Rapid Assessment Program

A Rapid Biological Assessment of the Aquatic Ecosystems of the Okavango Delta, Botswana: High Water Survey

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27

Editors
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Organizational Profiles

CONSERVATION INTERNATIONAL

Conservation International (CI) is an international, nonprofit organization based in Washington, DC. CI believes that the Earth's natural heritage must be maintained if future generations are to thrive spiritually, culturally and economically. Our mission is to conserve the Earth's living heritage, our global biodiversity, and to demonstrate that human societies are able to live harmoniously with nature.

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CONSERVATION INTERNATIONAL – BOTSWANA (CI-BOTSWANA)

The mission of Conservation International – Botswana is to conserve the biodiversity of the Okavango River Basin and to demonstrate that human societies are able to live harmoniously with their natural environment. CI-Botswana's activities focus on Corridor Planning and Management, Policy and Advocacy, Biodiversity Research and Monitoring, and Community Conservation through Ecotourism and Enterprise development. Research focuses on elephants *(Loxodonta africana)*; the African wild dog *(Lycaon pictus)*; Wattled crane *(Bugeranus carunculatus)*; White Rhinoceros *(Ceratotherium simum)*; Nile crocodile *(Crocodylus nilotica)*; and Cheetah *(Acinonyx jubatus)*. CI-Botswana's vision is to see that by 2010, the Okavango River basin is functioning as a biodiversity corridor that spans three countries (Angola, Botswana, and Namibia). This corridor will be managed by the riparian states as a transboundary natural resource with active participation of the local communities. The benefits of the region's economic development will accrue to local communities.

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DEPARTMENT OF FISHERIES, BOTSWANA

The Fisheries Section of the Botswana government is mandated with the responsibility for the management of Botswana's fish resources. To that extent the Section is involved in two main activities: 1) Fisheries Extension - to teach fishers (primarily subsistence and commercial) the appropriate technologies of fish harvesting, preservation, preparation, etc. and 2) Fisheries Research - to determine maximum sustainable levels (MSY) of harvesting and appropriate gear technology in the utilization of the fisheries resources.

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DEPARTMENT OF WATER AFFAIRS, BOTSWANA

The Department of Water Affairs (DWAF) falls under the Ministry of Mineral, Energy & Water Affairs who are responsible for national water resources planning and development. The DWAF acts as the secretariat of a Board whose members include major stakeholders in government, farmers, and the community at large. Its responsibilities are discharged through five technical divisions including: Hydrology and Water Resources (co-ordination of national water resources planning, studies and developments of surface water, hydrological data collection and management, aquatic weed control); Groundwater (groundwater planning, investigation, assessment, development, protection, and management); Design and Construction (planning, designing, and construction of water supplies for government institutions, major and rural villages); Operation and Maintenance (operation and maintenance of water supply for 17 major villages, water quality and pollution monitoring activities); and Electro-Mechanical.

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HARRY OPPENHEIMER OKAVANGO RESEARCH CENTRE

The HOORC was established in Maun, under the University of Botswana in 1993 to concentrate on the development and conservation issues in the Okavango Delta region. The aim is to support the development of sustainable resources used by local communities in the whole river basin so as to promote its long-term conservation. The objectives of the HOORC are: 1) through research, teaching, documentation, and outreach, enhance the understanding of the natural systems of the Okavango River Basin; 2) to explain the relationships between human activity and the functioning of the those natural systems; 3) to facilitate, evaluate, and monitor community-based natural resource management activities; 4) to develop recommendations on enhanced planning and management of natural resource use and economic and settlement activitiy in the Okavango Region; 5) to document and disseminate information and knowledge on the Okavango River Basin; 6) to monitor environmental, social, and attitudinal change; 7) to develop regional and local expertise with the ambition and ability to convey this aim and these objectives into the future.

