Flora of the Cuvelai wetlands, northern Namibia

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The Cuvelai basin drains water from the central Angolan highlands into the Etosha Pan in Namibia. The characteristic vegetation of these seasonal wetlands was studied at a number of sites during the wet season of 1996-1997. The plants and their vegetational zones are outlined and their seasonality is discussed. The flora is compared between sites, with the Kunene and Okavango River systems, and with Olushandja Dam. Environmental monitoring and characteristic species are discussed.

INTRODUCTION

The Cuvelai drainage basin in the north central regions of Namibia is densely populated, having a population of over 400,000 people in an area of approximately 10,000 square kilometres (UNDP 1996). The periodic flows of the Cuvelai *oshanas* (shallow watercourses) recharge aquifers, renew grazing and translocate fish into the area. Despite their importance as a support system, relatively little research has been undertaken in order to understand the functioning of this environment.

The Cuvelai drainage basin arises in the Sierra Encoco Mountains in southern Angola and terminates in the Etosha Pan in Namibia (*vide* Figure 1 in Clarke & Rayner 1999, this volume). Its basin is flat and sandy with elevations at the Angolan border of approximately 1105 m, gradually decreasing southwards to 1080 m over a distance of 160 km (an average drop of 15 cm in 1 km = 1: 6700). The system is subject to sluggish, unpredictable ephemeral water flow in *oshanas,* which converge into a series of pans at Lake Oponono (18°08'00"S, 15°47'00"E). Floodwaters from Angola reach Lake Oponono on average twice every three years. Only in exceptional flood years does water flow down the Ekuma River to reach the Etosha Pan (Lindeque & Archibald 1991).

The climate is semi-arid with unpredictable rainfall averaging 300 mm (west) to 500 mm (east) per year, and annual potential evaporation averaging 2,500 mm per year. About 99% of the annual precipitation occurs from October to April, but is highly variable from year to year and from location to location (Marsh & Seely 1992).

Lindeque & Archibald (1991) present a brief description of the ecology of the Cuvelai basin, although their emphasis was on the Etosha section of the system. Large numbers of young fish migrate from the upper perennial sections of the Cuvelai basin during periods of flood and colonize the *oshanas*. As the flood-waters recede, those fish which have not found their way into artificial reservoirs, or other perennial systems eventually die (Clarke pers. obs.).

Upwards of sixty species of predominantly aquatic birds, are known to breed in these seasonal wetlands, while the Etosha Pan is the only known, regular mass breeding ground for flamingos (predominantly *Phoenocopterus minor* Geoffroy, 1798 (Phoenocopteridae)) in Southern Africa (Lindeque & Archibald 1991).

Rodin (1985) recorded common plant species of the area and their uses but the wetland plant communities have remained unstudied.

Marsh & Seely (1992) compiled a report summarising land use in the Cuvelai basin. Traditional agricultural practices are the cultivation of subsistance crops and pastorialism. Environmental degradation resulting from the over collection of woody vegetation and from over grazing by livestock is apparent. Fresh water is limited to seasonal surface water, the shallow aquifer being recharged by rain and floods. The deeper aquifers contain only saline water. To provide a secure domestic supply, water is transferred from the Kunene River *via* a system of canals and pipelines for distribution to rural communities following purification. This infrastructure has also contributed to environmental degradation, as outlying rural communities concentrate in the vicinity of water supply points. While the Cuvelai drainage system runs from north to south, the majority of infrastructure, such as roads and canals run from east to west. This has inhibited water flow, leading to a reduced groundwater and surface water recharge and vegetation productivity. Large culverts have been constructed beneath roads at the points where they cross main *oshana* channels, and inverted siphons pipe canal water below ground to avoid obstruction and the mixing of surface and piped water.

A number of studies in the northern region have highlighted environmental problems in the Cuvelai drainage basin (Curtis 1999 this volume; Environmental Evaluation Associates 1992a, 1992b; Environmental Evaluation Unit 1995; Finnconsult 1994). These reports have made recommendations for environmental monitoring and mitigation of impacts of water supply projects.

The aim of this study was to provide a description of the vegetation of the *oshanas* and adjacent water bodies, in an attempt to establish an environmental monitoring programme for the area. The aim was further to compare sites that were upstream and downstream of roads and canals to see if any impacts on the vegetation could be detected.

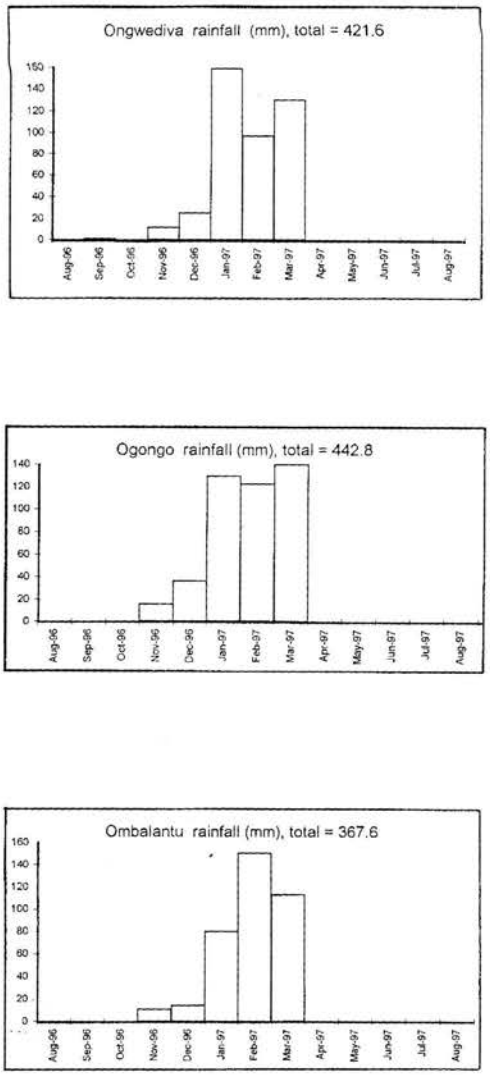

Figure 1. Rainfall data from the Cuvelai basin, northern Namibia for the 1996-1997 season (data from the Meteorological Office, Windhoek).

METHODS

Nine sites were sampled (*vide* Figure 2 in Clarke & Rayner 1999 this volume) *viz.* Lashivanda, 17°28'17"S, 15°32'03"E, 1100 m (1); Shashimwaku, 17°26'50"S, 15°42'00"E, 1100 m (2); Ogongo, 17°38' 17"S, 15°16'23"E, 1097 m (3); Ogongo East, 17°40'00"S, 15°23'00"E, 1096 m (4); Oshikuku, 17°39'29"S, 15°27'57" E, 1097 m (5); Sheenkombo, 17°42'40"S, 15°33'20"E, 1095 m (6); Shashuuli, 17°47'20"S, 15°21'00"E, 1098 m (7); Elim junction, 17°47'22"S, 15°30'10"E, 1094 m (8); Ehangano, 17°47'30"S, 15°37'30"E, 1094 m (9).

