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Wetland plant communities in the Potchefstroom Municipal Area, North-West, South Africa

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Keywords: Braun-Blanquet, DECORANA, disturbed areas, MEGATAB, TURBOVEG, TWINSPAN, urban open spaces

ABSTRACT

Wetlands in natural areas in South Africa have been described before, but no literature exists concerning the phytosociology of urban wetlands. The objective of this study was to conduct a complete vegetation analysis of the wetlands in the Potchefstroom Municipal Area. Using a numerical classification technique (TWINSPAN) as a first approximation, the classification was refined by using Braun-Blanquet procedures. The result is a phytosociological table from which a number of unique plant communities are recognised. These urban wetlands are characterised by a high species diversity, which is unusual for wetlands. Reasons for the high species diversity could be the different types of disturbances occurring in this area. Results of this study can be used to construct more sensible management practises for these wetlands.

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INTRODUCTION

According to the Ramsar Convention, which is also known as The Convention on Wetlands of International Importance, wetlands can be described as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary (Cowan 1995). The water of wetlands can be static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six metres. Wetlands may include adjacent riparian and coastal areas (Cowan 1995). Wetlands also refer to a mosaic of ecosystems that typically form transition zones between uplands and aquatic environments, although some do have discrete boundaries thus not providing gradual transitions (Catallo 1993).

Wetlands have many beneficial functions which are of chemical, biological, socio-economical and physical or hydrological nature (Williams 1990) and they play an important role as water reservoirs, stream flow regulators, flood attenuators, water purifiers and controllers of soil erosion (Walmsley 1988). Additionally, wetlands form specialised habitats for a great variety of plant and animal species.

Many natural wetlands have been destroyed in the course of agricultural, industrial and urban development (Archibald & Batchelor 1992), and are regarded as one of South Africa's most endangered ecosystem types (Walmsley 1988). The increasing use of fertilisers and insecticides in catchment areas of wetlands and the further threat of pollution by industries and the almost indiscriminate use of some areas for grazing, contribute greatly to the degradation of wetlands (Fuls *et al.* 1992). As early as 1951, Louw made the observation that the modification of natural vegetation and the destructive consequences of man's interference in the Potchefstroom area, is nowhere as evident as along the numerous vleis, wetlands and spruits.

Conservation and management of wetlands need to be addressed to ensure the natural functioning of these areas as well as the maintenance of species diversity (Eckhardt *et al.* 1993a). The need for the conservation of urban wetlands resulted in the development of programmes such as the Metropolitan Open Space Systems (MOSS) programme of which the Durban MOSS (D'MOSS) is a prime example. This programme proposed a new holistic approach to city planning, one whereby indigenous plants form an integral part of the urban landscape (Roberts 1993). Because rivers, streams, pans, marshes, estuaries, and lagoons are critically important to both man and wildlife (Cooper & Duthie 1992), wetlands within urban areas should form the essential core areas of any MOSS network. The MOSS approach is presently also being implemented in Durban, Pietermaritzburg, East London, Port Elizabeth, Bloemfontein, the East Rand, Port Alfred and Empangeni.

One of the first priorities, before a system such as MOSS can be implemented, is an extensive phytosociological survey of the plant communities within the municipal borders (Roberts 1993). Before conservation strategies can be successfully implemented, detailed knowledge and information of individual biotopes, their ecological characteristics, location, and distribution within the municipal area should be obtained, as well as knowledge of the faunal and floral composition of these

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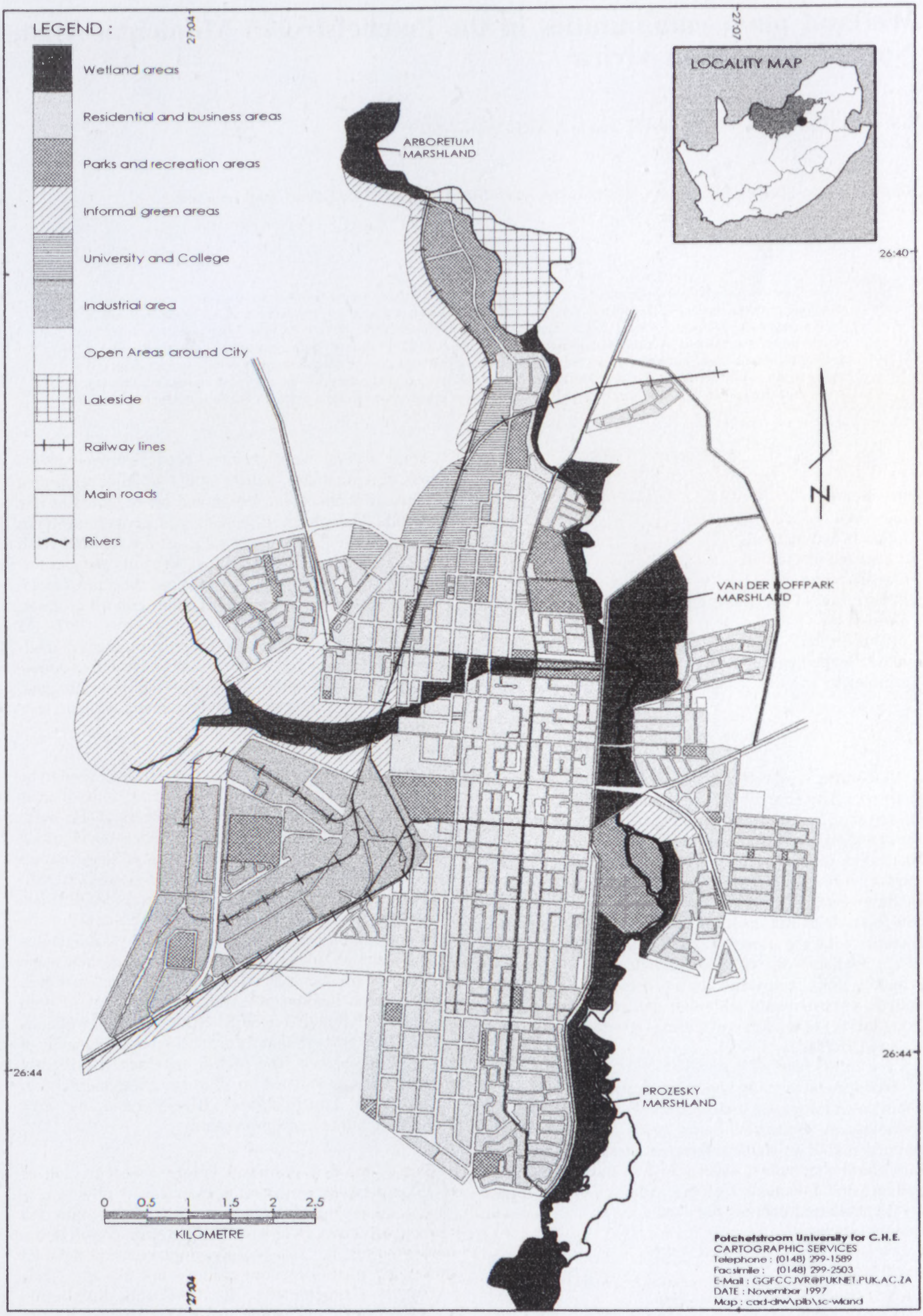

FIGURE 1.—Location of the wetlands and adjacent areas with different land use in the Potchefstroom Municipal Area, North-West, South Africa.

biotopes (Starfinger & Sukopp 1994). The presence or absence of some species in these biotopes may often serve as a bio-indication of the disturbance or pollution in these biotopes (Starfinger & Sukopp 1994).

Although phytosociological studies of wetlands in natural areas in the Grassland Biome have been done by, among others, Kooij *et al.* (1991), Fuls *et al.* (1992), Bloem *et al.* (1993), Eckhardt *et al.* (1993a), Myburgh *et al.* (1995) and Smit *et al.* (1995), no literature concerning the phytosociology of urban wetlands exists. Bezuidenhout (1993) did not study wetlands in his comprehensive syntaxonomical and synecological study of the western Transvaal Grasslands, which include the natural areas around Potchefstroom. The only study on the wetlands of the Potchefstroom area was that of Louw (1951).

The objective of this study was, therefore, to conduct a complete vegetation analysis of wetlands within the Potchefstroom Municipal Area. Through this study it should be possible to ascertain the extent of disturbance due to urbanisation. This study forms part of an extensive study of urban open spaces in a number of cities in the North-West, South Africa, with the ultimate aim of a phytosociological and syntaxonomical synthesis of all urban open spaces.

STUDY AREA

Potchefstroom is situated in the Dry Sandy Highveld Grassland (Bredenkamp & Van Rooyen 1996) of the Grassland Biome (Rutherford & Westfall 1994).

The present study covered the wetlands within the Potchefstroom Municipal Area (between 27° 04' and 27° 07' longitude and 26° 40' and 26° 44' latitude) in the North-West province (Figure 1). Potchefstroom is located around the Mooi River, near the confluence of the Mooi River and Loopspruit. Geologically this area is underlain by Pretoria Group strata, namely shale and quartzite with major diabase intrusives. The diabase sills and the Pretoria Group shale are major sources of clay, which may be supplemented by Karoo age clays weathered from palaeokarst in Malmani Dolomite along the upper reaches of the Mooi River (Nel *et al.* 1939).

The rainfall in Potchefstroom is erratic, but the mean annual rainfall exceeds 600 mm. Summer temperatures are high, the mean monthly maximum temperatures exceed 32° C during October to January, whereas the mean monthly minimum temperatures are below −1° C during the months of June to August (Weather Bureau 1988).