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UNIVERSITY OF BOTSWANA

The University of Botswana came into existence in 1982. The University is an autonomous institution, national in character but with its focus increasingly becoming regional and global. The University offers a wide range of undergraduate and graduate programs spanning a wide range of disciplines including Business, Education, Humanities, Science, Engineering, and Social Sciences. Programmes are taught from Certificate, Diploma, Bachelor's degrees through to Master's and Doctoral degrees. The Faculty of Science was started as a local Unit of School of Science of the then University of Botswana, Lesotho, and Swaziland in 1971. The four departments, namely Biology, Chemistry, Mathematics, and Physics, which constituted the faculty at the time were involved only in teaching part I of the BSc degree programme. In 1975 the Lesotho campus dissociated from UBLS and the University of Botswana and Swaziland (UBS) was formed. In the same year, the teaching of Part II (years 3 and 4) was started in the the four departments. Departments of Environmental Science, Geology, and Computer Science were added to the faculty before the University of Botswana came into existence in 1982.

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SOUTH AFRICAN INSTITUTE FOR AQUATIC BIODIVERSITY (SAIAB)

The South African Institute for Aquatic Biodiversity (SAIAB), formerly the JLB Smith Institute of Ichthyology, is a National Facility of the National Research Foundation in South Africa. The institute's vision is to "serve Africa's needs in understanding fishes and aquatic environments" and its mission is "to be an interactive hub focussed on serving the nation through generating, disseminating, and applying knowledge to understanding and solving problems on the conservation and wise use of African fishes and aquatic biodiversity." Institute staff (a) conduct scientific research to address South African, SADC, and African fish research and information needs in aquatic biodiversity, (b) manage and develop the JLB Smith Fish Collection and Margaret Smith Library, (c) disseminate knowledge of fishes and aquatic biodiversity through environmental education and communication products and services, and (d) link with stakeholders and partners to facilitate conservation of African aquatic systems.

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Acknowledgments

Conservation International and the Okavango AquaRAP Team would like to thank all those who contributed to the success of the Okavango AquaRAP survey, particularly the Department of Fisheries, the Department of Water Affairs, the Harry Oppenheimer Okavango Research Centre, and the University of Botswana. We also thank the following South African institutions for permitting their scientists to participate in the AquaRAP survey: the University of Natal (Durban and Scottsville), CSIR, the University of Venda, and the South African Institute for Aquatic Biodiversity (formerly the JLB Smith Institute of Ichthyology). We are also grateful to the Government of Botswana for granting the relevant research visas and permits.

The AquaRAP survey was a success due to the outstanding contributions and assitance from individuals living in the Okavango Delta, including Jan and Eileen Drotsky, Jeff and Nookie Randall, Peter Sandenberg, and Jasmin Potts, who hosted the team and supported the work in many ways. We are also grateful to Game Trails who provided boats with drivers who knew how to navigate the waterways, to the mokoro polers at Delta Camp, and to Delta Air, who flew us safely between sites. We also deeply appreciate the time and effort put in by Alison Brown to ensure the safety of the team. The AquaRAP scientists would like to recognize and thank Lee-Ann Nordin for her hard work, positive attitude, and excellent coordination, which resulted in a very successful AquaRAP expedition. We also thank Karen Ross and Innocent Magole of CI-Botswana for initiating and supporting this survey.

The plant group thanks E. Adams, H. Hurrypursad, A. Schoultz, and F. Sokolic for providing technical support. The invertebrate group would like to thank the following people for helping to identify the invertebrate collections: Heteroptera - Mr. P.E. Reavell (University of Zululand); mollusks - Dr. D.S. Brown (The Natural History Museum, London), and Odonata adults - Prof. M.J. Samways (University of Natal). We thank Dr. Nancy A. Rayner for kindly identifying the micro-Crustacean collections.

