DINTERIA No. 26:25-44 – Windhoek, Namibia – November 2000

Plant diversity of a man-made wetland – The Olushandja Dam in north central Namibia

Antje Burke

EnviroScience, P.O.Box 90230, Klein Windhoek, Namibia
e-mail: enviroscience@iafrica.com.na

Abstract

Wetland plant communities were investigated in an impoundment positioned in a former temporary wetland in northern Namibia. To establish the potential sources of colonisation of this man-made wetland, the floral composition of the derived plant communities was analysed by investigating floral affinities with wetland communities on a local and regional level. Plant diversity was comparable to diversity in other permanent wetlands such as the Okavango Delta, yet dominant species differed. Potential sources of colonisation of the dam were the surrounding temporary wetlands of the Oshana system, Kavango River and possibly dams along the Kunene river north of Olushandja Dam. Benefits of the biological diversity to wildlife and rural communities in northern Namibia ask for a careful management combining the maintenance of biological diversity with appropriate management interventions. Long-term monitoring of wetland plant communities in response to different water regimes and environmental conditions is required to develop appropriate recommendations for water management.

Keywords: Aquatic vegetation, water management, wetland vegetation

Introduction

Wetlands in arid regions are important. They control water cycles and provide life sustaining resources to a large part of the population living in their surrounding (Breen 1991). The wetlands of the Cuvelei system in the study area in north central Namibia, referred to as Oshanas, are of ephemeral character and persist for several months most years. During the rainy season the Oshanas support wetland vegetation adapted to these seasonal conditions. Although the importance of wetland plant resources to local communities in north central Namibia has long been recognised and potential overexploitation is a crucial issue (Marsh & Seely 1992), very little is known about floral composition, establishment processes and population dynamics of these wetland plant communities. However, to suggest appropriate measures for conservation and sustainable development of these plant resources, the processes determining floral composition and dynamics need to be understood (Heeg & Breen 1982; Ellery *et al.* 1991).

Water supply is considered a first priority by administrative water authorities all over southern Africa. Although there are few published studies dealing with wetland plant management in southern Africa, the water supply policy demands ecologists to predict vegetation change in response to managed flow regimes (Rogers 1997). Descriptive and predictive data are thus urgently asked for. Most management interventions in man-made water systems result in large fluctuations in the water level. As a study in the South African Highveld pans showed, large fluctuations in water level can result in complete change of vegetation from submerged to emergent aquatic and indicating distinct vegetation cycles, if studied over several years (Rogers *et al*. 1989, as cited in Rogers 1997).

In general, most wetland plant species show a wide distribution range or even cosmopolitan distribution, such as *Phragmites australis*. Many wetland species are renowned for colonising new areas very rapidly, causing problems in the management of largely man-made wetlands such as dams.

The Olushandja Dam is an artificial permanent water body situated within the ephemeral Oshana wetlands in northern Namibia. Apart from the Kunene and Okavango Rivers, it presents the only larger permanent water body within a 200 km radius. The dam was established in 1973 as a balancing dam for the main water supply canal and as an emergency reservoir to supply the northern regions. All water is pumped from the Kunene River (apart from local rain and runoff). Until this study was conducted it has been kept at about 40 % of its full capacity.

This study gives an account of the wetland plant communities that have established themselves in and around the dam and analyses their relationship with other wetland plant communities to establish their importance in a local and regional context and to elucidate their potential sources of establishment.

Methods

Study area

The dam is located on tertiary sand and calcrete deposits of over 10 m thickness (Geological Survey 1980). The climate in the region is subtropical, receiving an average of 493 mm rainfall per annum (measured over 83 years at Ondangwa, Weather Bureau). In the rainy season 1994/1995 (July-April) a total of 387 mm was recorded at the closest weather station (Ruacana) with major rains of 300 mm in February (Weather Bureau). Average daily minimum and maximum temperatures range from 15°C in winter to 31°C in summer and frosts are rare events (measured at Ondangwa over 41 years, Weather Bureau). The dam is positioned in a former ephemeral oshana, stretching 20 km in a north-south direction and 0.2 to 2 km in a west-east direction (Fig. 1). The maximum water depth was about 3.5 m at the time of the survey.

Due to its close proximity to the B1 main road to Ruacana and providing a permanent water source the area around the dam is densely populated with small settlements scattered around the dam. Fishing, small-scale irrigation and livestock farming are the main activities carried out by the local population and depend directly on the existence of the dam.

Field survey

The survey of aquatic, wetland and terrestrial plants associated with the dam was undertaken in April 1995. The sampling sites were chosen according to dominant vegetation to represent all aquatic community types. One to three quadrates of 5x5 m, a recommended size in wetland communities (Ellery *et al.* 1991), were positioned at each sampling site. A total of 28 quadrates was recorded. In each quadrate the cover was estimated per species according to the Braun-Blanquet method (Müller-Dombois & Ellenberg 1974) and a height class assigned for each species (Table 1A and 1B). A voucher specimen of unknown plant species was taken for later identification. The nomenclature follows Arnold & de Wet (1993) and Kolberg *et al.* (1992). A habitat description accompanied each quadrate and water depth was measured randomly three times in each quadrate and then averaged.

