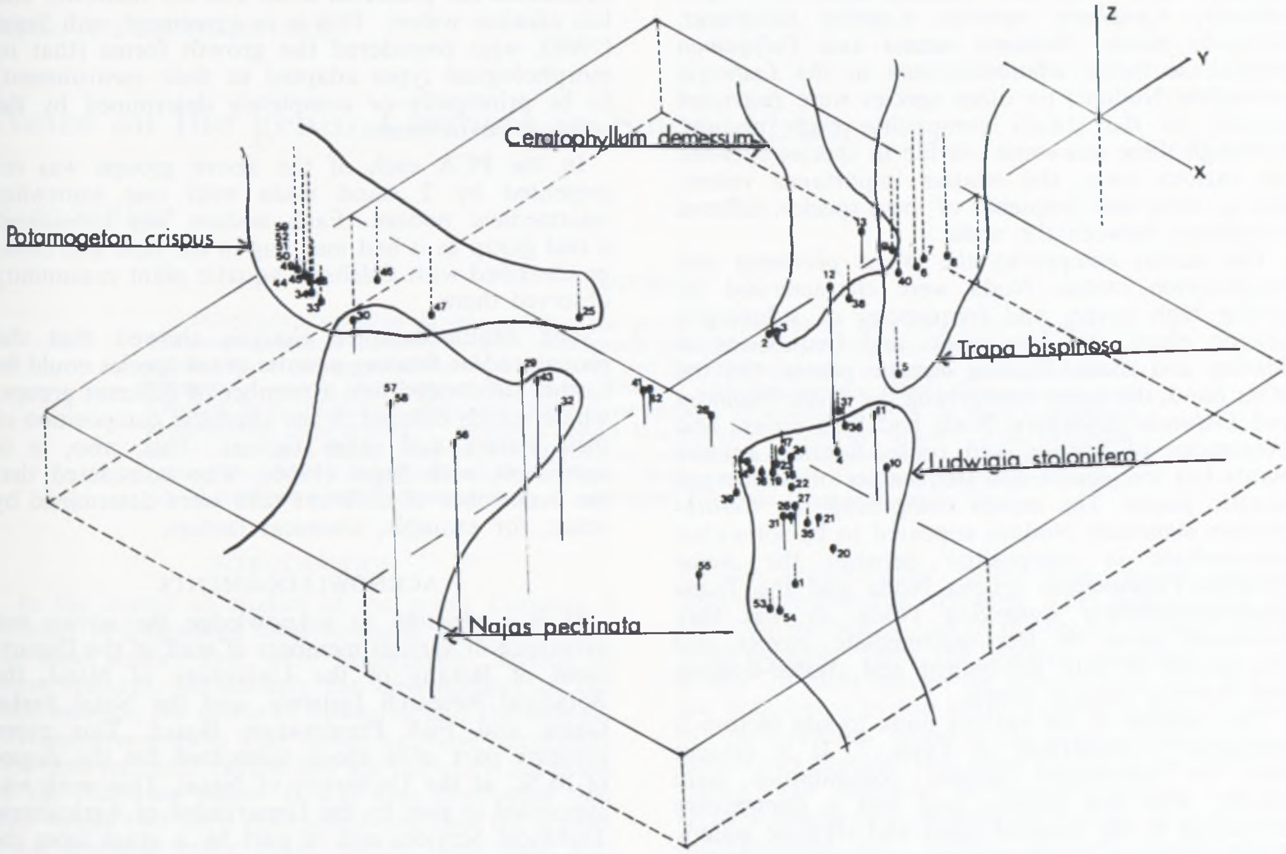

FIG. 6.—Delineation of noda within 3-dimensional stand ordination. Each nodum is named after the species with the highest mean cover and frequency in the stands of the group.

TABLE 4.—Vegetational characterization of *Trapa bispinosa* Nodum (6 stands)

Species	Mean IV	Constancy
	%	%
Trapa bispinosa	62,0	100,0
Ceratophyllum demersum	15,1	100,0
Paspalum vaginatum	6,7	83,3
Ludwigia stolonifera	6,0	100,0
Wolffia arrhiza	3,8	33,3
Utricularia gibba subsp. *exoleta*	3,7	50,0
Nymphaea lotus	1,2	50,0
Nymphaea caerulea	0,5	33,3
Total IV	99,0	

TABLE 5.—Vegetational characterization of *Ceratophyllum demersum* Nodum (4 stands)

Species	Mean IV	Constancy
	%	%
Ceratophyllum demersum	43,8	100,0
Trapa bispinosa	13,6	100,0
Potamogeton crispus	12,2	100,0
Nymphaea lotus	11,3	100,0
Ludwigia stolonifera	1,5	50,0
Total IV	82,4	