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Report at a Glance

A RAPID BIOLOGICAL ASSESSMENT OF THE AQUATIC ECOSYSTEMS OF THE OKAVANGO DELTA, BOTSWANA: HIGH WATER SURVEY

Dates of Studies
June 5-22, 2000

Description of Location
The Okavango Delta is one of southern Africa's largest wetlands. It is situated in the semi-arid Kalahari of north-western Botswana, where rainfall is seasonal and in the region of 500 mm per year. Being a semi-arid subtropical environment, potential evaporation is 5-6 times that of rainfall.

The main source of water for the Okavango Delta is the Okavango River, which has a mean annual discharge of approximately 9.86 x 10^9 m^3, with peak flows in March and April and low flows in October and November. However, the flood waters from the Okavango River take many months to reach the seasonal swamps such that the maximum extent of flooding in the Delta is in the dry season (August to September). Given large differences in water supply and demand, the Okavango wetland fluctuates in area from 6,000-8,000 km^2 during the non-flood season to over 15,000 km^2 during the flood season.

The Okavango River arises from a series of headwater streams on the southern slopes of the Angolan highlands, forms the boundary between Angola and Namibia for hundreds of kilometers, and then crosses the Caprivi Strip in Namibia before entering Botswana as a single broad river. As such the drainage basin of the Okavango River is shared by three countries. Upon entering Botswana, the Okavango River is approximately 200 m wide and 4 m deep. In its upper reaches in Botswana, the Okavango River is confined within a depression known as the Panhandle, where it meanders within a broad floodplain before water spreads out over the surface of the large alluvial fan that is known as the Okavango Delta.

Five major wetland habitats are recognized in the Okavango Delta, including the riverine Panhandle, upper permanent swamp, lower seasonal swamp, drainage rivers, and lakes. The riverine Panhandle and upper permanent swamp habitats cover approximately two-thirds of the area of the Delta. Most of these areas are perennially flooded with surface waters up to 4 m deep in areas of open water. Areas of swamp and floodplain are flooded to a much shallower depth. There are numerous tributaries and oxbow lagoons associated with the main river channels. The channels are lined with dense stands of a wide variety of aquatic plants.

Reasons for the AquaRAP Expedition
While most of the large terrestrial mammals of the Okavango Delta are well-known and well-studied, the aquatic organisms have received much less attention. The aquatic ecosystems are very complex and can change yearly depending upon annual flood levels. Not since 1976, when the Botswana Society held the Symposium on the Okavango Delta and its Future Utilisation, which focused on aquatic systems (including fishes, crocodiles, plants), have the aquatic resources of the Okavango Delta been studied in a comprehensive manner. Scientific

data on the aquatic organisms and system are needed to make informed management plans for the Delta.

The principal objectives of the AquaRAP survey were to:

1) obtain an overview of the existing diversity and integrity of the main ecological systems making up the Okavango Delta ecosystem;

2) highlight and publicize the biodiversity and unique features of the Okavango Delta to increase awareness of this unique ecosystem and promote its conservation;

3) provide recommendations to guide local, national, and international conservation policies relating to the Okavango Delta; and

4) provide useful "on-site" training for graduate students under the guidance of experienced field ecologists.

Threats to the Aquatic Ecosystems of the Okavango Delta

Pollution, introduced species, low flood levels, fishing, a growing tourism industry, increasing local human populations, and widespread insecticide spraying have been increasingly impacting the aquatic ecosystems of the Okavango Delta over the last few years, creating an ever more urgent need to assess the status of the aquatic ecosystems throughout the Delta. Proposed water abstraction (extraction), hydro-electric power generation in Namibia, and agricultural and tourism development projects in all three basin states are amongst the most serious issues that need to be addressed in considering the wise management and/or use of this remarkable system.