Table 1: Variables determined within each quadrate

(A) cover

r	one individual
+	several individuals, but < 1 % cover
1	1- 5 %
2	6-25 %
3	26-50 %
4	51-75 %
5	> 75 %

(B) height class (above water level)

1	0- 25 cm
2	26- 50 cm
3	51-100 cm
4	101-200 cm
5	> 200 cm

(C) habitat/growth form[1]

EA	emergent aquatic (rooted in water, but emerging above the water surface)
LFA	leaf-floating aquatic (plants rooted or free floating, but leaves always floating on the water surface)
RU	ruderal (terrestrial, weedy species)
SA	submerged aquatic (entirely below the water surface)
SFA	stem-floating aquatic (rooted in water, stems floating)
T	terrestrial
TI	terrestrial on islands
WA	wetland associated (growing in damp areas, usually around the edge of the water)

Data analysis

The plant species were classified according to their growth form/habitat (Table 1C) and geographic distribution in order to describe the ecological niches and to indicate species distributions in a local and regional perspective. Distribution classes were assigned according to Arnold & de Wet (1993), Merxmüller (1968), Craven (1999) and own observations. The following distribution classes were used:

- introduced
- endemic to Namibia
- regional endemic (northern Namibia and Okavango Delta)
- occasional in southern Africa (< 4 regions) and
- widespread in southern Africa (≥ 4 regions).

To determine the potential sources of colonisation of wetland plants, the floral composition of wetland species in the dam was further compared with species lists of wetland surveys from surrounding areas (Bethune 1991; Clarke 1999).

Results

Description of plant communities

Since the establishment of the dam about 20 years ago, six wetland plant communities and two transitional communities had colonised Olushandja Dam at the time of the survey. No obvious zonation of wetland vegetation, but a clear zonation of terrestrial vegetation was found around the dam. Wetland communities, in turn, were patchily distributed and often intermingled.

[1] adapted from Bethune (1991)

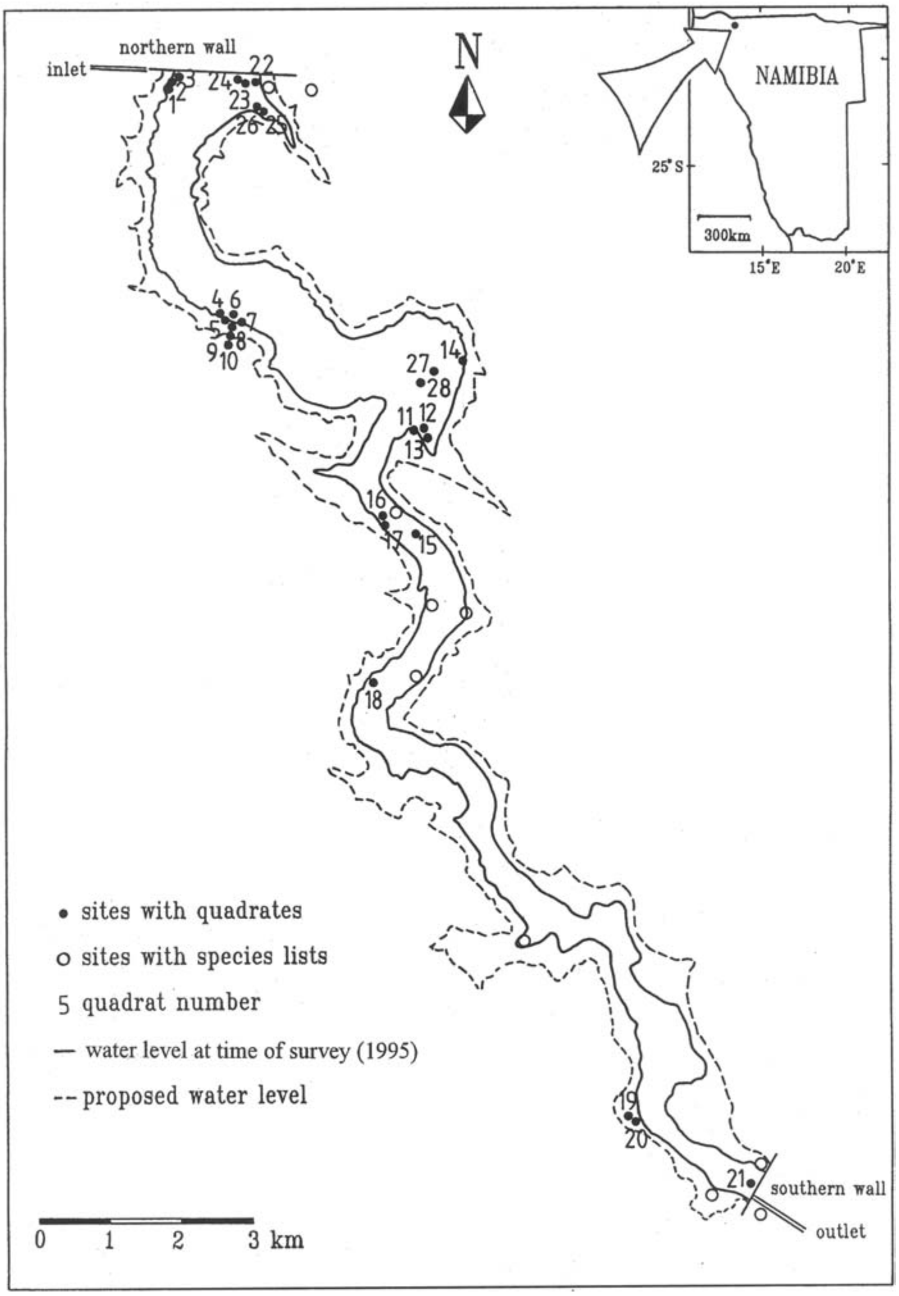

Figure 1: Study area and sampling points of botanical survey at Olushandja Dam, north central Namibia.

For easier reference, plant communities were grouped and described according to:

- wetland
- transitional and
- terrestrial communities.