Regular sampling was concentrated in the central Cuvelai area. Sites were selected in the vicinity of good well maintained roads to allow access during floods. An attempt was made to select sites with equivalent habitats upstream and downstream of infrastructure such as roads, canals and reservoirs. This proved problematical, as each *oshana* exhibited highly variable features throughout its length. Eventually eight *oshanas* were selected for regular sampling at intervals of approximately one month.

As well as the large shallow watercourses of the *oshanas*, small deeper pools termed *ondombes* occur. Most *ondombes* have been enlarged and deepened by people over many years. The flora of four *ondombes* was sampled. One was sampled at Oshikuku and the three others were associated with *oshanas* already selected for sampling. A small sedge pool near to Ehangano *oshana* was also sampled.

Sites were located and relocated using a Garmin GPS 75 navigation system as illustrated in Figure 2 of Clarke & Rayer (1999, this volume). *Oshanas* were sampled a few hundred metres north and south of the road. Estimates of vertical profiles across *oshana* and *ondombe* sites were made when they were dry and water depths were estimated over the wet season by wading across channels.

Vegetation distribution across the *oshanas* was surveyed along a transect line established between two GPS positions. Distances were measured in paces, later calibrated to metres using the GPS positions, and direction was determined by compass bearings. Sampling points were determined by changes observed in plant species composition, elevation, or at 100 m intervals if no change in either of these two variables occurred. Samples covered a 2 m radius within which total plant cover (%) was estimated and plant species cover was recorded using a scale of 1 = 1-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%. Plant species were identified provisionally in the field and voucher collections were made for identification and deposition at the Herbarium of the National Botanical Research Institute, Windhoek, Namibia. Nomenclature follows Craven (1999).

Nineteen transects were investigated at the eight *oshana* sites. Each transect was repeated at approximately one month intervals between 16 January and 30 May 1997. Vegetation was also surveyed at the four *ondombes* on a monthly basis over the same time period.

Sampling point data from the transects were tested for community associations using Primer software. Dendrogram groupings with over 50% similarity and stress values below 3.0 are considered to indicate significant associations.

RESULTS

Location maps are given in Clarke & Rayner (1999, this volume, Figures 1 & 2). Rainfall data (from the Meteorological Office, Windhoek) for the 1996-1997 season are presented in Figure 1 for three stations across the Cuvelai: Ongwediva (43 km south-east of Ogongo), Ogongo (18°43'00"S, 15°18'00"E) and Ombalantu (28 km north-west of Ogongo).

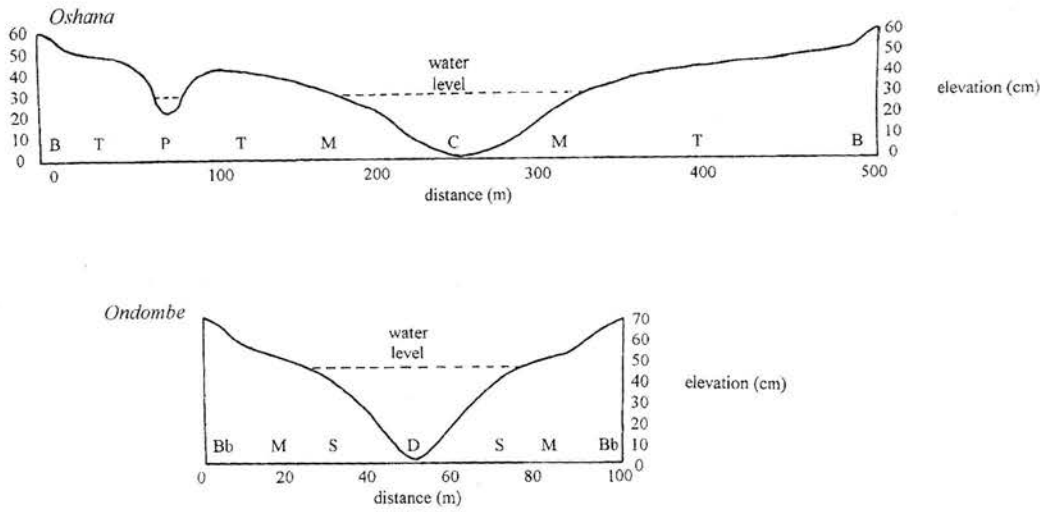

Figure 2. Diagrammatic profiles of an *oshana* and an *ondombe*. Zones: *Oshana* - B = bank, T = terrace, M = margin, C = channel, P = pool; *Ondombe* - Bb = bank, M = margin, S = shallow, D = deep.

Generalised profile diagrams for an *oshana* and an *ondombe* are illustrated in Figure 2 with the constituent zones indicated below. The zones were identified from transect data taking into account the relative elevations and vegetation types encountered.

Community associations were tested using Primer software (Primer 1994). An example is shown of a Bray-Curtis similarity dendrogram in Figure 3 using the transect data with abundance scores for March at Ehangano *oshana* and *ondombe*. Ordination by non-metric multidimensional scaling gave a stress value of 0.14. The sampling points are labeled with the zone identified from the transect data. The bank zone was usually distinct and well defined (Bray-Curtis Similarities over 50%). Pool and channel zones were distinct but difficult to distinguish from one another, both sharing the same aquatic plant species. The terrace or floodplain zone samples generally grouped together well (over 50% similarity) while the margin zone was less distinct being a transition zone between terrace and channel. The terrace and margin zones contained the greatest species diversity.

A provisional list of plant species, their zones and monthly records, is shown in the Appendix. Large areas of grasses (40 species recorded) and sedges (35 species) dominate the *oshanas*. Other plants included 18 species of monocotyledons and 60 species of dicotyledons, of which 16 were trees or shrubs, mostly associated with *ondombes*. The bank, terrace and channel zones each had a total of approximately 40 species while the margin had a slightly higher number of species. Very few submerged aquatic plants were found (*Utricularia inflexa, Lagarosiphon cordofanus*) as the water is very turbid with a high silt content.

The characteristic plants of the Cuvelai wetlands and their zones are discussed below. Water depth is a major environmental determinant of species distribution in wetlands (Ellery *et al.* 1991). The zones correspond to different elevations and therefore degree of flooding. There is a gradation from the deep *oshana* channel to the shallow edges, *oshana* pools and *ondombes*. The same aquatic species occupy these zones. The main difference being the presence of steep banks with woody vegetation which is fully developed in the larger *ondombes*, occasional around pools and absent in *oshanas*.