TABLE 6.—Vegetational characterization of *Ludwigia stolonifera* Nodum (21 stands)

Species	Mean IV	Constancy
	%	%
Ludwigia stolonifera	41,2	100,0
Echinochloa pyramidalis	17,9	71,4
Pistia stratiotes	16,1	52,4
Azolla pinnata var. *africana*	13,7	52,4
Ipomoea aquatica	13,5	14,3
Scirpus cubensis	12,3	38,1
Nymphaea capensis	11,2	14,3
Paspalum vaginatum	10,8	14,3
Cyperus fastigiatus	7,2	14,3
Nymphaea lotus	7,0	47,6
Utricularia gibba subsp. *exoleta*	6,5	61,9
Trapa bispinosa	5,6	66,7
Ceratophyllum demersum	5,5	81,0
Najas pectinata	4,3	9,5
Limosella maior	3,8	14,3
Neptunia natans	1,4	19,0
Potamogeton crispus	1,4	42,8
Nymphaea caerulea	1,3	57,1
Polygonum senegalense forma *albotomentosum*	1,0	23,8
Total IV	170,40	

The tables show that apart from certain species, such as *Cynodon dactylon* in the *Potamogeton crispum* Nodum; *Paspalum vaginatum* and *Wolffia arrhiza* in the *Trapa bispinosa* Nodum; and *Pistia stratiotes*, *Azolla pinnata* var. *africana*, *Ipomoea aquatica*, *Scirpus cubensis*, *Nymphaea capensis*, *Cyperus fastigiatus*, *Limosella maior*, *Neptunia natans* and *Polygonum senegalense* forma *albotomentosum* in the *Ludwigia stolonifera* Nodum; no other species were restricted entirely to the stands comprising each nodum. Although there was some overlap in species between the various noda, the relative importance values, that is, cover and frequency of these species, differed completely between the noda.

The stands comprising the *Najas pectinata* and *Potamogeton crispus* Noda were characterized by having high covers and frequencies of submerged aquatic plants and low covers and frequencies of floating and rooted-floating aquatic plants. On the other hand, the stands comprising the *Trapa bispinosa* and *Ludwigia stolonifera* Noda had high covers and frequencies of floating and rooted-floating aquatic plants but low covers and frequencies of submerged aquatic plants. The stands comprising the *Ceratophyllum demersum* Nodum appeared to be somewhat intermediate in compositon between the *Najas pectinata-Potamogeton crispus* Noda and the *Trapa bispinosa-Ludwigia stolonifera* Noda, in that they contained more or less intermediate covers and frequencies of both submerged and rooted-floating and floating aquatic plants.

The relation of the various noda to site factors is adequately summarized in Table 7. It is evident that the submerged aquatic communities were simple, with few species, and had a competitive advantage in the exposed areas and alkaline waters. The floating and rooted-floating aquatic communities, on the other hand, were more complex and dominated the protected areas and less alkaline or neutral water.

TABLE 7.—Environmental and other factors characterizing noda on the Pongola pans

Nodum	pH values	Exposure rating	Number of species per stand
Potamogeton crispus	8,5–9,0	4 (exposed)	1–4
Najas pectinata	7,0–8,5	4 (exposed)	1–4
Ceratophyllum demersum	7,0–7,5	4 (exposed)	5–7
Trapa bispinosa	7,0–7,5	3 (partially exposed)	5–7
Ludwigia stolonifera	6,3–7,5	1, 2 (protected)	8–11

CONCLUSIONS

The Braun-Blanquet and PCA approaches showed that the aquatic vegetation in the pans of the Pongolo River flood plain could be divided into two groups of growth forms, the submerged and the floating and/or rooted-floating aquatic plants, each showing a distribution influenced primarily by physical habitat factors. The submerged aquatics succeeded best in the exposed areas and deeper and more alkaline waters, whereas the rooted and/or floating aquatics dominated the protected areas and the shallower and less alkaline waters. This is in agreement with Segal (1966), who considered the growth forms (that is, morphological types adapted to their environment) to be principally or completely determined by the physical environment.

In the PCA each of the above groups was represented by 2 stand noda with one somewhat intermediate nodum. Each nodum was considered a real group as it had meaning in the field and could be identified with a definite aquatic plant community observed there.

The Braun-Blanquet analysis showed that the rooted and/or floating aquatic plant species could be further subdivided into a number of different groups, whose stands differed in the chemical composition of their waters and other factors. This, also, is in agreement with Segal (1966), who considered that the occurrence of different taxa were determined by other, for example, chemical factors.

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