The entire Potchefstroom area is drained by the Vaal River and its tributaries, of which the Mooi River and Loopspruit are the most important. The latter has its origin near Losberg. The Mooi River is a perennial stream, fed by a number of strong springs in the dolomite formation, within and beyond the northern limits of the area.

The study area includes three large marshland areas which will be referred to as the Arboretum, Van der Hoff Park and Prozesky marshlands (Figure 1) and a number of very small marshland areas which will not specifically be referred to. The Arboretum is a conservation area on the city margin in the northern part of Potchefstroom, northwest of the Potchefstroom Dam and is bordered by natural grasslands. This area is relatively undisturbed in comparison with the other two marshlands, although it is invaded by large reedswamps. The Van der Hoff Park marshland is situated between two residential areas close to the city centre, but is heavily disturbed due to grazing especially by horses. It is a very flat bottomland area without any deep depressions or drainage canals. The marshlands referred to as the Prozesky marshlands are situated in the O.P.M. Prozesky Bird Sanctuary. This conservation area, which stretches from relatively close to the city centre to the southern municipal border, is characterised by deep depressions and drainage canals with higher-lying areas in between, which are heavily grazed by cattle. This wetland is interrupted by a road before it links to a number of dams of the municipal sewage plant. The remaining parts of the banks of the Mooi River houses recreational facilities, sports grounds, including a trim park and a golf course, as well as a number of residential gardens (Figure 1). The Wasgoedspruit which drains the western parts of the city, including industrial areas, as well as natural areas, into the Mooi River, is also part of the system. The Wasgoedspruit is disturbed and part of it is layed out with concrete.

MATERIALS AND METHODS

Relevés were compiled in 102 sample plots during the period January to March 1996. Plot sizes were fixed at 16 m^2 for herbaceous communities and 100 m^2 for woody communities (Bredenkamp & Theron 1978). For each species present in the sample plots, the cover-abundance values according to Braun-Blanquet scales were used (Mueller-Dombois & Ellenberg 1974)

Habitat parameters recorded, included topography, aspect, slope, soil type and various soil properties, including physical and chemical analyses. The soil properties in the A and B horizons included percentage gravel, sand, silt and clay; exchangeable K^+, Na^{2+}, Mg^+ and Ca^+; soil conductivity, soil pH (H_2O), soil depth and the *in situ* soil compaction (together with gravimetric water content) in accordance to the Soil Classification Work Group (1991). Different aspects of direct or indirect anthropogenic influences (human impact) such as mowing, weeding, trampling, grazing, the use of chemicals and erosion, were also recorded as thoroughly as possible. It was impossible, though, to quantify the intensities of these anthropogenic influences, but terms such as heavy trampling, heavy grazing and frequent mowing are used in the text to express extreme levels of anthropogenic influences.

The TWINSPAN classification algorithm (Hill 1979a) and the BBPC suite (Bezuidenhout *et al.* 1996) were used for analysing the floristic data, as first approximation, and subsequently Braun-Blanquet procedures were used to refine these results. A phytosociological table (Table 1) was obtained through these procedures.

This approach proved to produce ecologically reliable results in many phytosociological studies in natural areas

TABLE 1.—Phytosociological table of wetlands in the Potchefstroom Municipal Area, North-West, South Africa

RELEVE NUMBER																																																														1											1																			1									
	5	5	8	6	1	6	6	9	5	5	6	6	8	6	6	6	7	7	7	7			7	8	8	9	9	6	7	2	7	7	2	3	8	1	1	3	3	8	1	4	4	4	4	4	7	2	2	4	2	2	3	3	6	7	1	1	3	3	3	8	0	1	1	1	2	2	3	3	4	5	8	0			2	4		5	5	2	4	4	5	8	5			9	9	9	0	5	8	9		1	9		9	9
	6	8	6	0	3	5	7	0	7	9	1	2	9	4	6	3	0	1	3	4	1	2	5	1	8	2	3	9	2	6	7	8	1	9	0	6	8	4	6	4	5	2	5	7	8	9	9	7	8	3	0	4	3	8	8	6	4	9	1	2	7	2	0	1	2	7	3	9	0	5	1	4	5	1	8	9	2	0	3	3	5	5	4	6	0	7	1	6	7	5	7	8	2	2	3	6	5	0	9	4	4	1
TURBOVEG NUMBER	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	1	2	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	2	2	2	1	1	2	1	1	2	1	2	2
	7	7	0	7	2	8	8	0	7	7	7	7	0	8	8	7	8	8	8	9	1	1	9	9	0	0	0	8	8	4	9	9	3	5	9	3	3	5	5	0	3	5	6	6	6	6	9	4	4	5	3	4	4	5	8	9	3	3	4	4	5	9	1	2	2	3	3	4	4	5	5	7	0	1	2	2	3	5	1	6	7	4	6	6	6	0	6	2	2	1	1	1	1	6	9	1	2	2	1	2	1	0
	2	4	2	6	9	1	3	6	3	5	7	8	5	0	2	9	6	7	9	0	7	8	1	7	4	8	9	5	8	2	3	4	7	5	6	2	4	0	2	0	1	8	1	3	4	5	5	3	4	9	6	0	9	4	4	2	0	5	7	8	3	8	6	7	8	3	9	5	6	1	7	0	1	7	4	5	8	6	9	9	1	1	0	2	6	3	7	2	3	1	3	4	8	8	9	2	1	6	5	0	0	7
SPECIES NUMBER	2	1	1	1		1	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1		1	1	1	1	1	1	1	1		1	1			2	1	1	1	2	3	2	1	2	1		2	1	1	1	1	2	1	1	1		1	1				1	1			1	1	1	1	1	1		1	1	1	1	1	1				1					1	1				1					1				
PER RELEVE	3	9	1	3	5	8	4	2	3	6	2	2	3	8	4	2	1	5	7	1	3	1	9	9	1	6	8	4	3	7	2	8	7	3	9	8	2	1	6	1	1	2	0	6	7	5	9	1	1	5	7	5	1	5	5	1	6	2	0	6	9	7	1	0	7	9	0	1	1	0	1	0	5	4	6	4	4	1	4	7	8	9	0	6	6	3	3	5	3	6	4	3	4	4	5	7	5	0	2	7	4	1
COMMUNITY	1																2				3							4					5.1																													5.2															5.3						6				7	8		9			10							11		12
SUBCOMMUNITY	1.1			1.2		1.3			1.4																								5.1.1																	5.1.2						5.1.3					5.2.1		5.2.2																																						
VARIANT																																	5.1.1.1									5.1.1.2						5.1.1.3																																																														
SPECIES GROUP A																																																																																																										
Rhus pyroides v. pyroides -s1	A	3	1	1					+																			r		+	A																																																																										
Maytenus heterophylla -s1	+	r	+																																																																																																										
*Pyracantha angustifolia -s1	3																															r																																																																														
SPECIES GROUP B																																																																																																									
*Populus x canescens -t2	+			4	5																																																																																																								
SPECIES GROUP C																																																																																																									
*Populus wislizenii -t1						3	4	3																																																																																																			
*Fraxinus pennsylvanica -t2							1																																				r		r																																																												
SPECIES GROUP D																																																																																																										
*Salix babylonica -t1	1	3	3	3		B	3	3	3	A	3	3	3	3	3	3																																																																																							
*Araujia sericifera -hl	+	+		+	+	A			+		1	A			A	1															1																																															r																									
*Morus alba -t3		1	+	A		+				1	A	A	4		1																																																																																							
*Celtis sinensis -t2	+	1					+		A		1			A	1	1																																																																																						
*Melia azedarach -t2	+					+	1		1	1	+	+				+																																																																																							
*Solanum nigrum -s2	r	+		r			r		+	1														r																																																																											
Merremia tridentata -hl				+		r		1		1				r	1						+	+	r																																																																												
*Ligustrum lucidum -t2	1			1		+			+	1																																																																																												
*Pyracantha coccinea -s1	1			1					r					+	+																																																																																						
Equisetum ramosissimum -hl						+	1							B	A																																																													+											+												
Celtis africana -t2				1								+		1		+															A																																																																				
SPECIES GROUP E																																																																																																									
*Amaranthus hybridus -hl																	+	1	+	A									1	+										1	r									+	+		r	+																																																	
*Modiola caroliniana -hl																	+	+	+	+																				A										+																																																						
*Datura stramonium -hl																		+	+	+					+				+																																																																										
*Sorghum halepense -hl													3				1	1																																																																																						
Solanum panduriforme -hl																	+			1																							+																																																											
Commelina benghalensis -hl																	+	+																																																																																					
SPECIES GROUP F																																																																																																								
*Ipomoea purpurea -hl	+				1				r	1	A		+	1		3	+	1	+										+											A												r			r																																															
*Bidens pilosa -hl									+	r		+		r				+	+	+			B																																																																										r		
SPECIES GROUP G																																																																																																								
*Pennisetum clandestinum -hl	1	+		+		A	B	3	A	3	A	3	A	A	4	B	A	B	4	1																						r																																																												
SPECIES GROUP H																																																																																																								
Themeda triandra -hl																					1	+	B	1	3	4	4															r			+																																																									
Berkheya radula -hl	r																				B	B	1	A		B																1														1																																			+	+		+											
Panicum stapfianum -hl																					r	r				1																																																																												
Digitaria eriantha -hl																					+	r		r																																			r																																															
Eragrostis chloromelas -hl																									1		1		+																																																																								
Sida spinosa -hl	r	r																	+							+	+			+													+																																																												
Cymbopogon plurinodis -hl		A																																																																																																				

TABLE 1.—Phytosociological table of wetlands in the Potchefstroom Municipal Area, North-West, South Africa (cont.)