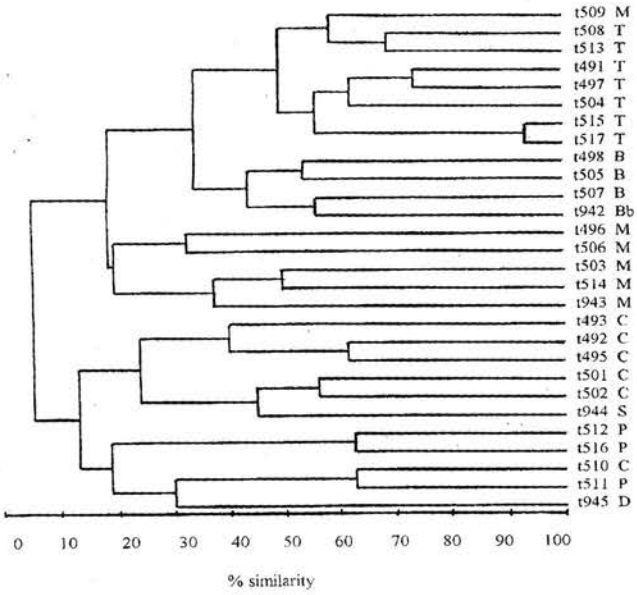

Figure 3. Bray-Curtis similarity dendrogram for Ehangano March sample points. Ordination by non-metric multidimensional scaling stress value = 0.14. Zones: *Oshana* - B = bank, T = terrace, M = margin, C = channel, P = pool; *Ondombe* - Bb = bank, M = margin, S = shallow, D = deep. NE transect points t491-t498 (t494 no plants), NW transect points t501-t507, S transect points t508-t517, *Ondombe* transect points t942-t945.

DESCRIPTION OF VEGETATIONAL ZONES

Bank - This formed the transition between the higher ground terrestrial vegetation, such as Mopane Savanna, and the *oshana* or *ondombe*. The bank was rarely inundated and supported some woody species. The commonest trees beside *oshanas* were *Acacia hebeclada* ssp. *tristis* and *Hyphaene petersiana*. Other common trees included *Acacia arenaria, Acacia nilotica, Combretum imberbe, Ziziphus mucronata* and *Colophospermum mopane*. The shrub *Pechuel-Loeschea leubnitziae* was common. The grasses *Brachiaria xantholeuca* and *Aristida stipoides* were common on the bank and terrace. The banks of the *ondombes* supported the same tree species except that *Diospyros mespiliformis,* (usually dominant) and *Ficus sycomorus* were common. Herbs included *Asparagus* sp., *Justicia exigua* and *Kleinia longiflora*, and the grass *Cynodon dactylon*.

Terrace or floodplain – Situated on very flat ground often with a very gradual gradient declining to the middle of the *oshana*. It is the equivalent of a floodplain often covering the greatest area of the *oshana* but is absent from the *ondombe*. It is inundated regularly during the wet season but is normally above the water level. It supports a low sward dominated by grasses. The small grasses *Wilkommia sarmentosa* and *Eragrostis trichophora* dominate accompanied by a wide variety of herbs, such as *Oxygonum alatum, Gisekia africana, Limeum viscosum, Mollugo cerviana, Sesuvium sesuvioides* and *Portulaca collina*.

Lilies were common early in the year *(Dipcadi crispum, Trachyandra arvensis)* while the composite *Geigeria ornativa* appeared later. The grass *Sporobolus ioclados* and the small sedges *Bulbostylis hispidula, Kyllinga alata* and *Monandrus squarrosus* (= *Cyperus aristatus*) were abundant.

Margin - This can be a wide transitional zone between the terrace and the main channel of the *oshana* or a narrow zone between the bank and the shallow water of the *ondombe*. It is usually wet, being at water level or below during the wet season. The grasses *Eragrostis trichophora* and *Sporobolus ioclados* were abundent in this wetter zone. These were accompanied by herbs such as *Vahlia capensis, Ammania baccifera, Nicolasia costata, Scilla* sp., *Aponogeton junceus, Commelina subulata,* and grasses such as *Brachiaria deflexa, Brachiaria humidicola, Eragrostis rotifer* and a number of sedges *Cyperus haspan, Kyllinga albiceps, Pycreus pumilus*. At the onset of the wet season *Crinum carolo-schmidtii* was abundent in the flooded margin and deep water. By the end of the wet season the grass *Elytrophorus globularis* and the two sedges *Fuirena angolensis* and *Schoenoplectus senegalensis* became abundant in the drying margins of the channels and pools together with seedlings of the composite *Sphaeranthus peduncularis*.

Shallow Water - This zone was dominated by rooted emergents including *Marsilea* spp. (also floating leaved species), *Aponogeton junceus* and *Burnatia enneandra*. Of the grasses, *Diplachne amboensis* and *D. cuspidata* covered large areas of the open water habitat in the *oshanas*. Other common grasses included *Echinochloa stagnina*, with *Oryza longistaminata* and *Oryzidium barnardii* at the edges of deep water. The sedges, *Cyperus procerus, C. longus, C. sphaerospermus* and *Pycreus chrysanthus*, were abundant along the edges of *oshana* water channels and in the shallows of *ondombes*. The submerged aquatic *Utricularia inflexa* could be found in shallow water but turbidity was high.

Deep Water - The deepest part of the *oshana* channel carried flowing water and was usually without vegetation. At the sides of the main channel and in the centre of *ondombes*, the floating leaved but rooted waterlily *Nymphaea nouchali* dominated deeper water with *Ottelia exserta* appearing later in the season. *Nymphoides rautanenii* (rooted with floating leaves), *Neptunia oleracea* and *Ipomoea aquatica* (floating stems) were also common.

Pool - Separated from the main *oshana* channel, usually along the outer edge of the terrace zone, this habitat was often well vegetated with narrow zones of plant species. Pools shared the same aquatic plants as the channel, being dependent on size and depth. Some woody vegetation occurred around the larger pools at the edges of *oshanas*, causing them to resemble *ondombes*. The semi-parasitic, *Cycnium tubulosum*, and the composite *Eclipta prostrata*, frequently occurred beside pools and *ondombes*.

Saline Pools - These were usually open, sandy flat areas at higher elevation with shallow water and sparse vegetation cover. The shallow water became saline as a result of evaporation and salt crystals were seen to have formed at the margins. The small grass *Sporobolus coromandelianus* and large clumps of *Sporobulus ioclados* were characteristic species.

Pan – If there is little change in elevation, no distinct channels form through which water may flow, this results in the shallow water becoming saline through evaporation and the formation of pans.

Pans were relatively poorly vegetated. Sandy edges supported *Sporobolus spicatus* and *Odyssea paucinervis*. *Diplachne* spp. occurred in less saline water. *Cyperus articulatus* and *Bolboschoenus maritimus* were found along the margins of the large Uupeke Pan near Lake Oponono. Trees are scarce at the southern end of the Cuvelai drainage basin presumably due to increasingly saline soils.