Major Results

Four focal areas were surveyed: the Upper Panhandle, the Lower Panhandle, North-western Moremi Game Reserve, and south-east of Chief's Island along the Boro River. Water quality variables were measured, and all results reflected benign and healthy conditions, with the exception of the dissolved oxygen levels, which were low, especially in the upper Permanent Swamps/lower Panhandle. A high proportion (about one-quarter) of the approximately 1250 plant species known from the Delta were recorded. The vegetation varied appreciably between the four focal areas; species richness (number of species encountered) increased from the Upper Panhandle to the lower reaches of the Delta, with landscape level heterogeneity show a similar trend. The invertebrates displayed both moderate diversity and abundance (likely due to difficulty sampling in high water levels), and maintained surprisingly uniform populations throughout the open system. The AquaRAP fish team found measurable differences in the fish community diversity between the four focal areas, indicating that the entire delta must remain intact to preserve the overall biodiversity. A breeding colony of birds was also documented which harbors 14 species and could represent the most important breeding site in southern Africa for two rare and endangered species.

Number of species recorded (for each taxonomic group)

Aquatic and terrestrial vegetation:	
Upper Panhandle	77 species
Lower Panhandle/ Guma Lagoon	131 species
Moremi Game Reserve/ Xakanaxa	154 species
Chief's Island	108 species
Invertebrates:	
Heteroptera (waterbugs)	38 species
Odonata (damselflies and dragonflies)	48 species
Hirudinea (leeches)	4 species
Decapoda (crabs and shrimps)	2 species
Gastropoda (snails)	15 species
Bivalvia (mussels)	9 species
Fishes:	64-66 species
Aquatic birds:	63 species

Species new to science

Heteroptera (Belostomatidae):
Appasus ?ampliatus
Fishes:
Aplocheilichthys sp. (topminnow)

New records for the area

Fishes:
Aplocheilichthys sp. (topminnow)
Gastropoda (Thiariidae):
Melanoides victoriae
Bivalves (Sphaeriidae):
Pisidium reticulatum
Pisidium sp.
Eupera parasitica
Heteroptera (Belostomatidae):
Appasus ?ampliatus

Conservation Recommendations

The main recommendations from the AquaRAP team are:

1) **Protect aquatic diversity throughout the Delta** to conserve the wide variety of habitats and species, as well as the enormous array of ecological functions that these species fulfill,

2) **Give special attention to protecting the Panhandle and Upper Delta**,

3) **Limit water abstraction (extraction)** from the Delta as well as from the Okavango River in Botswana and the neighbouring countries that share the watershed and ensure that flow patterns are not modified,

4) **Maintain processes that promote the dynamic channel changes of the Delta**, particularly by ensuring that sediment supply is not restricted by the construction

of any impoundments in the catchment or within the upper Delta, by promoting the integrity of papyrus swamp that fringes the upper channels, and by promoting hippo populations that maintain channels and water flow,

5) **Protect riparian forest vegetation** that promote localized disposal of salts that would otherwise poison surface waters in the Okavango Delta,

6) **Develop and enforce regulations for commercial fisheries** and consider dividing fishing areas between commercial and tourist operations either locally or regionally.

Additional local recommendations include:

1) Prevent the disposal of all forms of garbage along the river banks in the Upper Panhandle,

2) Prevent contamination by agricultural chemicals in the Upper and Lower Panhandle zone,

3) Ensure that all septic tanks at tourist facilities are properly designed and managed,

4) Continue to combat the spread of the invasive plant *Salvinia molesta* (Kariba Weed) and other invasive plant species,