Wetland communities

Floating mats and floating-leafed vegetation

Floating mats are plant assemblages dominated by aquatic plants with stem-floating growth form. In Olushandja Dam *Ludwigia stolonifera* was the most prominent stem-floating plant species, often accompanied by emergent aquatic sedges such as *Cyperus imbricatus* and emergent aquatic perennials which were rooted in the floating mats. *Ludwigia octovalvis* ssp. *brevisepala* and *Eclipta prostrata* were the most common emergent aquatic perennials associated with this community. *Ludwigia stolonifera* was rooted in the ground, but produced long runners forming dense mats. Occasionally sedge species such as *Courtoisina assimilis* and *Cyperus pectinatus* as well as young *Phragmites mauritianus* plants rooted in these mats.

Floating mats usually developed close to the shore (0-10m), only reaching as far as 30 m into the water in sheltered bays. Average water depths within this community ranged between 15 and 45 cm and plants were rooted in the shallow water. Wave action further away from the shore, as well as greater depths, might have restricted the development of larger mats within the dam. Floating mats were the most widely distributed community type and patches occurred all around the dam, although they were more concentrated in the northern part.

Floating-leafed vegetation drifts on the water and thus often occurs in other communities as accompanying species. Floating-leafed vegetation formed uniform stands in some parts of the dam, with an average of three species within this community. *Nymphoides indica* and *Ludwigia stolonifera* were the dominant species, interspersed by tall sedges such as *Cyperus imbricatus* and *Schoenoplectus corymbosus*. At average water depths of 30 cm the floating-leaved vegetation extended up to 25 m from the shore into the water. Wave action restricted the distribution of *N. indica* to few sheltered places along the eastern shore and made it the rarest of the aquatic communities.

Reedbeds

Reedbeds were found at several places along the old shoreline as well as in the centre of the dam. The latter were usually associated with previous termite mounds or excavations which were partially or totally covered by the present water level. In most cases the reedbeds formed uniform one-species stands of either *Cyperus articulatus*, *Phragmites mauritianus* or *Typha capensis*. Since *Phragmites* reedbeds reached heights of up to 5 m, they formed very prominent features in the dam. Reedbeds consisting of *Typha* were usually slightly lower, reaching up to 3.5 m in height. Occasionally reedbeds consisting of the sedge *Cyperus articulatus* occurred. These were smaller in extent and in height (up to 2 m). The average water depth of these communities ranged from 50 to 120 cm. Reedbeds were growing near the northern and southern dam wall as well as in the central parts of the dam.

Sedge communities

The most prominent sedge communities in Olushandja Dam reached heights up to 1.5 m and consisted mainly of *Cyperus imbricatus* and *Schoenoplectus corymbosus*. Accompanying species were *Bolboschoenus nobilis*, the submerged *Utricularia gibba* and *Ludwigia stolonifera*. Growing in the vicinity of the shoreline, but rooted in the water, sedge communities colonised water depths of 5 to 35 cm on average. They usually did not exceed distances of 10 m from the shoreline. The average number of species in this community was six. Sedge communities were scattered around the dam, usually in sheltered places, but like the floating mats, were more frequent in the northern part of the dam.

Ephemeral ponds

Dominated by two water fern species, *Marsilia* cf. *unicornis* and *Marsilia* sp., and accompanied by the water lily *Nymphaea nouchali* var. *caerulea,* the vegetation in ephemeral ponds differed substantially from the wetland vegetation in the dam. These ephemeral ponds were at the time of the survey not connected with the dam and so rainwater-fed

Transitional plant communities

Fringe vegetation

At the interface of water and land, diverse assemblages of wetland-associated species occurred. Subjected to often rapidly receding water levels, species growing at the dam margin either tolerate a wide range of conditions from submerged to exposed or they are short-lived, fast growing annuals. These germinate rapidly once the water level starts receding after the rainy season and complete their life cycle before the margins have entirely dried out. Frequently encountered species around the dam margin were *Ludwigia stolonifera*, which grew in damp areas on land as well as floating in the water, the weakly succulent creeper *Ammannia baccifera* and the sedge *Cyperus compressus*. Compared to the purely aquatic communities, the fringe vegetation was more diverse, since wetland associated and terrestrial species occurred together. An average of 10 species was found in this community. From the water level at the time of the survey the fringe vegetation extended up to 5 m inland depending on the slope of the shore.

Cynodon *lawns*

Cynodon dactylon is one of the grass species which occurred all around the dam, forming small patches of lawn at several locations. Since it is a common floodplain grass adapted to seasonal flooding, it grows quickly when the water rises and dies back when the water level drops again (Heeg & Breen 1982; Bethune 1991).

Terrestrial plant communities

A belt of terrestrial vegetation, about 15 - 20 m wide, enclosed the dam. The vegetation was dominated by terrestrial grasses and herbs and occasional *Acacia nilotica* and *Acacia hebeclada* subsp. *tristis* trees. Further away from the dam was an about 100 m wide belt dominated by the shrub *Pechuel-Loeschea leubnitziae*. This is an aromatic, unpalatable shrub which indicates overgrazing. The next zone was about 200 m wide and was characterised by coppiced *Colophospermum mopane* (mopane). It was interspersed with grazing indicators, such as *Geigeria ornativa*. Natural mopane woodland followed this zone.

Special habitats within the dam were the islands associated with termite mounds. Some of these harboured dense reed beds, others were inhabited by *Acacia* and mopane trees. Besides the reeds and trees, only common herbs, some of which are weedy (*Amaranthus thunbergii* and *Setaria verticillata*) were found on these islands.

Distribution of species

Of the 47 aquatic species, 51% are also reported to occur in the Okavango River system (Bethune 1991). These include species with southern African distribution such as *Ludwigia stolonifera, Nymphoides indica* and *Typha capensis*, but also the regional endemic *Lagarosiphon ilicifolius*.

In total, 70 % of the wetland species showed southern African distribution, while 19 % occur occasionally in southern Africa (Table 2). There were no Namibian endemic wetland plants, but 11 % of the species were regional endemics, occurring in wetland systems in northern Namibia and the Okavango basin, such as *Mariscus hamulosus, Marsilia unicornis* and *Oryzidum barnadii*.