SPECIES OCCURRENCE OVER THE WET SEASON

The early part of the wet season was characterised by regular filling and dessication of *oshanas*,

ondombes and pools. It was some time before they retained water long enough for the wetland flora to develop (Clarke pers. obs.).

In the study area during 1997, water in *oshanas* appeared to reflect local rainfall events, rather than infilling being the result of floods from further north. The number of plant species was generally highest in March, when the percentage plant cover and height were also at their greatest. Water levels reached their peak in February or March and had begun to decline by the end of March.

Some plant species were noted throughout the wet season. These included terrace zone species such as: *Mollugo cerviana, Gomphrena celosioides, Chamaesyce* sp., *Litogyne gariepina, Hirpicium gorterioides* and the grasses *Eragrostis trichophora* and *Wilkommia sarmentosa.* In the wetter zones (margin, pool, channel) *Nicolasia costata, Sporobolus ioclados, Brachiaria deflexa, B. humidicola, Diplachne amboensis* and *Echinochloa stagnina* were recorded in every month sampled.

Species recorded at the beginning of the wet season (January to March) included the following terrace zone species: *Oxygonum alatum, Limeum viscosum, Indigofera charlieriana, Heliotropium ovalifolium, Grangea anthemoides,* the lilies; *Camptorrhiza strumosa, Dipcadi crispum, Eriospermum rautanenii, Ornithogalum rautenenii, Trachyandra arvensis,* the grasses *Brachiaria xantholeuca* and *Microchloa kunthii* and the sedge *Kyllinga alata.* The lily *Scilla* sp. was common on the flooded margins while *Crinum carolo-schmidtii* was extremely abundant in deeper water flowering in February.

Species recorded during the middle of the wet season (February to April) at peak water levels included the margin zone species *Eriocaulon cinereum, Kyllinga albiceps,* and *Rhynchospora holoschoenoides* and the aquatics *Nymphaea nouchali, Burnatia enneandra* and *Aponogeton junceus.*

From the middle to the end of the wet season (March to May) the following species were recorded: *Blepharis* sp., *Aeschynomene indica, Lindernia parviflora, Nicolasia nitens, Geigeria ornativa.* Grasses prevalent at this time were *Aristida stipoides, Digitaria milanjiana, Eragrostis rotifer, E. membranacea, Pogonarthria fleckii, Sporobolus coromandelianus,* while the sedges *Cyperus articulatus, C. longus,* C. *procerus, Pycreus chrysanthus,* and the floating aquatics *Neptunia oleracea, Nymphoides indica, Ipomoea aquatica* and *Ottelia exserta* also occurred.

Species appearing at the end of the wet season in May were: *Bergia spathulata* and *Scleria foliosa* while a common association on drying margins in April and May was: *Elytrophorus globularis, Fuirena angolensis,* and *Schoenoplectus senegalensis.* Seedlings of the composite *Sphaeranthus peduncularis* colonised drying margins and matured during the dry season.

COMPARISON OF SITES

The species lists with maximum abundance scores were compared for all sites using the Bray-Curtis test (Figure 4).

Site 23 was not grouped with any other site. It was a small shallow sedge pool at the edge of Ehangano *oshana* with very limited zonation and species, dominated by the sedge *Pycreus chrysanthus.*

The two transects at Lashivanda were similar (t1, t2, over 60% similar) but were separated from the main *oshana* grouping. Lashivanda had pan-like characteristics being isolated with no connecting channel, the water became quite saline and species diversity was very low.

The transects at Elim Junction SW, Sheenkombo S, and Shashimwaku N were grouped (t18, t14, t4, over 60% similar). They were all shallow water sites (no deep channel) and had low species diversity.

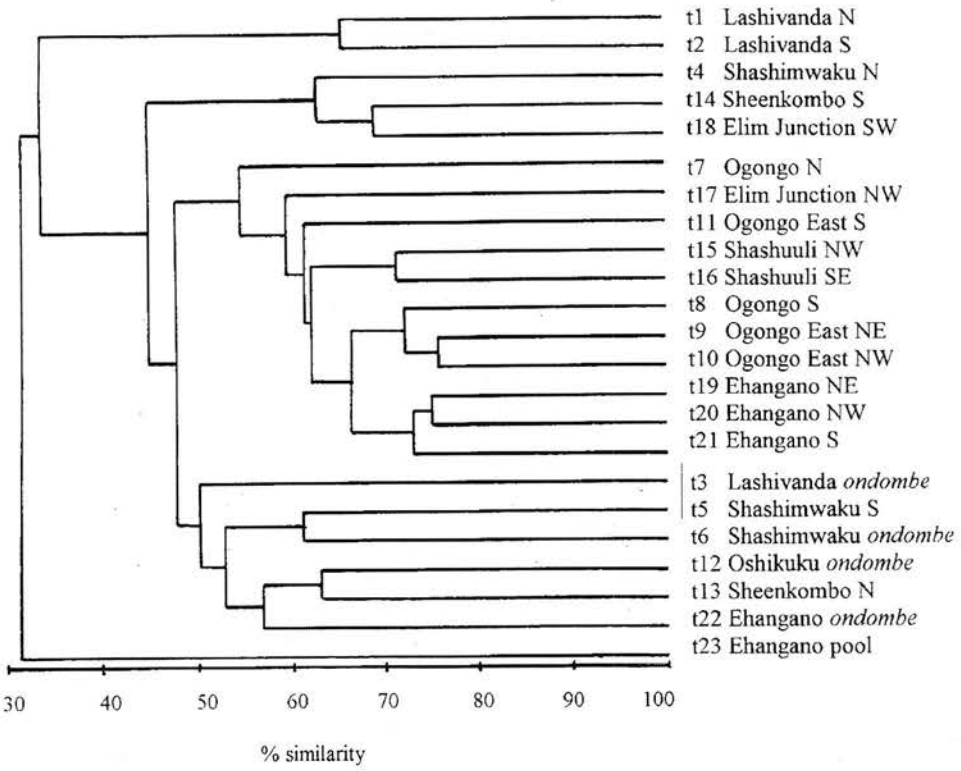

Figure 4. Bray-Curtis similarity dendrogram for all sites. Ordination by non-metric multidimensional scaling stress value = 0.17.

The remaining sites formed two main groups: one containing most of the *oshanas* and the other containing the *ondombes*. The two *oshana* sites, Sheenkombo N and Shashimwaku S, were, however, grouped with the *ondombes*. This was due to the presence of deeper pools along the *oshana* transects with the trees *Diospyros mespiliformis, Acacia hebeclada* and *Hyphaene petersiana*, abundant sedges *Cyperus procerus* and *C. sphaerospermus* and deep water species such as *Nymphaea nouchali* and *Crinum carolo-schmidtii*.