RELEVE NUMBER	56	58	86	60	13	65	67	90	57	59	61	62	89	64	66	63	70	71	73	74	1	2	75	81	88	92	93	69	72	26	77	78	21	39	80	16	18	34	36	84	15	42	45	47	48	49	79	27	28	43	20	24	33	38	68	76	14	19	31	32	37	82	100	11	12	17	23	29	30	35	41	54	85	101	8	9	22	40	3	53	55	25	44	46	50	87	51	6	7	95	97	98	102	52	83	96	5	10	99	4	94	91
COMMUNITY	1																2				3							4					5.1																													5.2															5.3						6				7	8		9			10							11	12
SUBCOMMUNITY	1.1			1.2		1.3			1.4																								5.1.1																		5.1.2						5.1.3					5.2.1		5.2.2																																									
VARIANT																																|5.1.1.1|							|5.1.1.2|				|5.1.1.3|																																																																
SPECIES GROUP I																																																																																																								
Hyparrhenia hirta -hl																							+				3	1	3	3	B																								+																																																								
*Chenopodium mucronatum -hl |1|																									|+| |1|																																																																																	
Urochloa panicoides -hl																										|+| |+|																																																																																		
SPECIES GROUP J																																																																																																								
Asparagus laricinus -s2	A	+	1		A	1	B	B	A	r	A	A	1	1	1	1							+	1	A	A	+	4	+	3	B						r		r			r	r							+				r		+																																					+												
SPECIES GROUP K																																																																																																								
*Physalis viscosa -hl													+			+						+	+	+	1		1		+						r	+	1	+	1	r												r			1																A							+												+					r							
*Verbena bonariensis -hl	r		r																	+				A		+	1	+		+		B					+		1	r		+						r	r	+																									1									r					+								r		r		
Crotalaria virgulata -hl													A													A		+		+							1	1	r																																																																
Haplocarpha lyrata -hl									+												+	+				r											+		r			+														r																																+	+													
SPECIES GROUP L																																																																																																								
*Ambrosia psilostachya -hl													+				r																		1							A	+	A	1	+	1																										+									1				1																		
Eragrostis micrantha -hl																																				A		1				1	1	1	1	+																		1				1												+			3																				
Oxalis pes-caprae -hl	+																																									+		+	+	+																																							+																		
Andropogon schirensis -hl																					r																					A			+	+									+																				1	1												+														
SPECIES GROUP M																																																																																																								
Gomphocarpus fruticosus -s2																					+	+																										r	B	+																												r																								
SPECIES GROUP N																																																																																																							
*Physalis angulata -hl																																																			+	+		+	+																																																		
SPECIES GROUP O																																																																																																								
*Sesbania bispinosa -s2																																				+		A						1													B	A	+	A	B				+				1																						+	r													
*Flaveria bidentis -hl																																								|+|											|r|			|r|	|r|																																																		
SPECIES GROUP P																																																																																																								
*Cichorium intybus -hl																																					B				+	+		+	+	+		A	3	+	+	1	1	+	1		+	r		r	r																									1																		
*Xanthium strumarium -hl						r	1			r				r	1																		+	1	r		r				+	r	r		+			r	r	r	+	A	r	+	B				r																					1	r	+																					
Helictotrichon turgidulum -hl																																	+	+		1		A	A		1					+						1	1	1	1											+				1					r	1		+																										
Eragrostis plana -hl																								r							A						A						+	+	r			+			1	+																										1																									
SPECIES GROUP Q																																																																																																								
Hibiscus trionum -hl								r						r														1		+			+	+			1		r						r			1	r		1			1				A	r	r	B									r		r					r	r																								
*Schkuhria pinnata -hl								+																		+	+	1		1			+	1		+	+	1	1		1			1						+			+					+	r		+									r																																
SPECIES GROUP R																																																																																																								
Cynodon dactylon -hl	1	+				A		A					A				1	+		A				A	1	A		1	A	1	3		3	3	B	A	4	3	4	4	A	4	3	4	3	3	1	A	B	5	B	3	B	3	4	B	4	A	5	4	3								r		r	+	B	1									+																			
*Tagetes minuta -hl						1		+	+	1	1	+		+			+	+	+	+			3	r	+			+	B	1	A						r		1	r	+	+	r	+							+	+	+	+	+	r																																													r		
*Bidens bipinnata -hl	+	1		+		1		+	+	A	+	1	+	+		A	+			1				+	+	+		1	B	1	r	1								+	1	1	+	3	+	+	1	A	B	1	+	+	+	+	+																					1								1																						
SPECIES GROUP S																																																																																																									
Rumex conglomeratus -hl																		1																																												3	3													r									+														A	r	r		+	+	
Veronica anagallis-aquatica -hl																																																																1																																				+							
SPECIES GROUP T																																																																																																									
Berula erecta -hl																																																														A	A	3	1	+	3	3	A	B	4	A	1	3	1	+												+	1				1	B				r	1		+	A	
Mentha aquatica -hl																																																															1	A	1		+		1		+					B		r																						r	1					

TABLE 1.—Phytosociological table of wetlands in the Potchefstroom Municipal Area, North-West, South Africa (cont.)

RELEVE NUMBER	56	58	86	60	13	65	67	90	57	59	61	62	89	64	66	63	70	71	73	74	1	2	75	81	88	92	93	69	72	26	77	78	21	39	80	16	18	34	36	84	15	42	45	47	48	49	79	27	28	43	20	24	33	38	68	76	14	19	31	32	37	82	100	11	12	17	23	29	30	35	41	54	85	101	8	9	22	40	3	53	55	25	44	46	50	87	51	6	7	95	97	98	102	52	83	96	5	10	99	4	94	91
COMMUNITY	1																2				3							4					5.1																														5.2															5.3						6				7	8		9			10							11		12
SUBCOMMUNITY	1.1			1.2		1.3			1.4																								5.1.1																		5.1.2						5.1.3					5.2.1		5.2.2																																								
VARIANT																																	5.1.1.1									5.1.1.2						5.1.1.3																																																							
SPECIES GROUP U																																																																																																							
Conyza podocephala -hl																					+	+		r		1				1			r	1		1	r	r	1		1	B	r	1	1	+		r					r													r				+					+																												
**Plantago lanceolata* -hl							r												r					1				+		+		1				+	1	1	1		1	1	r		+			r	r	+	+		1	+			r							r			1	1			1			1		1																										
**Oenothera rosea* -hl																								r			+														r	+			+	r		1		r			r										+									+						+																							
Setaria sphacelata -hl																					A	1		A	+		B		1													+	+	+	+						1			1					r																													1	+														
**Melilotus alba* -hl					1	r													A						1				+		1						r		1		+	r						1			+	r	+		r	r									+				1										r									r	r		+											
SPECIES GROUP V																																																																																																						
Carex schlechteri -hl																																	r												r													+				1				r	1			+	+			3	+		B	B	+		1		1											A									
SPECIES GROUP W																																																																																																						
Cyperus marginatus -hl																							A	1																	A										A	1	+	B	1	B		+	r		+	+	+	1			+	r			+			4	+		+	1	1											+			1									
SPECIES GROUP X																																																																																																							
Cyperus longus -hl						+									1																+		+	1	B		A		A		A			r	+		A				3	A	A	3	A	B	+	4		1	3	+	+	1	3		B	r	4		3	1	B		+	3	3	A	+	A	B							r	1													
**Paspalum dilatatum* -hl		+	+			1	+	+					+	+			+																1	1	1		+		1	A	A	A	3	1	B	+	+	B	+	+		B	B		A									+			1	3	r		A	+			+	1	+	+						r										r								
Ranunculus multifidus -hl																	r																1	1	A		r	r	r		r				r		1	r	1				+				r	+	r	r			A				1	1	r					1			+	1		B	B	r																				
Falckia oblonga -hl																								1			+						A	B								1		1	1	1	A	1																B	B		1	B	+		1	3		3					+			+			1			+					1									
Stenotaphrum secundatum -hl																																	+									1			B	A		A		1													1	3	3	A		B	B	B						1			1	A	A	A																r				
Senecio inornatus -hl																										r									r							r	r		r	3	r	B	3	3	B			3											+				r						+				B		r	B			1			+	+													
Crinum bulbispermum -hl		+	+						r	r				+																			r	r							r						r					r	r		r	r				r				r		r		r	r	r	r			1	r							r	r					r					+									
SPECIES GROUP Y																																																																																																						
Cyperus fastigiatus -hl							+	+						r	A		+																									r																																									A	3	B	B							1			3		+	1			
SPECIES GROUP Z																																																																																																							
Leersia hexandra -hl													1					1																							+							A					A										1										+				A	3	A	A	+		3	3	A									B				+				
Rumex lanceolatus -hl																	+		+																																																+													1		r	+	+										A								
SPECIES GROUP AA																																																																																																						
Schoenoplectus corymbosus -hl																																																1																																								4											r				
SPECIES GROUP BB																																																																																																										
Paspalum distichum -hl																				A															r																																																			3	3	B	+	B															
SPECIES GROUP CC																																																																																																							
Eleocharis palustris -hl																																	+																														1																											3	B				1									
Chironia palustris -hl																																																																																											+	A													
Samolus valerandi -hl																																																																																											r	r													
Lobelia thermalis -hl																																																																																											+													
SPECIES GROUP DD																																																																																																									
Carex acutiformis -hl																																																																																													4	5	4										
SPECIES GROUP EE																																																																																																									
Typha capensis -hl															r			A																																																								+													r					+	4	4	3	3	4	4	4			
Hydrocotyle verticillata -hl																																																																													1												r					B					+			A	
SPECIES GROUP FF																																																																																																									
Phragmites australis -hl											+	+				1																																																		r				+				+			+	+															1							4	5	
SPECIES GROUP GG																																																																																																										
**Azolla filiculoides* -hl																																																																																																										3

* introduced species

(Behr & Bredenkamp 1988; Bredenkamp *et al.* 1989). An additional software package (TURBOVEG) was used for capture, processing, and presentation of phytosociological data (Hennekens 1996a) as well as a visual editor (MEGATAB) for phytosociological tables (Hennekens 1996b). Introduced species are clearly marked in Table 1. The occurrence of each species in a specific stratum is indicated with a symbol, namely, t1 for a high tree layer (> 10 m), t2 for an intermediate tree layer (5–10 m), t3 for a low tree layer (< 5 m), s1 for a high shrub layer (> 2 m), s2 for a low shrub layer (< 2 m) and hl for a herbaceous layer, in Table 1. Differentiation between trees and shrubs was based on definitions proposed by Edwards (1983). Two different numbering systems were used in Table 1, namely a relevé number which starts at 1 and indicates the relevé numbers which were used in this particular study and a TURBOVEG number which indicates the unique relevé number in the South African phytosociological data base.