A comparison of Olushandja wetland species with a study conducted at several sites in the adjacent Oshanas (Clarke 1999), revealed that nearly 44 % of the wetland species in the dam also occurred in the surrounding Oshanas. However, some conspicuous plants of the Oshanas, such as the common *Ipomoaea aquatica*, were not found in the dam, while several wetland species usually found in permanent water, like *Ceratophyllum demersum*, both *Ludwigia* species and *Utricularia gibba* were not recorded in the Oshanas. Apart from the presence of *Ipomoaea aquatica,* also many more sedge species were recorded in the Oshanas.

Discussion

Plant communities and potential sources of colonisation

Understanding the processes which lead to and maintain the floral composition of a man-made wetland is crucial to provide the means for making recommendations concerning wetland management. A first step towards elucidating this process is the analysis of floristic affinities with other wetland communities in a local and regional context.

Local perspective: Affinities with surrounding wetland communities

The closest wetlands in the vicinity of Olushandja Dam are the Oshanas and the Kunene River. The Oshanas are part of an ephemeral river system, while the Kunene is a permanently flowing river. Thus conditions in both of these differ from those in a permanent, not flowing water body. The wetland vegetation of the Oshanas is largely composed of short-lived annuals which survive the dry period in form of seeds and plants with underground storage organs (Clarke 1999). Both of these life form strategies are well adapted to extreme seasonal fluctuations of their habitat and endure the dry period in a dormancy stage. However, despite the difference in flooding and seasonal regimes between the dam and surrounding Oshanas, quite a large number of species occurred in both, seemingly able to cope with ephemeral as well as permanent aquatic conditions. These include floating stem-aquatics like *Neptunia oleracea* and *Nymphoides indica*. Although there is some species overlap, species composition of ephemeral ponds was different from the remaining wetland vegetation. The Oshanas thus only partially provide the source for colonisation of the Olushandja Dam, but may have been the first source to colonise the newly established wetland habitat. The higher diversity of sedges in the surrounding Oshanas, possibly reflects the higher sampling intensity and thus capturing of seasonal changes or could indicate more variety of habitats for short-lived sedges following the seasonal change of filling and drying up of these ephemeral wetlands.

The Kunene River with permanently flowing water is another potential source of wetland species which have colonised the dam. A channel links the Kunene River directly to the northern part of Olushandja Dam which may have served as a corridor for wetland vegetation to the dam. Unfortunately, the lack of information on wetland plants in the Angolan part of the Kunene River which also holds a large impoundment north of Olushandja Dam, does not allow a detailed analysis. Wetland vegetation downstream of the inlet to Olushandja is relatively species-poor and bears little resemblance to the Olushandja wetland flora (pers. obs.).

The Etosha Pan, although only some 100 km to the south, is characterised by high salinity and is either bare or supports vegetation along its fringes which is adapted to cope with these saline conditions. There are thus no species common to both water systems (le Roux *et al*. 1988).

At Olushandja Dam, unlike natural wetland systems (Hughes 1988; Dunham 1989), the wetland vegetation showed no zonation pattern, but was patchily distributed around the dam. Although the classical zonation is often ascribed to wetland systems, many wetlands are modified in the form of a mosaic rather than linear bands of vegetation (Rogers 1997), reflecting local influences of water regime and currents. Similar forces, in addition to fluctuating water levels, may have been acting upon wetland communities in the dam. The terrestrial vegetation, in turn, showed clear zonation which can be attributed to different types and levels of utilisation around the dam. Mopane trees near the water's edge were cut at the time of establishment of the dam and since the dam has seldom reached its full capacity these areas provided convenient places for settlements. Grazing pressure is thus high in the vicinity of the dam, accounting for the presence of many overgrazing indicators such as *Pechuel-Loeschea leubnitziae* and *Geigeria ornativa*.

Regional perspective: What is special about Olushandja Dam?

The fact that more than half of the wetland species occur in the adjacent Okavango River system (Bethune 1991) and 70 % show southern African distribution (Table 2), supports the idea that, given sufficient time, species adapted to permanent aquatic conditions eventually colonise man-made water bodies provided water levels are kept fairly constant (Allanson *et al.* 1990). Water birds, wildlife and humans may have served as vectors bringing seeds and vegetative parts which then established in the dam.

Table 2: Geographic distribution of wetland species in and around Olushandja Dam (total species = 47).

Distribution	Percent
Southern Africa	70
Occasional in southern Africa	19
Namibian endemic	0
Regional endemic (northern Namibia and Okavango Delta)	11

On a species level, the reedbeds were composed of two common reed species (*Phragmites australis* and *Typha capensis*) in southern Africa which have also colonised dams in South Africa (e.g. Pieterse & Keulder 1982). In terms of species diversity, aquatic plant communities are generally species poor, usually dominated by one to five species, or rarely up to 17 species (Ellery *et al*. 1991). The one to seven species recorded in aquatic plant communities in Olushandja Dam is thus in line with findings elsewhere. The relative species scarcity can be attributed to the fact that many aquatic plants reproduce vegetatively forming massive clones of few individuals. This is especially true for reed and sedge species (*Phragmites australis, Typha capensis, Cyperus* spp.), but also some for stem-floating species, such as *Ludwigia stolonifera*.

On a community level, a study in the Okavango Delta delimited seven plant communities (Ellery *et al.* 1991), only one more aquatic community than found in the Olushandja Dam. The average of five species recorded in the floating mats corresponded to species numbers a study in the Okavango delta, although the species differed (Ellery *et al.* 1991). However, sedge communities at Olushandja Dam reached only about half the number of species recorded in the Okavango Delta (Ellery *et al.* 1991) and apart from *Schoenoplectus corymbosus*, the species composition differed. This might be explained by the fact that sedge communities are usually late successional plant communities, which require long, undisturbed periods to develop (Ellery *et al.* 1993). Fluctuating water levels in the dam may not have provided the conditions for successional development.