Of the *oshana group*, the three transect sites at Ehangano *oshana* (t19, t20, t21) were found to be over 70% similar. The two north transects at Ogongo East were closely associated with each other and with the south transect at Ogongo (t9, t10, t8, over 70% similar). These three transects had pools and were diverse sites. The two transects at Shashuuli were grouped together (t15, t16, over 70% similar). The transects at Elim Junction NW, Ogongo N, and Ogongo East S were not closely associated with others but belonged to the larger *oshana* grouping (t17, t7, t11, 50% similar).

If there were large differences caused by infrastructure it would be expected that sampling sites north of the road would be more similar than sites south of the road. No grouping of sites into north of the road and south of the road were evident. Differences were due more to variation between and within *oshanas* indicating that the infrastructure was not consistently altering *oshana* vegetation at these sites.

DISCUSSION

FLORISTIC COMPARISON WITH OTHER WETLANDS

The Cuvelai drainage lies between the Kunene and the Okavango Rivers. Although geographically close to the Kunene River system the Cuvelai appears to be unrelated floristically. The dominant submerged plant in the Kunene river channel is the distinctive *Hydrostachys polymorpha* Klotsch (Hydrostachyaceae), while *Phragmites mauritianus* Kunth (Poaceae), *Vetiveria nigritana* (Benth.) Stapf (Poaceae) and Polygonaceae beds dominate the margins (Clarke pers. obs.). Small trees commonly overhang the river bank (*Ficus capreifolia* Delile (Moraceae), *Sesbania sesban* (L.) Merr. (Fabaceae), *Rhus quartiniana* A. Rich. (Anacardiaceae), *Salix mucronata* Thunb. (Salicaceae)). The large Kunene riverbank tree, *Faidherbia albida* (Delile) A. Chev. (Fabaceae), and the smaller *Ximenia caffra* Sond. (Olacaceae) and *Syzigium guineense* (Willd.) DC. (Myrtaceae) were not recorded in the Cuvelai. However, some of the riverine forest trees are found on the banks of the larger Cuvelai *ondombes* including *Diospyros mespiliformis, Hyphaene petersiana, Ficus sycomorus, Combretum imberbe* and *Gymnosporia senegalensis.* In the Cuvelai, *Acacia hebeclada, A. nilotica* and *A. arenaria* were common but they occur infrequently along the Kunene.

Olushandja Dam is an artificial permanent water body formed by flooding Etaka *oshana* with Kunene river water *via* a canal to provide emergency water storage. It is 20 km from north to south and 0.2-2 km from east to west with a maximum water depth of 3.5 m. It might be expected to have an intermediate flora between the Kunene and the Cuvelai. In fact, Burke's study (1995) shows that, apart from a similar terrestrial zone (*A. hebeclada, A. nilotica, Pechuel-Loeschea leubnitziae, Geigeria ornativa* and *Colophospermum mopane*) and some species in the fringe vegetation (e.g. *Cynodon dactylon, Ammania baccifera, Cyperus compressus*) there appears to be little relationship with the Cuvelai. Floating mats of *Ludwigia adscendens* (L.) Hara *(=L. stolonifera)* (Onagraceae), which were abundant in Olushandja, (also seen in side pools of the Kunene) were only seen in artificially excavated pools in the Cuvelai. The large reed beds (*Typha capensis* (Rohrb.) N. E. Br. (Typhaceae), *Phragmites mauritianus*) at Olushandja did not occur in the Cuvelai. Some elements of the floating-leaved community were the same (*Nymphoides, Nymphaea, Ottelia, Burnatia*) but the sedge communities were quite different. *Cyperus imbricatus* Retz. (Cyperaceae), one of the dominant sedges at Olushandja, was only recorded in excavations in the Cuvelai. The other common sedge, *Schoenoplectus corymbosus,* as well as *Cyperus articulatus,* did occur in the deeper channels of the *oshanas.* The dominant sedges of the Cuvelai (*Cyperus longus, C. procerus, C. sphaerospermus, Eleocharis acutangula* and *Pycreus chrysanthus*) were not recorded from Olushandja.

The Namibian section of the Okavango River showed a much higher wetland plant diversity (291 species) than the Cuvelai (155 species) due to the wider range of habitats, (river, floodplain and seasonal swamps) (Bethune 1991).

Aquatic plants found here but not in the Cuvelai include species of the following genera: *Polygonum, Ludwigia, Trapa* L. (Trapaceae), *Ceratophyllum* L. (Ceratophyllaceae), *Myriophyllum* L. (Haloragaceae), *Potamogeton* L. (Potamogetonaceae), *Najas* L. (Najadaceae), *Zannichellia* L. (Zanichelliaceae), *Vallisneria* L. (Hydrocharitaceae) and *Typha.* Some genera are represented by several species in the Okavango while only one was recorded in the Cuvelai, for example, *Nymphaea, Ipomoea, Utricularia, Lagarosiphon, Commelina, Aeschynomene* and *Ottelia.* A similar pattern is indicated by the more limited checklist for East Caprivi wetlands (Schlettwein *et al.* 1991).

Table 1. Indicative species of habitats in the Cuvelai basin.

Woodland savana
Acacia erioloba
Acacia fleckii
Adansonia digitata (agricultural fields)
Berchemia discolor (agricultural fields)
Burkea africana
Colophospermum mopane
Combretum collinum
Sclerocarya birrea (agricultural fields)
Terminalia sericea

Banks of pools and water course
Acacia arenaria
Acacia hebeclada spp. *tristis*
Acacia nilotica
Diospyros mespiliformis
Ficus sycomorus
Hyphaene petersiana

***Oshanas* and *ondombes* (pools)**
Wetland grasses
Brachiaria deflexa
Brachiaria humidicola
Diplachne amboensis
Diplachne cuspidata
Echinochloa stagnina
Elytrophorus globularis (late season)
Oryzidium barnardii
Sporobolus ioclados
Wilkommia sarmentosa

Wetland sedges
Cyperus procerus
Cyperus schinzii
Cyperus sphaerospermus
Eleocharis acutangula
Fuirena angolensis (late season)
Kyllinga alba
Monandrus squarrosus
Pycreus chrysanthus
Schoenoplectus senegalensis (late season)

Wetland herbs
Aponogeton junceus
Burnatia enneandra
Commelina subulata
Crinum carolo-schmidtii
Ipomoea aquatica
Marsilea spp.
Nicolasia costata
Nymphaea nouchali
Nymphoides indica
Scilla sp.
Utricularia inflexa

Saline soils
Odyssea paucinervis
Sporobolus spicatus
Cyperus articulatus

Disturbed areas

Grasses
Cynodon dactylon
Eragrostis viscosa
Pogonarthria fleckii
Tragus racemosus