Species which were only encountered once or twice during the study or which are not diagnostic for a specific community or group of communities are not included in Table 1. These species are, however, included in Table 2 and are also mentioned in the results. An ordination algorithm, DECORANA (Hill 1979b) was applied to the floristic data to determine floristic relationships between communities and to detect possible habitat and/or disturbance gradients associated with vegetation gradients.

Taxa names conform to those of Arnold & De Wet (1993), but are updated to November 1996 according to the PRECIS floristic data base of South Africa, managed by the National Botanical Institute in Pretoria. Soil nomenclature follows the classification of the Soil Classification Working Group (1991). No attempt was made to formally fix syntaxa names because this is normally avoided in detailed local studies. Formal syntaxonomy will follow after the analyses of all the different land use types in the urban area of Potchefstroom. Formal syntaxa which are referred to in this study were already described by other authors. The names of these formal syntaxa are used as they were published without any attempt to validate invalid names or to correct any typographical errors.

RESULTS AND DISCUSSION

Classification

The classification resulted in the recognition of one major community, 14 communities, nine subcommunities and three variants. The specific position of some of the communities in the three marshland areas are shown in Figure 2.

From the phytosociological table (Table 1) the following communities could be recognised:

1. *Salix babylonica* Woodland Community
1.1. *Rhus pyroides* Subcommunity
1.2. *Populus × canescens* Subcommunity
1.3 *Populus wislizenii* Subcommunity
1.4 *Salix babylonica–Pennisetum clandestinum* Subcommunity
2 *Amaranthus hybridus–Pennisetum clandestinum* Ruderal Community
3 *Berkheya radula–Themeda triandra* Grassland Community
4 *Hyparrhenia hirta* Grassland Community
5 *Cyperus longus* Major Wetland Community
5.1 *Cichorium intybus–Xanthium strumarium* Invasive Community
5.1.1 *Paspalum dilatatum* Subcommunity
5.1.1.1 *Cynodon dactylon* Variant
5.1.1.2 *Ambrosia psilostachya* Variant
5.1.1.3 *Senecio inornatus* Variant
5.1.2 *Cyperus marginatus* Subcommunity
5.1.3 *Sesbania bispinosa* Subcommunity
5.2 *Berula erecta* Community
5.2.1 *Rumex conglomeratus* Subcommunity
5.2.2 *Falckia oblonga* Subcommunity
5.3 *Leersia hexandra* Community
6 *Cyperus fastigiatus–Paspalum distichum* Wetland Community
7 *Schoenoplectus corymbosus* Wetland Community
8 *Eleocharis palustris* Wetland Community
9 *Carex acutiformis* Wetland Community
10 *Typha capensis* Reedswamp Community
11 *Phragmites australis* Reedswamp Community
12 *Azolla filiculoides* Floating Community

Description of the plant communities

1. *Salix babylonica* Woodland Community

This woodland community occurs on the banks of the entire Mooi River, with the exception of parts of the Van der Hoff Park marshland (Figure 2). The soils are deep (> 120 cm) but shallower and with lower clay content (< 50%) than that of the marshland communities. The dominant species in this community is *Salix babylonica* (species group D, Table 1), an introduced tree which is naturalised along watercourses in southern Africa (Henderson 1991). These trees are planted at dams and along riverbanks, but its extensive occurrence along the Mooi River is most likely due to self (vegetative) propagation and dispersal by floodwaters.

Although these trees are aesthetically pleasing and beneficial to man and the environment under certain circumstances, they also have disadvantages such as being a potential threat to the conservation of indigenous riparian and wetland vegetation (Henderson 1991). The prolific lateral root system of *Salix babylonica* is very effective in arresting soil erosion of the river banks, but it may also lead to the damming up of small streams and possibly even flooding during high rainfall seasons.

The diagnostic species of this community are those of species group D (Table 1), and include introduced trees such as *Salix babylonica*, *Celtis sinensis*, *Morus alba* and *Ligustrum lucidum*, as well as the declared invader *Melia azedarach* and the indigenous tree, *Celtis africana*. Other diagnostic species are the shrubs *Solanum nigrum* and *Pyracantha coccinea*, the climbers *Araujia sericifera* and *Merremia tridentata* and the highly invasive rhizomatous fern-like plant, *Equisetum ramosissimum* (species group D, Table 1). Other species in this commu-

TABLE 2.—List of species which occurred only a few times and have relatively low cover-abundance values, as well as species not restricted to specific communities in wetlands of Potchefstroom Municipal Area, North-West, South Africa

Communities	Species	Relevé no.	Cover abundance values
1	**Celtis australis*	57	+
		59	1
		60	1
	**Ligustrum* sp.	58	+
		63	1
	**Robinia pseudoacacia*	58	+
		65	r
1.1	**Achyranthes aspera*	56	r
	**Bidens formosa*	56	r
	**Chenopodium murale*	86	+
	**Malvastrum coromandelianum*	86	r
1.4	**Arundo donax*	57	r
	Rhus lancea	57	+
	**Ulmus parvifolia*	57	r
2	*Echinocloa colona*	71	+
	Urochloa mosambicensis	73	+
3	*Ammocharis coranica*	93	+
	Berkheya pinnatifida	75	+
	Blepharis serrulata	93	r
	Corchorus asplenifolius	93	+
	Crabbea angustifolia	93	1
	**Galinsoga parviflora*	75	+
	Gazania krebsiana subsp. *serrulata*	92	r
	Haplocarpha scaposa	81	1
	Monsonia angustifolia	93	+
	Rhynchosia totta	93	1
	Rorippa fluviatilis	93	+
	Sporobolus fimbriatus	93	1
	Wahlenbergia undulata	2	r
4	*Enneapogon cenchroides*	72	+
	Grewia flava	72	r
	Vigna unguiculata subsp. *stenophylla*	77	r
5.1.1.1	**Argemone mexicana*	18	r
		36	r
	Lactuca inermis	21	r
		39	r
	Xysmalobium undulatum	21	r
		39	r
5.1.1.2	*Asclepias decipiens*	47	r
		48	r
	**Gleditsia triacanthos*	48	r
	**Gomphrena celosioides*	45	+
	Hyparrhenia tamba	45	1
	**Oenothera tetraptera*	42	r
	Salvia stenophylla	42	+
5.1.3	*Tragus berteronianus*	31	r
5.2.2	**Aster squamatus*	9	r
	Persicaria sp.	101	+
	Pycreus betschuanus	8	A
	**Sonchus* sp.	101	1
5.3	**Euphorbia helioscopia*	40	+
	**Euphorbia heterophylla*	22	r
6	*Asclepias decipiens*	50	r
9	**Picris echioides*	97	+
10	*Bulbostylis* sp.	102	+
	**Lycopersicon esculentum*	83	1
	Mentha sp.	102	1
	Peucedanum magalismontanum	5	r
No specific community	*Acacia karroo*	45	r
		57	r
		63	1
		72	+
		93	+
No specific community	*Albuca setosa*	1	+
		3	+
		18	r
		19	1
		25	B
		31	r
		34	r
		48	r
	Aristida congesta	42	+
		73	+
	Brachiaria eruciformis	73	+
		88	1
	**Chenopodium album*	57	+
		58	r
		92	+
	Chloris virgata	59	r
		73	1
		78	1
	**Cirsium vulgare*	9	r
		22	+
		24	+
		42	r
		68	+
		83	r
		84	+
		96	+
		101	r
	**Conyza bonariensis*	15	r
		18	r
		57	r
		58	r
		70	+
		73	r
		96	+
	Dichondra repens	58	+
		70	r
	Imperata cylindrica	8	+
		9	1
		44	+
	Juncus exsertus	6	r
		7	r
		8	+
		9	1
	Kniphofia ensifolia	101	+
		102	1
	Mariscus congestus	8	+
		15	1
		18	r
		21	r
		23	+
		27	r
		33	r
		36	r
		41	r
		78	A
	Marsilea capensis	9	A
		27	r
		42	r
		44	B
		46	1
		48	+
		53	1
		59	1
		78	3
		80	1
	Ornithogalum tenuifolium	1	r
		16	r
		36	r
	Panicum coloratum	19	1
		22	+

* introduced species.

TABLE 2.—(cont.)