Two environmental factors strongly affecting the dam are shallowness (and resulting turbidity of the water) and, although moderate compared to other dams in Namibia, fluctuating water levels (i.e. frequency, duration and depth of flooding). Fluctuating water levels are characteristic for most man-made impoundments in southern Africa (Allanson *et al*. 1990), yet most impoundments are much deeper than Olushandja Dam. The shallowness results in turbid water for most of the year which strongly affects plant and animal communities by limiting photosynthetic activity.

The value of a man-made wetland system in northern Namibia

Biodiversity and benefits for wildlife

The species richness of wetland plants and community types at Olushandja Dam, a man-made system, is comparable to natural wetland systems in the region (e.g. Bethune 1991, Ellery *et al.* 1991) and thus presents a biological diversity which should be maintained.

Floating mats provide shelter and nesting sites for a variety of aquatic and wetland insects, reptiles, snails, birds and, most importantly, fish. The floating mats might also help to reduce wave action along the margins, thus increasing the clarity of the otherwise turbid water in most parts of the shallow dam. However, floating mats also provide a home for bilharzia-carrying snails. A number of bird species, such as Red Bishops (*Euplectes orix* L.), use reedbeds for nesting sites (Roberts 1995). Normally, reedbeds are found along the margins of rivers and standing waters, but hardly ever in the centre of a large water body. The reedbeds in the middle of the dam thus provide a refuge for birds away from the water's edge which is often frequented by people. In areas with water pollution problems reedbeds and sedge communities are often used as natural filters to purify water (Brix 1994); those within the dam are likely to help filtering domestic pollutants in the water.

In terms of biodiversity conservation, at the time of the survey Olushandja dam was home to one of the very few populations of an indigenous, close relative of cultivated rice, the wetland grass *Oryza longistaminata*. This grass may prove to be a genetic source for traits that may be of agricultural importance (Brindley 1992).

Utilisation

At present the vegetation surrounding the dam is heavily utilised for grazing, cutting of fuel wood and fencing. Accordingly the entire margin of the dam shows severe signs of over-utilisation. The fringe communities have been subjected to severe trampling and grazing, especially in the vicinity of villages, which is gradually changing their habit and composition to a few low growing, unpalatable species. *Cynodon dactylon* lawns which have a high grazing value have been reduced to few patches and may have been more common in the past. Sedges and reeds are used for thatching and fencing, but are either not used as heavily as other plant resources or regenerate fast enough not to show obvious signs of over-utilisation.

Implications for management

Securing water supply and biological diversity

The prime objective of Olushandja Dam is as an emergency water supply for northern Namibia. The low utilisation level of the past has resulted in the establishment of diverse wetland communities supporting wildlife and rural communities in form of permanent fishing grounds. Maintaining the biological diversity while carrying out required management interventions should ideally go hand in hand.

The impact of a raise in the water level, as suggested by the Department of Water Affairs, for example, could be minimised by following simple guidelines. From a botanical point of view, most wetland communities, such as reedbeds and floating mats are adapted to seasonal changes in water level (Ellery *et al.* 1993) and, provided that the filling of the dam is extended over a sufficiently long period of several months, the wetland vegetation in the Olushandja Dam will be able to colonise new habitats. A rise in water level could have two contrasting effects on the fringe vegetation: in areas where the proposed water level will move closer to habitations, the fringe vegetation may suffer more severe pressure by grazing and trampling than at present. Where the proposed water level inundates present settlements, the negative human impact may be removed and may help the re-establishment of new fringe vegetation.

Research needs

The importance of wetlands in Namibia has been recognised (Simmons *et al.* 1991), but Namibian wetlands are poorly understood (Breen 1991). Many practical questions related to management of natural and artificial wetlands arose in this study. These could be answered in future, if long-term observations are carried out. For example, little is known about the life cycle of Namibian wetland plants, their main growing season, germination requirements and responses to environmental and biotic factors. Yet for management purposes, these processes need to be understood to develop management interventions. Allelopathic interactions, for example, have been reported in many aquatic plants, inhibiting germination and growth of their neighbours (Elakovich & Wooten 1995). On the other hand, many wetland species form mycorrhiza, which might enhance their establishment potential (Rickerl *et al.* 1994). Nothing is known about Namibian wetland plants in these respects.

Permanent wetlands naturally experience some fluctuations in water level. Thus wetland plants are adapted to changes in water depths and different periods of inundation, both of which make up the water regime (Rea & Ganf 1994). Which water regimes Namibian wetland plants can tolerate is speculative at present. Although the flooding regime has been recognised to be the most important variable determining the composition of wetland plant communities in southern Africa (e.g. Ellery *et al.* 1991, Roger 1997), substrate can also play an important role (Coetzee & Rogers 1991). Understanding the response of wetland vegetation to different water regimes will allow to make recommendations for future impoundments and the management of existing ones.

The apparent conflict of maintaining floating mats for the benefit of fishing, potential pollution control and biodiversity conservation versus their negative impact as shelter for bilharzia vectors needs further study.