Sedges
Courtoisina cyperoides
Cyperus compressus
Cyperus difformis

Herbs
Acrotome inflata
Geigeria ornativa
Heliotropium ovalifolium
Justicia exigua

Shrubs
Pechuel-Loeschea leubnitziae

Herbaceous species not recorded for the Okavango or East Caprivi occurring in the Cuvelai were *Vahlia capensis, Neptunia oleracea,* cf. *Kohautia amboensis, Nicolasia nitens, Sphaeranthus peduncularis* and *Ottelia exserta.*

The Okavango wetlands possess several large grasses (Poaceae) not found in the Cuvelai. These include the aquatic species *Vossia cuspidata* Wall. & Griff., *Miscanthus junceus* (Stapf) Pilg. and *Phragmites* spp., and the floodplain species *Vetiveria nigritana, Hyparrhenia rufa* (Nees) Stapf, *Imperata cylindrica* (L.) Raeusch. and *Panicum* spp. L. The seasonal swamp grass *Paspalum scrobiculatum* L. was also absent from the Cuvelai. Grasses found in the Cuvelai but not recorded for the Okavango include *Diplachne cuspidata, Echinochloa holubii, Eragrostis membranacea, Odyssea paucinervis, Oryzidium barnardii* (with floating stems like a small *Vossia), Sporobolus coromandelianus* and *Wilkommia sarmentosa.*

Sixty-seven sedge species (Cyperaceae) were recorded for the Okavango of which twenty-three were also found in the Cuvelai. The large *Cyperus papyrus* L. was absent from the Cuvelai while *Cyperus procerus, C. esculentus, Fuirena angolensis, Pycreus pumilus, Schoenoplectus muricinux* and *S. senegalensis* were recorded in the Cuvelai but not in the Okavango.

In conclusion the seasonal and unpredictable water flow of the Cuvelai favours opportunistic species most of which have wide distributions. As well as the hydrology, the increasing salinity from north to south and the enlarged pools or *ondombes* provide unique features for this wetland.

MONITORING

Using the community analysis for all sites, the effects of infrastructure on the *oshanas* could not be detected by this sampling method. The complexities of *oshana* structure such as channel width, depth, the presence of pools, excavations, tracks and connections with other channels makes simple comparisons difficult to interpret. The design of large culverts for the roads and inverted siphons for the canal seems to allow adequate water flow. Only at one site (Sheenkombo) was local ponding of water observed above the culvert. Lower down the same *oshana* system, however, the site at Ehangano showed the normal complement of species. It may be that the plants are opportunistic enabling them to take advantage of local unpredictable rainfall, therefore, being resilient to environmental change.

There has been considerable alteration of the terrestrial habitats in the Cuvelai region. Mixed woodland dominated by the trees *Burkea africana* Hook. (Fabaceae) *Acacia erioloba* E. Mey. (Fabaceae) and *Terminalia sericea* Burch. ex DC. (Combretaceae) has been replaced with an agricultural landscape. Further impact on the *oshana* system is likely to occur, with future development processes. Future surveys of the same sites over time would allow species change to be monitored. If the dominant species disappear, or are replaced by others, then some form of environmental impact is indicated. For example, abundance of the composites *Pechuel-Loeschea leubnitziae* and *Geigeria ornativa* indicated overgrazing while the grass *Eragrostis viscosa* dominated areas of disturbance (e.g. soil compaction by vehicles). Wetland plants that seemed to be associated with disturbance included the sedges, *Cyperus compressus, C. difformis* and *Courtoisina cyperoides* and the grasses *Echinochloa colona* and *Eragostis membranacea.* According to herbarium records at WIND, the semi-aquatic plant *Hygrophila auriculata* was collected from *oshanas* in previous years (1890, 1959, 1966, 1991). During this study some heavily grazed stems probably belonging to this species were found but no flowering plants were seen. This may be a case of a plant species declining due to grazing pressure. As part of an ongoing monitoring

programme a simplified survey using key indicator species is proposed. This could be undertaken when the majority of plants are abundant, in the third month of heavy rain (above about 60 mm) (March in 1996-1997). Table 1 presents a provisional list of species expected to be common in most *oshana* and *ondombe* habitats as well as species associated with disturbed habitats. Caution is required when assessing habitat condition, however, as variable rainfall between locations and years can drastically alter species composition and abundance. More plant sampling is required in order to further expand the species list for the area.

ACKNOWLEDGEMENTS

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Appendix 1. Provisional list of the flora of the Cuvelai basin, northern Namibia. Vegetational zones are indicated as: B = bank; Bb = bank (*ondombe*); M = margins; S = shallows; D = deep; T = terrace (*oshana*); P = pan; SA = saline pool; E = excavation. Months are: J - M = January - May. Maximum % cover: 1 = 1-5, 2 = 6-25, 3 = 26-50, 4 = 51-75, 5 = 76-100.

Order/Family	Provisional Name	Zone	J	F	M	A	M
Charophyta	*Nitella hyalina* (DC.) Ag.	E					
Pteridophyta							
Marsileaceae	*Marsilea aegyptiaca* Willd.	S			1		
Marsileaceae	*Marsilea nubica* A. Braun	M,S			2		1
Marsileaceae	*Marsilea vera* Launert	M,S	2	1	2	1	2
Marsileaceae	*Marsilea* sp. L.	M,S	1	2	1		1
Dicotyledonae							
Moraceae	*Ficus sycomorus* L.	Bb	1	1	1	1	1
Polygonaceae	*Oxygonum alatum* Burchell var. *alatum*	T		1	1		
Amaranthaceae	*Gomphrena celosioides* Mart. * alien species	B,T,M	1	1	2	1	1
Gisekiaceae	*Gisekia africana* (Lour.) Kuntze var. *africana*	B,T	1	1	1		
Molluginaceae	*Limeum viscosum* (J. Gray) Fenzl ssp. *viscosum*	T,M	1	2	2		
Molluginaceae	*Mollugo cerviana* (L.) Ser. ex DC.	T,M	1	1	1	1	1
Aizoaceae	*Sesuvium sesuvioides* (Fenzl.) Verdc.	T	1	1	1	1	
Portulacaceae	*Portulaca collina* Dinter	B,T	1	1	1		
Nymphaeaceae	*Nymphaea nouchali* Burm.f. var *caerulea* (Sav.) Verdc.	D		1	2	2	
Vahliaceae	*Vahlia capensis* (L.f.) Thunb. ssp. *vulgaris* Bridson	T,M		1	1		
Fabaceae	*Acacia arenaria* Schinz	B	1	1	1	1	1
Fabaceae	*Acacia hebeclada* DC ssp. *tristis* A. Schreiber	Bb	2	2	2	2	2
Fabaceae	*Acacia nilotica* (L.) Willd. ex Del.	Bb	1	1	1	1	1
Fabaceae	*Aeshynomene indica* L.	M			1		2
Fabaceae	*Colophospermum mopane* (Kirk ex Benth.) Kirk ex J. Leonard	B	1	1	1	1	1
Fabaceae	*Indigofera charlieriana* Schinz	B	1	1	1		
Fabaceae	*Neptunia oleracea* Lour.	D	1	1	1		2
Fabaceae	*Sesbania pachycarpa* DC. subsp. *dinterana* J.B. Gillett	E	1				
Geraniaceae	*Monsonia angustifolia* E. Meyer ex A. Rich	T			1		
Euphorbiaceae	*Euphorbia* cf. *prostrata* Aiton * alien	T	1	1	1		1
Celastraceae	*Gymnosporia senegalensis* (Lam.) Loes.	Bb	1	1	1	1	1
Rhamnaceae	*Berchemia discolor* (Klotzsch) Hemsley	Bb	1	1	1	1	1
Rhamnaceae	*Ziziphus mucronata* Willd.	Bb	1	1	1	1	1
Tiliaceae	*Grewia flavescens* Juss.	Bb	1	1	1	1	1
Malvaceae	*Abutilon* sp. Mill.	B					1
Elatinaceae	*Bergia spathulata* Schinz	M					1
Lythraceae	*Ammania baccifera* L.	M					1