Communities	Species	Relevé no.	Cover abundance values
No specific community	*Panicum coloratum* (cont.)	37	r
		40	+
		42	r
	Persicaria amphibia	67	r
		87	+
	Persicaria lapathifolia	45	+
		49	+
		70	1
		71	1
		73	1
		83	1
		89	B
		96	+
	Pseudognaphalium undulatum	17	r
		81	r
	**Rumex crispus*	101	+
		102	+
	Setaria pallide-fusca	70	+
		82	+
		84	A
		86	+
	Setaria verticillata	20	+
		70	+
	**Taraxacum officinale*	42	1
		61	+
		62	+
		63	r

* introduced species

nity are the turf grass, *Pennisetum clandestinum* (species group G, Table 1), the indigenous but invasive shrub, *Asparagus laricinus* (species group J, Table 1) and introduced annuals such as *Tagetes minuta* and *Bidens bipinnata* (species group R, Table 1).

Although Eckhardt *et al.* (1993a) mentioned the presence of huge specimens of *Salix babylonica* along the Klip River and in the Seekoeivlei area, northeastern Free State, no *Salix babylonica* Community was described.

Four subcommunities can be distinguished in the *Salix babylonica* Woodland Community, based on species composition:

1.1. *Rhus pyroides* Subcommunity

This subcommunity is situated mainly on the city margin in relatively dry areas on the river banks, but occurs on lower-lying areas which are seasonally waterlogged, as well. It is commonly associated with vertic soils, for example the Arcadia soil form. It is further characterised by the presence of a dense shrub stratum (canopy cover of 70% and up to 3 m tall) underneath the *Salix babylonica* trees. The diagnostic shrubs are the indigenous species *Rhus pyroides* and *Maytenus heterophylla* and the introduced species *Pyracantha angustifolia* (species group A, Table 1). Another shrub with relatively high cover in this subcommunity is *Asparagus laricinus* (species group J, Table 1) which is an important component of bush encroachment in disturbed areas in the Grassland Biome (Friedel 1987; Cilliers & Bredenkamp in press). The tree stratum of 70% canopy cover and height of 8 m is equally well developed and consists of the trees mentioned in species group D (Table 1). One other tree, *Robinia pseudoacacia* and a number of herbaceous species which occurred only once in this subcommunity are mentioned in Table 2. The herbaceous stratum is poorly developed with a canopy cover of 5% and a height of 90 cm. An average number of 17 species was recorded per sample plot of which 73% were introduced and only 23% were therophytes.

1.2. *Populus × canescens* Subcommunity

On wetter areas on the river banks and on small islands in the Mooi River, the prolific invader *Populus × canescens* (species group B, Table 1) forms dense stands

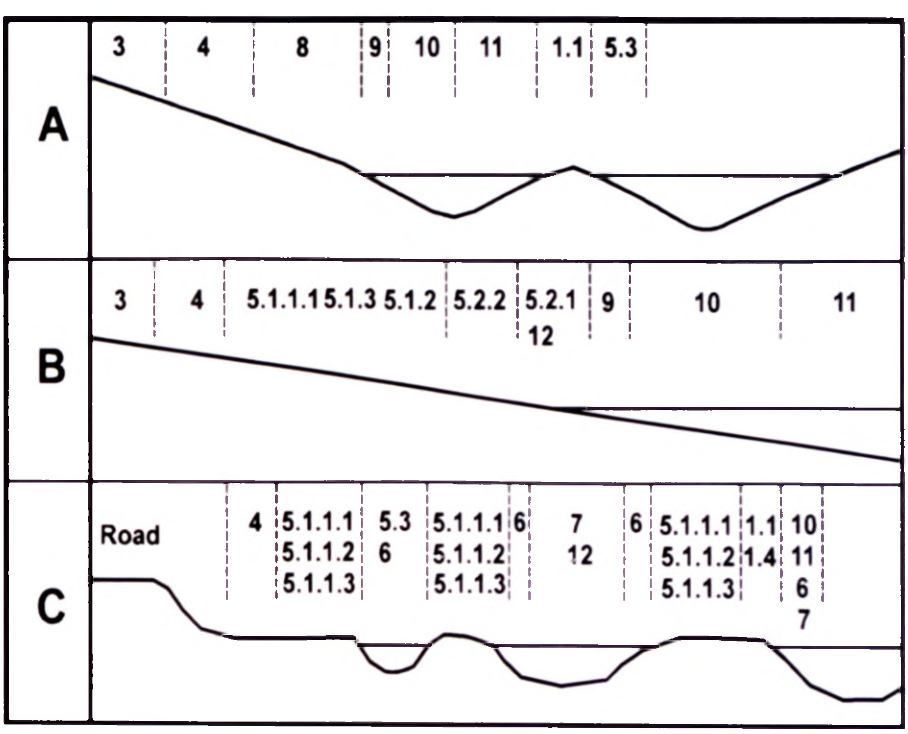

FIGURE 2.—Schematic illustration of some of the communities in three marshland areas in wetlands of Potchefstroom Municipal Area, North-West, South Africa. A, Arboretum; B, Van der Hoff Park; C, O.P.M. Prozesky Bird Sanctuary. All other symbols explained in text.

due to root suckering. Although *Populus × canescens* can also arrest soil erosion, it has the same disadvantages as *Salix babylonica,* namely a threat to indigenous wetland communities and it may also cause flooding. The shrub and herbaceous strata are poorly developed, in comparison with the tree stratum (canopy cover of 80% and 8 m tall). Not many other species grow in this subcommunity, apart from climbers such as *Araujia sericifera* and *Merremia tridentata* (species group D, Table 1), and the shrub *Asparagus laricinus* (species group J, Table 1). An average number of nine species was recorded per sample plot of which 81% were introduced and only 12% were therophytes.

1.3. *Populus wislizenii* Subcommunity

This subcommunity is characterised by the presence of the diagnostic tree *Populus wislizenii* (species group C, Table 1), a very large and conspicuous shade tree which is planted in adjacent parks. These trees propagate by means of cuttings and do not show any great tendency to sucker and therefore, it is not sure how they are spreading into the *Salix babylonica* Community from the parks. This subcommunity, established on the higher river banks, which are built up by man or which is the result of deep streambed incission, rarely occurs at water level. It is situated mainly on the man-made or anthropogenous soil type, Witbank, but still with a clay percentage of close to 40%. The very well-developed tree stratum with a canopy cover of nearly 100% and a maximum height of 12 m, makes this subcommunity very conspicuous. The shrub and herbaceous strata are poorly developed. An average of 14 species per sample plot was recorded for this community of which 76% were introduced and only 7% were therophytes.

1.4. *Salix babylonica–Pennisetum clandestinum* Subcommunity

The *Salix babylonica–Pennisetum clandestinum* Subcommunity occurs mainly along the river banks in parks, sports grounds and other recreational areas, but was occasionally encountered in some of the marshy areas as well. The main soil type on which this subcommunity occurs is the vertic Arcadia soil form, but it is also associated with the anthropogenous soil form, Witbank. The soils are relatively deep, with a high clay content and is sometimes heavily compacted (up to 4 kg/m^2). Although no diagnostic species occur in this subcommunity it is characterised by the absence of the species of species groups A, B and C (Table 1) and a relatively high cover of the turf grass, *Pennisetum clandestinum* (species group G, Table 1), which invades from adjacent lawns. The dominant tree is *Salix babylonica* in the well-developed tree stratum (canopy cover of 65% and up to 8 m high). The total lack of young trees establishing in this subcommunity is worth mentioning. The shrub stratum which consists mainly of *Asparagus laricinus* close to the stems of the trees, has a canopy cover of 20% and an average height of 1.5 m. Apart from *Pennisetum clandestinum,* the well-developed herbaceous stratum (70% canopy cover) consists mainly of introduced forbs such as *Taraxacum officinale* (Table 2) and the annuals, *Ipomoea purpurea, Bidens pilosa* (species group F, Table 1), *Tagetes minuta* and *Bidens bipinnata* (species group R, Table 1). Parts of this subcommunity are mown every 4–6 weeks together with adjacent lawns, according to Mr P. Labuschagne, Department of Parks and Recreation, Potchefstroom Municipality. An average number of 15 species per sample plot was recorded of which 64% were introduced and 13% were therophytes.

2. *Amaranthus hybridus–Pennisetum clandestinum* Ruderal Community

This community is situated on alluvial deposits in the beds of parts of the Wasgoedspruit as well as on its gently sloping inner banks. It is also developing on debris which is the result of an attempt to cover the beds of some areas with concrete. The Wasgoedspruit drains some of the natural areas on the west side of Potchefstroom, as well as industrial areas where a number of chemical plants are situated. Sporadic chemical pollution of this drainage canal was, therefore, encountered in the past. The pollution is probably one of the reasons why no true wetland or reedswamp communities developed in this area. The Wasgoedspruit is mostly dry, but is heavily disturbed during floods, making this a true ruderal community. The *Amaranthus hybridus–Pennisetum clandestinum* Ruderal Community is associated with the Witbank (anthropogenic) soil form with a clay content of < 40%, and which are at places rather heavily compacted (4.5 kg/m^2).

No tree or shrub stratum exists, but the herbaceous stratum is relatively well developed with a canopy cover of about 50% and an average height of 1 m. The turf grass *Pennisetum clandestinum* (species group G, Table 1) which invades from adjacent parks, is the dominant species. The diagnostic species include introduced forbs and grasses, such as the annuals *Amaranthus hybridus* and *Datura stramonium,* which is also a declared weed (Wells *et al.* 1986) and the perennials *Modiola caroliniana* and *Sorghum halepense,* as well as the indigenous forbs, *Solanum panduriforme* and *Commelina benghalensis* (species group E, Table 1). Other species which were only recorded once in this study are indigenous grasses such as *Chloris virgata, Urochloa mosambicensis, Brachiaria eruciformis, Echinocloa colona* and *Aristida congesta* (Table 2). Other species in this community are the highly invasive pioneer grass *Cynodon dactylon* and the conspicuous tall-growing annuals, *Tagetes minuta* and *Bidens bipinnata* (species group R, Table 1). An average number of 14 species was recorded per sample plot, of which 46% were introduced and 35% were therophytes.