Conclusion

The species richness of wetland plants and community types at Olushandja Dam was comparable to natural wetland systems in the region (e.g. Bethune 1991, Ellery *et al.* 1991) and thus presents a biological diversity which should be maintained. Potential sources of colonisation by wetland plants were the surrounding Oshanas, the Okavango River, and the Kunene River upstream of the dam, resulting in the dam's floral composition being comparable to permanent wetlands elsewhere in southern Africa. However, at Olushandja Dam, as a man-made and man-controlled system, fluctuating water levels and shallow depth provide an unusual combination of environmental factors determining the diversity of plant and animal life and resulting in largely turbid water. Maintaining biological diversity while carrying out required management interventions should ideally go hand in hand. Appropriate management interventions need to be backed up by research on Namibian wetland plants investigating, for example, life cycle, germination requirements and plant responses to different water regimes.

Acknowledgements

I am grateful to the Department of Water Affairs for the opportunity to undertake this study which is sponsored through development aid of the Dutch Government. Special thanks go to Kevin Roberts for invaluable logistic support, to Herta Kolberg for help with plant identifications and comments and to Shirley Bethune, Pat Craven, Stefan de Wet, Barbara Curtis, Ben Strohbach and two anonymous referees for comments on an earlier draft of this manuscript. Thanks also to Olga Karunga (Weather Bureau) for providing weather data, to the National Herbarium for access to the sedge collections and to Nicholas Clarke for providing unpublished material of his study of the Oshanas.

References

ALLANSON, B.R., HART, R.C., O'KEEFFE, J.H. & ROBARTS, R.D. 1990. *Inland waters of southern Africa*. Kluwer Academic Publishers, Dordrecht.

ARNOLD, T.H. & DE WET, D.C. 1993. *Plants of southern Africa: names and distribution.* Memoirs Botanical Survey of Southern Africa. No. 62, pp. 825.

BETHUNE, S. 1991. Kavango River wetlands. *Madoqua* 17:77-112.

BREEN, C.M. 1991. Are intermittently flooded wetlands of arid environments important conservation sites? *Madoqua* 17:61-65.

BRINDLEY, B. 1992. *Geneflow: biodiversity and plant genetic resources*. International Board for Plant Genetic Resources, Rome.

BRIX, H.1994. Use of constructed wetlands in water-pollution control - historical development, present status and future perspectives. *Water Science and Technology* 30:209-223.

CLARKE, N. V. 1999. Flora of the Cuvelai wetlands, northern Namibia. *Cimbebasia* 15: 99-115.

COETZEE, M.A.S. & ROGERS, K.H. 1991. Environmental correlates of plant species distribution on the Nyl River floodplain. *South African Journal of Aquatic Science* 17:44-50.

CRAVEN, P. (ed.) 1999. *A checklist of Namibian Plant Species*. Southern African Botanical Diversity Network Report No. 7.

DUNHAM, K.M. 1989. Vegetation-environmental relations of a Middle Zambesi floodplain. *Vegetatio* 82:13-24.

ELAKOVICH, S.D. & WOOTEN, J.W. 1995. Allelopathic, herbaceous, vascular hydrophytes. *ACS Symposium Series* 582:58-73.

ELLERY, K., W.N. ELLERY, K.H. ROGERS & B.H. WALKER 1991. Water depth and biotic insulation: Major determinants of back-swamp plant community composition. *Wetlands Ecology and Management* 1(3):149-162.

ELLERY, W.N., K. ELLERY & T.S. MCCARTHY 1993. Plant distribution in islands of the Okavango Delta, Botswana: determinants and feedbacks interactions. *African Journal of Ecology* 31:118-134.

GEOLOGICAL SURVEY 1980. *Geological map of South West Africa/Namibia.* Geological Survey, Windhoek.

HEEG, J. & BREEN, C.M. 1982. *Man and the Pongolo.* South African National Scientific Programmes Report 56. Council for Scientific and Industrial Research, Pretoria.

HUGHES, F.M.R. 1988. The ecology of African floodplain forests in semi-arid zones: a review. *Journal of Biogeography* 15:127-140.

KOLBERG, H., GIESS, W., MÜLLER, M.A.N. & STROHBACH, B. 1992. List of Namibian plant species. *Dinteria* 22: 1-121.

LE ROUX, C.J.G., GRUNOW, J.O., MORRIS, J.W., BREDENKAMP, G.J. & SCHEEPERS, J.C. 1988. A classification of the vegetation of the Etosha National Park. *South African Journal of Botany* 54:1-10.

MARSH, A. & SEELY, M. 1992. *Oshanas. Sustaining people, environment and development in central Owambo, Namibia*. Typoprint, Windhoek.

MERXMÜLLER H. 1966-1972. *Prodromus einer Flora von Südwestafrika*. Botanische Staatssammlung München, Vol. 1-4, Cramer Verlag, Lehre.

MUELLER-DOMBOIS, D. & H. ELLENBERG 1974. *Aims and Methods of Vegetation Ecology*. John Wiley & Sons, New York, London, Sydney, Toronto, 547 pp.

PIETERSE, A.J.H. & KEULDER, P.C. 1982. *The limnology of a shallow, turbid impoundment, Wuras Dam: a study of the role of suspensoids.* Working group for Limnology, University of the Orange Free State, Bloemfontein.

REA, N. & GANF, G.G. 1994. How emergent plants experience water regime in a mediterranean-type wetland. *Aquatic Botany* 49:117-136.

RICKERL, D.H. SANCHO, F.O. & ANANTH, S. 1994. VAM colonization of wetland plants. *Journal of Environmental Quality* 23:913-916.

ROBERTS, K. 1995. *Limnological investigation of the Olushandja Dam as part of the environmental evaluation of the proposed upgrading of the Calueque-Olushandja water supply scheme*. Department of Water Affairs, Report No: RR/94/6.

ROGERS, K.H. 1997. Freshwater wetlands. In: Cowling, Richardson & Pierce (eds) *Vegetation of southern Africa,* pp. 322-347. Cambridge University Press, Cambridge.

SIMMONS, R.E., BROWN, C.J. & GRIFFIN, M. (eds.) 1991. The status and conservation of wetlands in Namibia. *Madoqua* 17, Special wetlands edition.