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Order/Family	Provisional Name	Zone	J	F	M	A	M
Combretaceae	*Combretum collinum* Fresen.	B	1	1	1	1	1
Combretaceae	*Combretum imberbe* Wawra	B	1	1	1	1	1
Combretaceae	*Terminalia sericea* Burchell ex DC.	B	1	1	1	1	1
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. DC.	Bb	3	3	3	3	3
Salvadoraceae	*Salvadora persica* L.	Bb	1	1	1	1	1
Menyanthacea	*Nymphoides rautanenii* (N.E.Br.) A.Raynal	S		1	2		2
Asclepiadaceae	*Gomphocarpus fruticosus* (L.) Aiton f.	B	1				
Convolvulaceae	*Ipomoea aquatica* Forssk.	D		1	1		4
Boraginaceae	*Heliotropium ovalifolium* Forssk.	T	2	2			
Lamiaceae	*Acrotome inflata* Benth.	B			1		1
Solanaceae	*Solanum nigrum* L. * alien	B					1
Scrophulariaceae	*Bacopa floribunda* (R. Br.) Wettst.	M					1
Scrophulariaceae	*Cycnium tubulosum* (L.f.) Engl. subsp. *tubulosum*	M	1	1	1		
Scrophulariaceae	*Lindernia parviflora* (Roxb.) Haines	T				1	1
Lentibulariaceae	*Utricularia inflexa* Forssk. var. *inflexa*	S			1		
Acanthaceae	*Blepharis* sp. Juss.	T			1	1	1
Acanthaceae	cf. *Hygrophila auriculata* (Schumach.) Heine	M,S			1	1	
Acanthaceae	*Justicia exigua* S. Moore	B			1		1
Rubiaceae	*Gardenia volkensii* K. Schum.	Bb	1	1	1	1	1
Rubiaceae	cf. *Kohautia amboensis* (Schinz) Bremek.	M,S		1	1	1	1
Rubiaceae	*Kohautia subverticillata* (K. Schum.) D. Mantell	T			3		
Rubiaceae	*Kohautia virgata* (Willd.) Bremek.	T			2		
Asteraceae	*Eclipta prostrata* (L.) L. * alien	M		1	1		2
Asteraceae	*Emilia ambifaria* (S. Moore) C. Jeffrey	T		1	1		
Asteraceae	*Geigeria ornativa* O. Hoffm.	T			1		1
Asteraceae	*Grangea anthemoides* O. Hoffm.	T	1	1	1		
Asteraceae	*Hirpicium gorterioides* (Oliv. & Hiern) Roessl.	B,T	1	1	2	1	1
Asteraceae	*Kleinia longiflora* DC.	Bb			1	1	1
Asteraceae	*Litogyne gariepina* (DC.) Anderb	B,T,M	2	2	1	1	2
Asteraceae	*Nicolasia costata* (Klatt) Thell.	M	1	1	1	1	1
Asteraceae	*Nicolasia nitens* (O. Hoffm.) Eyles	T			1	1	1
Asteraceae	*Pechuel-Loeschea leubnitziae* (Kuntze) O. Hoffm.	B	2	2	2	2	2
Asteraceae	*Sphaeranthus peduncularis* DC.	M				3	1
Asteraceae	*Vernonia poskeana* Vatke & Hildebr. ssp. *botswanica* Pope	M					1

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Order/Family	Provisional Name	Zone	J	F	M	A	M
Monocotyledonae							
Aponogetonaceae	*Aponogeton junceus* Lehm.	S		1	1	1	
Alismataceae	*Burnatia enneandra* P. Micheli	S		1	1		
Hydrocharitaceae	*Lagarosiphon cordofanus* Caspary	S					1
Hydrocharitaceae	*Ottelia exserta* (Ridley) Dandy	D			1		
Arecaceae	*Hyphaene petersiana* Klotzsch	B	1	1	1	1	1
Lemnaceae	*Lemna aequinoctialis* Welw.	S		1			
Eriocaulaceae	*Eriocaulon cinereum* R. Br.	M				1	
Commelinaceae	*Commelina subulata* Roth	M,S		1	1		1
Colchicaceae	*Camptorrhiza strumosa* (Baker) Oberm.	T	1				
Colchicaceae	*Gloriosa superba* L.	Bb	1	1	1		
Asphodelaceae	*Trachyandra arvensis* (Schinz) Oberm.	B,T	1	2	1	1	
Asphodelaceae	*Trachyandra* cf. *laxa* (N.E.Br.) Oberm.	B	1				
Hyacinthaceae	*Dipcadi crispum* Baker	T	1	1			
Hyacinthaceae	*Ornithogalum rautanenii* Schinz	T		1			
Hyacinthaceae	*Scilla* cf. *nervosa* (Burch.) Jessop	M	1	1	1		
Eriospermaceae	*Eriospermum rautanenii* Schinz	B,T	1				
Asparagaceae	*Asparagus* sp. L.	Bb					1
Amaryllidaceae	*Crinum carolo-schmidtii* Dinter	D	1	2	1		
Poaceae	*Andropogon eucomus* Nees	E					
Poaceae	*Aristida adscensionis* L.	T					1
Poaceae	*Aristida stipoides* Lam.	B,T			3	1	3
Poaceae	*Brachiaria deflexa* (Schumach.) C.E. Hubb. ex Robyns	M,S	1	2	2	2	2
Poaceae	*Brachiaria humidicola* (Rendle) Schweick.	M	2	2	2	1	3
Poaceae	*Brachiaria schoenfelderi* C.E. Hubb. & Schweick.	E					
Poaceae	*Brachiaria xantholeuca* (Schinz) Stapf	B,T	2	2	1		
Poaceae	*Cynodon dactylon* (L.) Pers.	B	1	3	1	1	2
Poaceae	*Dactyloctenium aegyptium* (L.) Willd.	B,T		1	1		1
Poaceae	*Diandrochloa pusilla* (Hack.) De Winter	M					1
Poaceae	*Digitaria milanjiana* (Rendle) Stapf	B,T		1	1	1	4
Poaceae	*Diplachne amboensis* Roiv. var. *plurinodis* Roiv. Endemic	S	2	2	2	4	4
Poaceae	*Diplachne cuspidata* Launert	S	2	2	2	2	2
Poaceae	*Echinochloa colona* (L.) Link	S			1		1
Poaceae	*Echinochloa pyramidalis* (Lam.) Hitchc. & Chase	S					1
Poaceae	*Echinochloa stagnina* (Retz.) P. Beauv.	S	2	2	2	1	1