3. *Berkheya radula–Themeda triandra* Grassland Community

The *Berkheya radula–Themeda triandra* Grassland Community forms a transitional area between adjacent higher-lying grasslands and the lower-lying wetland communities in the study area (Figure 2). Although situated in bottomlands, it is still much higher than the marshlands. This community occurs on clay loam to sandy clay loam soil types, as well as on duplex soils with a high clay content (> 50%), representing the

Valsrivier and Rensburg soil forms, and occasionally on rocky soils of the Glenrosa soil form.

The diagnostic species of this community are those of species group H (Table 1). It includes the two dominant species, the indigenous grass *Themeda triandra*, which is widespread in the Grassland Biome, and the indigenous forb *Berkheya radula* which is characteristic of soils with a high clay content. Other diagnostic species are all indigenous grasses such as *Eragrostis chloromelas, Digitaria eriantha, Panicum stapfianum* and *Cymbopogon plurinodis*. Species which are also abundant in this community are the indigenous grass, *Setaria sphacelata* (species group U, Table 1) and the introduced forb, *Physalis viscosa* (species group K, Table 1). Forbs which are typically found in the adjacent grasslands, such as *Crabbea angustifolia, Rhynchosia totta, Corchorus asplenifolius* and *Monsonia angustifolia* (Table 2) were also encountered in this community. This community is further characterised by the encroachment of the shrub, *Asparagus laricinus* (species group J, Table 1) forming a canopy cover of up to 12% in some areas. No tree stratum exists in this community. An average number of 13 species per sample plot was recorded of which 25% were introduced and 11% were therophytes.

This community resembles, to a certain extent, the *Themeda triandra* Variant of the *Eragrostidetum planae*, an association described for the seasonally wet bottomlands of the Bc land type in which Potchefstroom is situated (Bezuidenhout & Bredenkamp 1991). A similar grassland community which represents a transitional zone between relatively dry and wet grasslands, the *Themeda triandra–Eragrostis plana* dry/wet grassland was described by Eckhardt *et al.* (1993b) for the northeastern Free State.

4. *Hyparrhenia hirta* Grassland Community

The *Hyparrhenia hirta* Grassland Community is also situated on the seasonally flooded bottomlands adjacent to marshlands, but usually higher than them (Figure 2). It is situated next to the *Berkheya radula–Themeda triandra* Community in some areas but on the lower-lying wetter parts on soils of the Valsrivier and Rensburg soil forms.

The dominant and also one of the diagnostic species is the indigenous grass *Hyparrhenia hirta* (species group I, Table 1). Other species in this community are those of species groups J, K, Q, R and U (Table 1). The herbaceous stratum is well developed with a canopy cover of 70% and a height of 1.5 m. No tree stratum exists in this community, but the shrub stratum with *Asparagus laricinus* and *Rhus pyroides* is relatively well developed (canopy cover of up to 30% and 1.8 m tall). The abundance of the invasive grass, *Cynodon dactylon* and the introduced annuals, *Tagetes minuta* and *Bidens bipinnata* (species group R, Table 1) is an indication of the gradual degradation of this community. An average number of 12 species was recorded per sample plot of which 47% were introduced and 23% were therophytes.

In a syntaxonomical and synecological study of the western Transvaal Grasslands, Bezuidenhout (1993) described a number of wetland communities where *Hyparrhenia hirta* is dominant, and which form part of the *Eragrostido planae–Hyparrhenietea hirtae* (Bezuidenhout *et al.* 1994a). The *Hyparrhenia hirta* Grassland Community, currently described, shows habitat and floristic resemblances to the *Eragrostidetum planae* (Bezuidenhout & Bredenkamp 1991) and the *Hyparrhenio hirtae–Eragrostidetum planae* (Bezuidenhout *et al.* 1994b), but with much lower species diversity.

5. *Cyperus longus* Major Wetland Community

This major wetland community is the largest of all the communities, fringing the reedswamps and is mainly situated in two of the three marshlands in the study area, namely Van der Hoff Park and Prozesky (Figures 1 and 2). It occurs in a very wide spectrum of habitats, namely from dry to seasonally wet to waterlogged areas, as well as in different stages of habitat degradation. All these variations are covered by the different communities, subcommunities and variants.

With the exception of isolated and scattered occurrence of trees and shrubs, no real tree and shrub strata is present in this community. The herbaceous stratum is well developed. The diagnostic species of this major wetland community are those of species group X (Table 1). The most conspicuous of these species are the tall-growing perennial sedge, *Cyperus longus*, which shows a great degree of plasticity as it is encountered in aquatic, helophytic and mesophytic habitats. Because of the effects of grazing and trampling, accompanied by the development of habitats better suited for other species, *Cyperus longus* is disappearing from some areas where it was dominant some years ago. The diagnostic species include true wetland species which are also diminishing in certain areas, such as *Ranunculus multifidus, Falckia oblonga, Stenotaphrum secundatum* and *Crinum bulbispermum*, and invasive species such as *Paspalum dilatatum* and *Senecio inornatus* (species group X, Table 1).

A similar broad major wetland community, the *Echinochloa holubii–Cyperus longus* Wetland was described by Kooij *et al.* (1991) for watercourses, riverbanks, valley flats, flood plains and stream channels in the Kroonstad area, Free State. Although the *Cyperus longus* Major Wetland Community, currently described, is situated on the same soil types it differs from the community described by Kooij *et al.* (1991) with respect to species composition. The difference in species composition is probably due to the type and intensity of disturbances in urban areas.

The *Cyperus longus* Major Wetland Community is divided into the following communities based on habitat and type and intensity of the disturbances:

5.1. *Cichorium intybus–Xanthium strumarium* Invasive Community

This community is highly disturbed and is situated in the heavily grazed areas in the Van der Hoff Park and Prozesky marshland areas (Figure 2). It is characterised by the extensive invasion of the dominant species, the grass *Cynodon dactylon* (species group R, Table 1), which could suggest an enriched nitrogen status of the soil (Kooij *et al.,* 1991), probably due to biotic effects, e.g. from animal excretions. This community is further characterised by the decrease of the sedge, *Cyperus longus* (species group X, Table 1), which probably was the dominant species in this area. The diagnostic species of this community are the introduced forbs, *Cichorium intybus* and the declared weed *Xanthium strumarium* (Wells *et al.* 1986) as well as the indigenous, perennial grasses *Helictotrichon turgidulum* and *Eragrostis plana* (species group P, Table 1). Other species which occur in this community are those of species groups Q and U (Table 1).

Three subcommunities can be distinguished in this community based on water content of the soil and degree of disturbance.

5.1.1. *Paspalum dilatatum* Subcommunity

This subcommunity is situated on the higher-lying, somewhat drier areas occupied by the *Cichorium intybus–Xanthium strumarium* Invasive Community (Figure 2). No diagnostic species occur but it is characterised by the abundance of the conspicuous introduced grass, *Paspalum dilatatum* (species group X, Table 1).

Three variants, which are forming interconnected mosaics or patches with each other, could be distinguished in the *Paspalum dilatatum* Subcommunity:

5.1.1.1. *Cynodon dactylon* Variant

The *Cynodon dactylon* Variant occurs on the flatter areas in footpaths (in the O.P.M. Prozesky Bird Sanctuary) and near entrance gates which are heavily trampled by man and grazing cattle and horses. The footpaths are sometimes mown as well. This variant is associated with the Witbank (anthropogenic) and Rensburg soil forms with deeply cracking, vertic clays, and is also heavily compacted (> 4.5 kg/m^2). With the exception of a number of herbaceous species which were recorded once or twice (Table 2), no diagnostic species were encountered in this variant. It is characterised, however, by the absence of species of species groups L and M (Table 1), the total dominance of *Cynodon dactylon* and a low species diversity in comparison with the other variants. Other species which occur are typically ruderal species which can probably withstand the effect of trampling and grazing such as *Physalis viscosa* (species group K, Table 1), *Plantago lanceolata* and the prostrate indigenous forb, *Conyza podocephala* (species group U, Table 1). An average of 12 species was recorded per sample plot of which 44% were introduced and 20% were therophytes.

5.1.1.2. *Ambrosia psilostachya* Variant

The *Ambrosia psilostachya* Variant of the *Paspalum dilatatum* Subcommunity is mainly associated with the drier, overgrazed areas in the wetlands of Prozesky, on the same soil types as the *Cynodon dactylon* Variant. The diagnostic species are the forbs *Ambrosia psilostachya* and *Oxalis pes-caprae* and the indigenous grasses *Eragrostis micrantha* and *Andropogon schirensis* (species group L, Table 1). Although no tree or shrub stratums exists in this variant, the indigenous shrub *Asclepias decipiens* and the introduced tree *Gleditsia triacanthos* (Table 2) have a scattered distribution. Due to the high levels of disturbance an unusually high average number for wetland areas of 22 species per sample plot was recorded, of which 42% were introduced and only 12% were therophytes.