Appendix I: List of aquatic and terrestrial plant species found in and around Olushandja Dam, north central Namibia. (Habitat and growth from: EA emergent aquatic, LFA leaf-floating aquatic, RU ruderal, sA submerged aquatic, SFA stem-floating aquatic, T terrestrial, TI terrestrial on islands, WA wetland associated (see Table 1C); Distribution: i introduced, NE Namibian endemic, rE regional endemic, oS occasional in southern Africa, sA widespread in southern Africa (see Table 2); ep ephemeral ponds only.

Species	Family	Habitat	Distribution
Abuliton pycnodon Hochr.	Malvaceae	TI	oS
Abuliton rehmannii Bak.f.	Malvaceae	T	sA
Acacia arenaria Schinz	Fabaceae	T	oS
Acacia hebeclada DC. ssp. *tristis* (Welw. ex Oliver) A.Schreiber	Fabaceae	T	rE
Acacia karroo Hayne	Fabaceae	T	sA
Acacia nilotica (L.)Willd. ex Del. spp. *krausiana* (Benth.)Brenan	Fabaceae	T	sA
Acacia tortilis ssp. *heteracantha* (Burch.)Brenan	Fabaceae	T	sA
Acrotome inflata Benth.	Lamiaceae	T,RU	sA
Adenium boehmianum Schinz	Apocynaceae	T	rE

Species	Family	Habitat	Distribution
Aeschynomene indica L.	Fabaceae	WA	sA
Aizoon canariense L.	Aizoaceae	WA	sA
Amaranthus thunbergii Moq.	Amaranthaceae	T,RU	sA
Ammannia baccifera L. spp. *baccifera*	Lythraceae	EA,WA	sA
Anthephora schinzii Hack.	Poaceae	T	sA
Aristida hordeacea Kunth	Poaceae	T,RU	oS
Aristida cf *stipitata* Hack. ssp. *stipitata*	Poaceae	T	sA
Bergia spathulata Schinz	Elatinaceae	WA	RE
Blumea cafra (DC.) O.Hoffm.	Asteraceae	T,RU	sA
Bolboschoenus nobilis (Ridley)Goetghebeur & Simpson	Cyperaceae	EA	oS
Bulbostylis humilis (Kunth) C.B.Clarke	Cyperaceae	WA	oS
Bulbostylis hispidula (Vahl) R.Haines	Cyperaceae	WA, T	sA
Burnatia enneandra P.A.Mich.	Alismataceae	SFA,ep	sA
Ceratophyllum demersum L. var. *demersum* forma *demersum*	Ceratophyllaceae	sA	sA
Chamaecrista absus (L.) Erwin & Barneby	Fabaceae	T	oS
Chamaesyce hirta (L.)Millsp.	Euphorbiaceae	WA	sA
Chamaesyce inaequilatera (Sond.) Sojak	Euphorbiaceae	T,RU	sA
Chloris virgata Swartz	Poaceae	T,RU	sA
Colophospermum mopane (Kirk ex Benth.) Kirk ex J.Leonard	Fabaceae	T	sA
Conyza bonariensis (L.) Cronq.	Asteraceae	T,RU	sA,I
Corallocarpus welwitschii (Naud.) Hook.f. ex Welw.	Cucurbitaceae	T	oS
Corchorus tridens L.	Tiliaceae	WA	sA,I
Courtisina assimilis (Steud.) P.Maquet	Cyperaceae	EA	sA
Crotalaria sphaerocarpa Perr. ex DC. ssp. *sphaerocarpa*	Fabaceae	T	sA
Cucumis africanus L.f.	Cucurbitaceae	T	sA
Cynodon dactylon (L.) Pers.	Poaceae	T,RU	sA
Cyperus articulatus L.	Cyperaceae	EA	sA
Cyperus compressus L.	Cyperaceae	EA	sA
Cyperus difformis L.	Cyperaceae	EA	sA
Cyperus digitatus Roxb. ssp. *auricomus* (Sieber ex Spreng.) Kückenth.	Cyperaceae	EA	sA

Species	Family	Habitat	Distribution
Cyperus imbricatus Retz.	Cyperaceae	EA	sA
Cyperus pectinatus Vahl	Cyperaceae	SFA	sA
Dactyloctenium aegyptium (L.) Willd.	Poaceae	T,RU	sA
Dicoma anomala Sond.	Asteraceae	T	sA
Diplachne cuspidata Launert	Poaceae	WA,ep	sA
Echinochloa crus-galli (L.) Beauv.	Poaceae	WA,SF A,TI	sA
Eclipta prostrata (L.) L.	Asteraceae	EA	sA, I
Elytrophorus globularis Hack.	Poaceae	WA	sA
Enneapogon cenchroides (Roem.& Schult) C.E.Hubb.	Poaceae	T,RU	sA
Eragrostis bicolor Nees	Poaceae	T	sA
Eragrostis cylindriflora Hochst.	Poaceae	T	sA
Eragrostis porosa Nees	Poaceae	T	sA
Eragrostis viscosa (Retz.)Trin.	Poaceae	T	sA
Fuirena ciliaris (L.) Roxb. var. *ciliaris*	Cyperaceae	WA	sA
Galenia papulosa (Eckl.&Zeyh.) Sond. var. *papulosa*	Aizoaceae	T,WA	oS
Geigeria acaulis Benth.& Hook.f. ex Oliv.& Hiern	Asteraceae	T	oS
Geigeria ornativa O.Hoffm.	Asteraceae	T,RU	sA
Gisekia africana (Lour.) Kuntze var. *africana*	Aizoaceae	WA,T	sA
Gomphrena celosioides Mart.	Amaranthaceae	T,RU	sA,i
Heliotropium supinum L.	Boraginaceae	T	sA
Helichrysum cf. *lineare* DC.	Asteraceae	T	sA
Hermannia cf. *depressa* N.E.Br.	Sterculiaceae	WA,T	sA
Hermannia modesta (Ehrenb.) Mast.	Sterculiaceae	T	sA
Hermbstaedtia argenteiformis Schinz	Amaranthaceae	T	oS
Hirpicium gorterioides (Oliv.& Hiern) Rössl. ssp. *gorterioides*	Asteraceae	T	sA
Hoodia cf. *parviflora* N.E.Br.	Asclepiadaceae	T	rE
Hyphaene petersiana Klotzsch	Arecaceae	T	oS
Indigofera holubii N.E.Br.	Fabaceae	T	sA
Ipomoea adenioides Schinz	Convolvulaceae	T	oS
Isolepis hystrix (Thunb.) Nees	Cyperaceae	WA	oS