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Order/Family	Provisional Name	Zone	J	F	M	A	M
Poaceae	*Elytrophorus globularis* Hack.	M				1	3
Poaceae	*Eragrostis cylindriflora* Hochst.	E	1				
Poaceae	*Eragrostis gangetica* (Roxb.) Steud.	M					1
Poaceae	*Eragrostis inamoena* K. Schum.	M				1	
Poaceae	*Eragrostis lappula* Nees	M			1		
Poaceae	*Eragrostis lehmanniana* Nees var. *lehmanniana*	B			2		
Poaceae	*Eragrostis membranacea* Hack. ex Schinz	M		2	4	4	3
Poaceae	*Eragrostis rotifer* Rendle	M		1	2		3
Poaceae	*Eragrostis trichophora* Coss. & Durieu	B,T,M	2	3	3	2	3
Poaceae	*Eragrostis viscosa* (Retz.) Trin.	B,T,M		1	3	2	3
Poaceae	*Microchloa kunthii* Desv.	T	2	1			
Poaceae	*Odyssea paucinervis* (Nees) Stapf	B,T			1	1	1
Poaceae	*Oryza longistaminata* A. Chev. & Roehr.	D			1		2
Poaceae	*Oryzidium barnardii* C.E. Hubb. & Schweick.	S,D			1		3
Poaceae	*Pogonarthria fleckii* (Hack.) Hack.	B,T			1	1	1
Poaceae	*Sacciolepis spiciformis* (A. Rich) Stapf	T				1	
Poaceae	*Setaria pumila* (Poir.) Roem. & Schult.	B					1
Poaceae	*porobolus coromandelianus* (Retz.) Kunth	Sa			2		2
Poaceae	*Sporobolus ioclados* (Trin.) Nees	T,M,Sa	2	3	2	1	2
Poaceae	*Sporobolus spicatus* (Vahl) Kunth	P					1
Poaceae	*Tragus racemosus* (L.) All.	B	1				
Poaceae	*Urochloa brachyura* (Hack.) Stapf	T		1			
Poaceae	*Wilkommia newtonii* Hack.	B		1			
Poaceae	*Wilkommia sarmentosa* Hack.	B,T	4	2	4	3	3
Cyperaceae	*Abildgaardia triflora* (L.) Abeyw.	T,M			2	1	
Cyperaceae	*Bolboschoenus maritimus* (L.) Palla	P,E					2
Cyperaceae	*Bulbostylis hispidula* (Vahl) R. W. Haines	B,T,M	2	1	2	1	2
Cyperaceae	*Courtoisina cyperoides* (Roxb.) Sojak	M			1		
Cyperaceae	*Cyperus articulatus* L.	D		1	2	2	1
Cyperaceae	*Cyperus compressus* L.	M,S			2		1
Cyperaceae	*Cyperus difformis* L.	M			1		1
Cyperaceae	*Cyperus esculentus* L.	M,S		1	1	1	1
Cyperaceae	*Cyperus haspan* L.	M		1		1	1
Cyperaceae	*Cyperus imbricatus Retz.*	E				1	
Cyperaceae	*Cyperus longus* L. var. *tenuiflorus* (Rottb.) Boeck.	S		1	1		1

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Order/Family	Provisional Name	Zone	J	F	M	A	M
Cyperaceae	*Cyperus procerus* Rottb.	S	1	2	2	2	2
Cyperaceae	*Cyperus schinzii* Boeck.	T	1	1	2		1
Cyperaceae	*Cyperus sphaerospermus* Schrad.	S		2	1	1	
Cyperaceae	*Eleocharis acutangula* (Roxb.) Schult.	S		3	2		1
Cyperaceae	*Eleocharis atropurpurea* (Retz.) J & C Presl	M			1		1
Cyperaceae	*Fimbristylis complanata* (Retz.) Link	M					1
Cyperaceae	*Fuirena angolensis* (C. B. Clarke) Lye	M				2	3
Cyperaceae	*Kyllinga alata* Nees	B,T,M	2	2	1		
Cyperaceae	*Kyllinga albiceps* (Ridl.) Rendle	M		1	3	2	
Cyperaceae	*Lipocarpha hemisphaerica* (Roth) Goetgh.	E				1	
Cyperaceae	*Mariscus hamulosus* (M. Bieb.) Hooper	M				1	
Cyperaceae	*Monandrus squarrosus* (L.) Vorster ined.	T,M			2	2	2
Cyperaceae	*Pycreus chrysanthus* (Boeck.) C.B. Clarke	S		2	3	1	1
Cyperaceae	*Pycreus macrostachyos* (Lam.) J. Raynal	S					1
Cyperaceae	*Pycreus pelophilus* (Ridl.) C. B. Clarke	S			1		
Cyperaceae	*Pycreus pumilus* (L.) Nees	M				2	1
Cyperaceae	*Rhynchospora holoschoenoides* (Rich.) Herter	M,S			2	1	
Cyperaceae	*Schoenoplectus corymbosus* (Roth. ex Roem. & Schult.) J.Raynal	S,D		3	3		2
Cyperaceae	*Schoenoplectus erectus* (Poir.) Palla ex J. Raynal	T,M			1	2	
Cyperaceae	*Schoenoplectus lateriflorus* (J. F. Gmel.) Lye	T				1	
Cyperaceae	*Schoenoplectus muricinux* (C.B.Clarke) J. Raynal	S			1		
Cyperaceae	*Schoenoplectus senegalensis* (Hochst. & Steud.) Palla	M			1	1	2
Cyperaceae	*Scleria foliosa* Hochst. ex A. Rich.	M					1
Cyperaceae	*Volkiella disticha* Merxm. & Czech	E				1	