5.1.1.3. *Senecio inornatus* Variant

The *Senecio inornatus* Variant is encountered in the slightly lower and wetter parts of the higher-lying areas in the wetlands of the O.P.M. Prozesky Bird Sanctuary. Although the diagnostic species is the indigenous shrub *Gomphocarpus fruticosus* (species group M, Table 1), the variant is better characterised by its dominant species, namely the introduced, prostrate grass *Cynodon dactylon* and the indigenous tall-growing forb, *Senecio inornatus*. Although *Senecio inornatus* is also present in other wetland communities, it develops here into relatively dense patches of conspicuous plants due to their height (2 m and higher) and their corymbs of brightly yellow coloured capitula. The sedge, *Cyperus longus*, which was the dominant species in this area about two to three years ago, is totally absent in this variant. An average number of 15 species was recorded per sample plot of which 52% were introduced and 16% were therophytes.

5.1.2. *Cyperus marginatus* Subcommunity

This subcommunity is associated with lower-lying, seasonally waterlogged areas (Figure 2) on the Rensburg soil form with soil compaction of up to 5 kg/m^2 or on the Bloemdal soil form with soil compaction of less than 2 kg/m^2. Although the annual, introduced forb *Physalis angulata* (species group N, Table 1) is the only diagnostic species, this subcommunity is better characterised by the presence of the tall-growing sedge, *Cyperus marginatus* (species group W, Table 1). The invasive grass, *Cynodon dactylon* and the other tall-growing sedge, *Cyperus longus* are still the dominant species. Louw (1951) described *Cyperus marginatus* as a robust species which plays a major role in succession in the Vaal River, but which is relatively unimportant elsewhere. Although this species was found in the Potchefstroom urban wetlands, the subcommunity in which it exists seems to diminish. This is probably due to the effects of trampling and grazing, because it is only situated in relatively small patches in lower-lying, wetter areas. The abundance of introduced annuals such as *Physalis angulata* (species group N, Table 1), *Tagetes minuta* and *Bidens bipinnata* and the declared weed *Xanthium strumarium* (species group R, Table 1) (Wells *et al.* 1986) is a further indication of the degraded state of the *Cyperus marginatus* Subcommunity. An average number of 15 species was recorded per sample plot of which 51% were introduced and 17% were therophytes.

5.1.3. *Sesbania bispinosa* Subcommunity

This subcommunity represents a more degraded form of the *Cyperus marginatus* Subcommunity. The diagnostic species are the introduced, annual to biannual invasive shrub, *Sesbania bispinosa* and the introduced forb, *Flaveria bidentis* (species group O, Table 1). An average number of 11 species was recorded per sample plot of which 53% were introduced and 30% were therophytes.

5.2. *Berula erecta* Community

The *Berula erecta* Community is found in seasonally wet bottomland areas which were at the time of the study partly under standing water of up to 10 cm (Figure 2). The soils are quite deep, undrained vertic soils with a high clay content (> 60%). The community is associated with areas close to or adjacent to the river, in the absence of a tree stratum.

The diagnostic species of this community are the low-growing, indigenous forbs, *Berula erecta* and *Mentha aquatica* (species group T, Table 1). Other species are the tall-growing sedge, *Cyperus longus*, the low-growing, mat-forming forb, *Falckia oblonga* and the indigenous vlei grass, *Stenotaphrum secundatum* (species group X, Table 1). The *Berula erecta* Community is further characterised by the absence of the species of species groups P, Q and R (Table 1), although *Cynodon dactylon* invades into the margins of this community. The vegetation seems to be relatively undisturbed, but trampling by the grazing animals keeps the wet soil in a permanently puddled condition, which favours the establishment of *Phragmites australis* and *Typha capensis* from the adjacent reedswamps (Communities 10 and 11). Although not recorded during the study, blooms of the very invasive water fern, *Azolla filiculoides* can sometimes be found in these puddles, as well. The indigenous geophyte, *Crinum bulbispermum* (species group X, Table 1), although not abundant, has a scattered distribution in this community.

Two subcommunities could be distinguished in this community.

5.2.1. *Rumex conglomeratus* Subcommunity

On slightly lower-lying areas of the *Berula erecta* Community, where water seems to stagnate when the rainfall is high (Figure 2), small clumps of the perennial forb, *Rumex conglomeratus* (species group S, Table 1) establish. An average number of only eight species per sample plot was recorded of which none were introduced and only 8% were therophytes.

5.2.2. *Falckia oblonga* Subcommunity

Although no diagnostic species were recorded for this subcommunity, it is characterised by the formation of small but dense mats of the small, rhizomatous forb, *Falckia oblonga* (species group X, Table 1) in areas where water drainage is faster (Figure 2), and where *Rumex conglomeratus* is absent. Although *Falckia oblonga* was also found on bare areas on the higher slopes of dry vleis, as was suggested by Louw (1951), they are always dominated by the invasive grass, *Cynodon dactylon*, in these areas. It is possible that *Falckia oblonga* finds refuge in the wetter areas, where *Cynodon dactylon* has not established so extensively. An average of 10 species per sample plot was recorded of which 34% were introduced and only 4% were therophytes.

5.3. *Leersia hexandra* Wetland Community

This community was encountered in shallow depressions or pools which are seasonally waterlogged in the O.P.M. Prozesky Bird Sanctuary and occasionally in water on the river's edge in the Arboretum, but never in deep water (Figure 2). Although no diagnostic species were recorded, this community is characterised by the high cover of rhizomatous grass species such as *Leersia hexandra* (species group Z, Table 1) and *Stenotaphrum secundatum* (species group X, Table 1). Other species include the tall-growing sedge, *Cyperus longus* and the forb *Ranunculus multifidus* (species group X, Table 1), as well as the low-growing sedge, *Carex schlechteri* (species group V, Table 1). An average number of 10 species was recorded per sample plot of which 33% were introduced and only 13% were therophytes.

A similar community, the *Leersia hexandra–Schoenoplectus paludicola* Wetland was described by Fuls *et al.* (1992) for the northern Free State.

6. *Cyperus fastigiatus–Paspalum distichum* Wetland Community

This community sometimes occurs on the river's edge, but is mainly associated with shallow to deep drainage depressions or pools which are seasonally waterlogged (Figure 2). In pools where water is stagnant for long periods, this community is mainly situated at the edges. The soils on which this community can be found are vertic soils of the Rensburg soil form, but occasionally also on the Champagne soil form.

The diagnostic species are the tall-growing sedge, *Cyperus fastigiatus* (species group Y, Table 1). The dominant species is the rhizomatous grass *Paspalum distichum* (species group BB, Table 1) which form very dense mats, and tends to grow in deeper water as well. Louw (1951) made the observation in the Vaal River that when this grass migrates to deeper water, its robustness increases and it behaves like a floating aquatic species. This community shows an affinity with the *Leersia hexandra* Community of the *Cyperus longus* Major Wetland Community, because of the presence of the grass, *Leersia hexandra* and the forb *Rumex lanceolatus* (species group Z, Table 1). The *Cyperus fastigiatus–Paspalum distichum* Wetland Community differs, however, from the *Leersia hexandra* Community with respect to the habitat and the fact that the tall-growing sedge *Cyperus longus*, is replaced by another tall-growing sedge, *Cyperus fastigiatus*.

Other species occurring in this community which is worth mentioning are the water fern *Marsilea capensis* and the tall-growing forb *Persicaria lapathifolia* (Table 2: under the heading, no specific communities). An average number of only six species was recorded per sample plot of which 26% were introduced and none were therophytes.

A similar community with an equally low species diversity, the *Paspalum distichum* Community associated with marshes, was described in the Grootvlei area in the eastern Transvaal (Myburgh *et al.* 1995).

7. *Schoenoplectus corymbosus* Community

This community is situated in deeper water in the Mooi River as well as in deep depressions or pools with stagnant water on the Champagne soil form (Figure 2). The diagnostic species is the tall-growing, robust sedge *Schoenoplectus corymbosus* (species group AA, Table 1). Occasionally the rhizomatous grass, *Paspalum distichum* (species group BB, Table 1) invades from the river banks into this community. No other species were recorded in this community.

8. *Eleocharis palustris* Wetland Community

This community is relatively undisturbed and occurs only on the city margin, in the Arboretum. It is situated on vertic soils which are seasonally waterlogged in bottomland areas fringing the reedswamps (Figure 2).

The diagnostic species of this community are the sedge, *Eleocharis palustris* and the forbs, *Chironia palustris, Samolus valerandi* and *Lobelia thermalis* (species group CC, Table 1). The forb *Chironia palustris,* when flowering in summer, transforms this specific community into a conspicuous and aesthetically pleasing pink mass, which was encountered nowhere else in the study area. Although the *Eleocharis palustris* Community is situated in the same type of habitat in which the *Berula erecta* Community occurs in other wetlands, there is no real affinity between these two communities regarding species composition. *Eleocharis palustris,* does, however, have an isolated distribution in the *Berula erecta* Community. An average number of 14 species was recorded per sample plot of which 17% were introduced and 5% were therophytes.

9. *Carex acutiformis* Wetland Community

This particularly species-poor community occurs in two of the three marshland areas (Figure 2), namely the Arboretum and Van der Hoff Park, as well as in other areas along the Mooi River, where it is associated with the *Typha capensis* Reedswamp Community. It either forms a narrow fringe along the reedswamps in waterlogged areas on the Champagne soil form, or it establishes in dense clumps on seasonally waterlogged, higher-lying areas on the Rensburg soil form. This community seems to invade the *Berula erecta* Community and the *Eleocharis palustris* Community.

The diagnostic and dominant, and most of the time the only species occurring in this community is the sedge, *Carex acutiformis* (species group DD, Table 1). All other species which were recorded are species from adjacent wetland communities.