Species	Family	Habitat	Distribution
Kohautia cf cynanchica DC.	Rubiaceae	T	sA
Kohautia cf *caespitosa* ssp. *brachyloba* (Sond.) D.Mantell	Rubiaceae	T	sA
Lagarosiphon ilicifolius Oberm.	Hydrocharitaceae	sA	rE
Limeum viscosum (Gay) Fenzl ssp. *Viscosum* var. *macrocarpum* Friedr.	Aizoaceae	T	oS
Lindernia parviflora (Roxb.) Haines	Scrophulariaceae	WA	oS
Ludwigia octovalvis (Jacq.) Raven ssp. *Brevisepala* (Brenan) Raven	Onagraceae	EA	oS
Ludwigia stolonifera (Guill.& Perr) Raven	Onagraceae	SFA	sA
Mariscus aristatus (Rottb.) Cherm. var. *atriceps* (Kück.) Podlech	Cyperaceae	WA	sA
Mariscus hamulosus (M.Bieb.) Hooper	Cyperaceae	WA	rE
Marsilea cf. *unicornis* Launert	Marsileaceae	EA,ep	rE
Marsilea sp.	Marsileaceae	LFA,ep	?
Merremia multisecta Hallier f.	Convolvulaceae	T	rE
Mollugo cerviana (L.) Ser. ex DC.	Aizoaceae	T	sA
Neptunia oleracea Lour.	Fabaceae	SFA	sA
Nymphaea nouchali Burm.f. var. *caerulea* (Sav.)Verdc.	Nymphaeaceae	LFA,ep	sA
Nymphoides indica (L.) Kuntze ssp. *occidentalis* A.Raynal	Menyanthaceae	LFA	sA
Oryza longistaminata A.Chev.& Roehr	Poaceae	EA	sA
Oryzidium barnadii C.E.Hubb.& Schweick.	Poaceae	SFA,ep	rE
Osteospermum sp.	Asteraceae	WA	?
Ottelia exserta (Ridley) Dandy	Hydrocharitaceae	LFA,ep	oS
Panicum maximum Jacq.	Poaceae	T	sA
Pechuel-Loeschea leubnitziae (Kuntze) O.Hoffm.	Asteraceae	T,RU	sA
Pentzia sp.	Asteraceae	WA	?
Phragmites mauritianus Kunth.	Poaceae	EA,SFA	sA
Pogonarthria squarrosa (Roem.& Schult.) Pilg.	Poaceae	T	sA
Polygala pallida E.Mey.	Polygalaceae	T	oS
Portulaca oleracea L.	Portulacaceae	T	sA,i
Pterodiscus aurantiacus Welw.	Pedaliaceae	T	oS
Pupalia lappacea (L.) A.Juss. var.	Amaranthaceae	T,RU	sA, i

Species	Family	Habitat	Distribution
lappacea			
Pycreus macrostachyos (Lam.) J.Raynal	Cyperaceae	EA	sA
Schmidtia kalihariensis Stent	Poaceae	T	oS
Schmidtia pappophoroides Steud	Poaceae	T,RU	sA
Schoenoplectus corymbosus (Roth.ex Roem.& Schult.) J.Raynal	Cyperaceae	EA	sA
Schoenoplectus praelongatus (Poir) J.Raynal	Cyperaceae	EA	sA
Schoenoplectus muricinux (C.B.Cl.) J.Raynal	Cyperaceae	EA	sA
Schoenoplectus sp.1	Cyperaceae	EA	?
Schoenoplectus sp.2	Cyperaceae	EA	?
Senna italica Mill. spp. *arachoides* (Burch.) Lock	Fabaceae	T	sA
Senna occidentalis (L.) Link	Fabaceae	T	sA,i
Sesamum triphyllum Welw. ex Aschers var. *triphyllum*	Pedaliaceae	T	sA
Sesbania microphylla Phill.& Hutch.	Fabaceae	T	rE
Sesuvium sesuvioides (Fenzl.) Verdc. var. *sesuvioides*	Aizoaceae	T	oS
Setaria verticillata (L.) Beauv.	Poaceae	T,RU	sA
Solanum nigrum L.	Solanaceae	T,RU	sA,i
Solanum rigescentoides Hutch.	Solanaceae	T	NE
Tephrosia purpurea (L.) Pers. ssp. *leptostachya* (DC.) Brummit	Fabaceae	T	oS
Terminalia prunioides Laws.	Combretaceae	T	oS
Tragus racemosus (L.) All.	Poaceae	T,RU	sA
Typha capensis (Rohrb.) N.E.Br.	Typhaceae	EA	sA
Utricularia gibba L.	Lentibulariaceae	sA	oS
Vahlia capensis (L.f.) Thunb. ssp. *vulgaris* Bridson var. *vulgaris*	Vahliaceae	T	sA