10. *Typha capensis* Reedswamp Community

This community which occupies large areas on seasonally or permanently waterlogged soils (Figure 2) was regarded by Louw (1951) as one of the important constituents of the reedswamps, together with *Phragmites australis.* The *Typha capensis* Community, when occurring together with the *Phragmites australis* Community, is always situated on its outside in shallower water, acting as a pioneer in reedswamp succession in some cases. The *Typha capensis* Community seems to expand rapidly into other communities such as the *Berula erecta* Community. It occurs on the Champagne soil form but also on vertic soils such as the Rensburg and Arcadia soil forms. It was observed in wetlands all over the world that small-seeded anemochorous plants such as *Typha* species, colonise mudflats during periods of drawdown, as well as areas that have been recently disturbed (Ellison & Bedford 1995).

The diagnostic species of this community is the indigenous, rhizomatous bulrush *Typha capensis* and to a lesser extent, the forb *Hydrocotyle verticillata* (species group EE, Table 1). Other species which only occurred once in this study includes the indigenous species *Kniphofia ensifolia* (Table 2: under the heading, no specific communities), which is situated at the edge of the *Typha capensis* Reedswamp Community. An average number of only six species was recorded per sample plot of which 27% were introduced and 17% were therophytes.

11. *Phragmites australis* Reedswamp Community

The *Phragmites australis* Reedswamp Community is mainly situated in permanently waterlogged areas, sometimes in water as deep as 2 m, in the river bed and in all three marshland areas (Figure 2). It colonises, together with the *Typha capensis* Community, also seasonally waterlogged and even higher-lying bare areas along the river. These bare areas are formed due to the destabilisation of substrates in the inner city after heavy rains, when water collects in larger volumes and passes through more quickly than usual.

The dominant and only diagnostic species of this community is the tall-growing reed *Phragmites australis* (species group FF, Table 1). Other species occurring on the edge of this community are ruderal species or species of adjacent wetland communities. This community can easily be distinguished from the other community in the reedswamp, the *Typha capensis* Commnunity, as it grows much higher (> 3 m) and is much denser in certain areas. The very dense growth of *Phragmites australis* may block waterways which lead to water stagnation and provide breeding places for mosquitoes and bilharzia snails (Marks *et al.* 1994; Bromilow 1995). An average number of five species was recorded per sample plot of which 55% were introduced and 44% were therophytes.

A similar community, the *Phragmites australis* Vlei was described by Bloem *et al.* (1993) in the North-eastern Sandy Highveld, Transvaal..

12. *Azolla filiculoides* Floating Community

The *Azolla filiculoides* Floating Community invades stagnant water in depressions, pools and drainage canals in some of the wetland areas in Potchefstroom (Figure 2). The only species in this community is the perennial, mat-forming, free-floating, aquatic fern *Azolla filicu-*

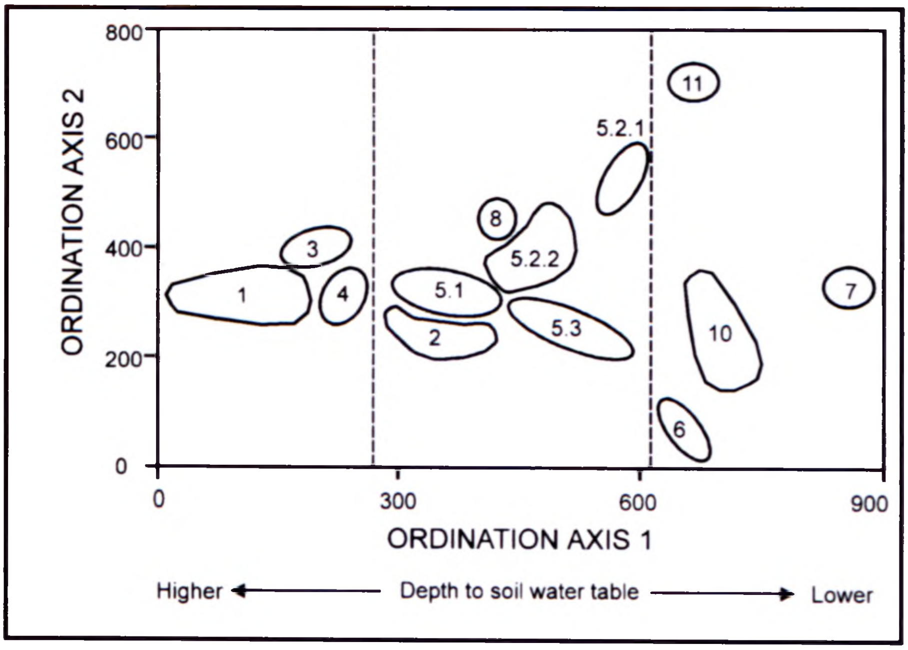

FIGURE 3.—Relative positions of plant communities along first two axes of ordination of wetland plant communities in Potchefstroom Municipal Area, North-West, South Africa.

loides (species group GG, Table 1). This species is a declared invader and is regarded as one of the most dangerous invaders of water bodies in temperate regions in southern Africa (Henderson 1995). This species was not mentioned by Louw (1951) in his study of the vegetation of the Potchefstroom area, but none of the floating or submerged plants observed by him were recorded in the study area.

Ordination

Figure 3 represents the distribution of 98 of the 102 relevés along the first and second axes of a DECORANA ordination. Although the relevés of the *Carex acutiformis* Wetland Community and the *Azolla filiculoides* Floating Community are excluded from Figure 3, they show a very clear discontinuity with each other and with all the other communities. This discontinuity was verified by the ordination of the total data set which is not presented in this paper.

With the exception of the subcommunities of the *Salix babylonica* Community (Community 1) and the subcommunities and variants of the *Cichorium intybus–Xanthium strumarium* Invasive Community (Community 5.1), the different plant units are restricted to specific spatial areas as shown in the scatter diagram (Figure 3). The diagram also illustrates a gradient along ordination axis 1 which could be related to depth of the soil water table (position in the whole wetland system, and ability to establish in deep water). Depth of the water table could have a major influence on the distribution pattern of vegetation (Eckhardt *et al.* 1993b). The communities found under extreme conditions, namely away from water or in water, occur on the periphery of the diagram (Figure 3). The grassland communities (Communities 3 and 4) which occur on the higher-lying areas, fringing the marshlands and the *Salix babylonica* Community (Community 1) which occurs on the river banks are situated at the left of the scatter diagram. Communities which typically establish in shallow to deep water (Commmunities 6, 7, 10 and 11) are situated to the right of the diagram. The *Cyperus longus* Major Wetland Community (Community 5) is situated in an intermediate position on the scatter diagram (Figure 3) which indicates that the communities, subcommunities and variants of this major community may establish on higher-lying drier areas as well as in lower-lying areas which are seasonally waterlogged. Another community in an intermediate position is the *Amaranthus hybridus–Pennisetum clandestinum* Ruderal Community (Community 2) which is situated very close to the other degraded community, the *Cichorium intybus–Xanthium strumarium* Invasive Community (Community 5.1) (Figure 3). The *Eleocharis palustris* Wetland Community (Community 8) which occurs in the same type of habitat than the *Berula erecta* Community (Community 5.2) but in less disturbed marshlands, is also situated in an intermediate position, close to the *Berula erecta* Community.

In ordinations which were separately performed on the *Salix babylonica* Woodland Community (Community 1) and the *Cichorium intybus–Xanthium strumarium* Invasive Community (Community 5.1), none of the subcommunities and variants were clearly distinguished from each other.

CONCLUSION

The establishment of many of the wetland communities is the result of direct or indirect anthropogenic influences. The large areas covered by communities such as the *Salix babylonica* Community show the great long-term impact of man on the structure and species composition of wetland plant communities. The yearly expansion of the *Cynodon dactylon* Invasive Community indicates the degraded condition of the urban wetlands in Potchefstroom, mainly because of the indiscriminate use of these areas for cattle and horse grazing.

Some of the communities described in urban wetlands in this study are to a certain extent, similar to those wetland communities described by Kooij *et al.* (1991); Fuls *et al.* (1992); Bloem *et al.* (1993); Eckhardt *et al.*

(1993a); Myburgh *et al.* (1995) and Smit *et al.* (1995), in natural wetland areas. The range and intensity of disturbances in certain areas of the Potchefstroom urban wetland, as well as the scale on which the current study was done, probably permitted the recognition of more communities which may also form small mosaics with each other. In none of the mentioned studies on natural wetlands, was the abundance of the invasive grass, *Cynodon dactylon* so profound, as in the current study.

Variations in those plant communities which could be related to specific environmental conditions are mainly ascribed to river bank wetness, period of wetness, depth of soil water table, soil type and drainage tempo of soil. With the exception of the anthropogenous soil form, Witbank, all the other soils are deep, poorly drained soils with high clay contents. No correlation between the different plant communities and data from either physical or chemical soil analyses, were found.

The present study should be used as the basis for future management and conservation of urban wetlands in Potchefstroom, and it should also lead to the development of a Metropolitan Open Space System (MOSS) network for Potchefstroom. The development of such a network, together with the involvement of the public in the conservation of the wetlands may prove to be the salvation of the Potchefstroom wetlands. One important aspect that should immediately be addressed in the management of these wetlands is the termination of all mowing and grazing practises, and the careful monitoring of any successional changes in the vegetation, to be able to assess the exact influence these grazing and mowing practises have on the vegetation.

The classification and description of the wetland communities in the Potchefstroom Municipal Area also serve as a basis for further studies in urban wetlands. Future research must concentrate more specifically on the conservation status and ecological importance of certain species and plant communities, the vegetation dynamics of wetland ecosystems under specific human influences and habitat changes, and the effect of certain toxic agents (ecotoxicology) on wetlands. All this information can eventually be used in the development of a model, such as the one of Ellison & Bedford (1995), which can predict the consequences of anthropogenic disturbances in wetlands.

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