5) Control the number and types of motorboats used in the Delta,

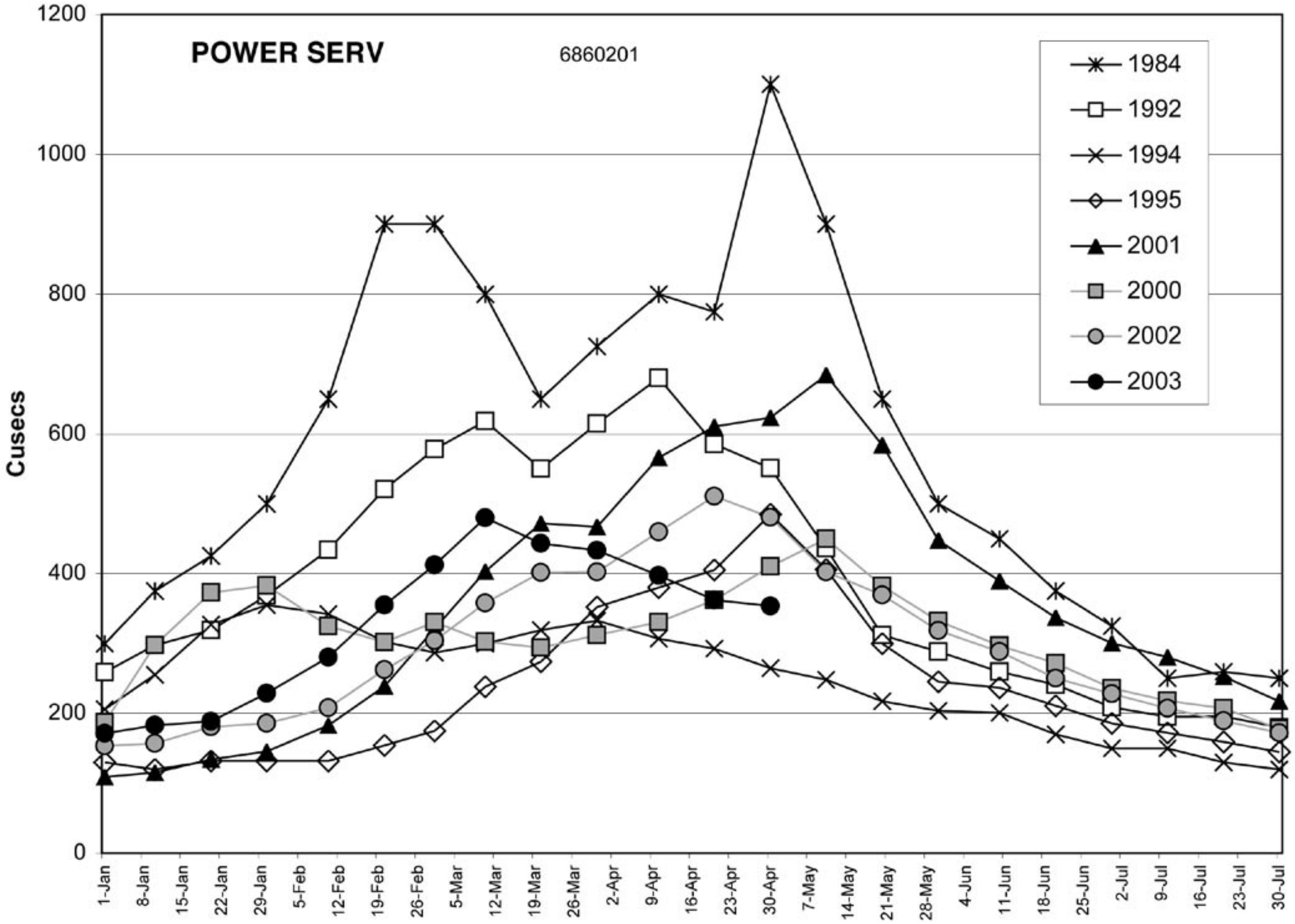
6) Regulate the number of boat launching sites and provide firm guidelines for all boat servicing and refueling operations/sites,

7) Monitor and study the effects of pesticide spraying on aquatic organisms and termites,

8) Study and conserve hippos, which are important in maintaining channels,

9) Regulate any attempts at fish farming and ensure that only native species are used, and

10) Protect existing heronries, especially the heronry at Gadikwe Lagoon.



Discharge data (in cusecs = cubic feet/second) for water flowing from the Okavango River into the Delta in the Upper Panhandle. Data provided by Power Serv.


Leeanne Alonso

AquaRAP plant team surveys plants in a flooded field along the Okavango River.

The AquaRAP Team at the Moremi Camp Site.


Leeanne Alonso

AquaRAP fish team enters their data into computers by lamplight.


Leeanne Alonso

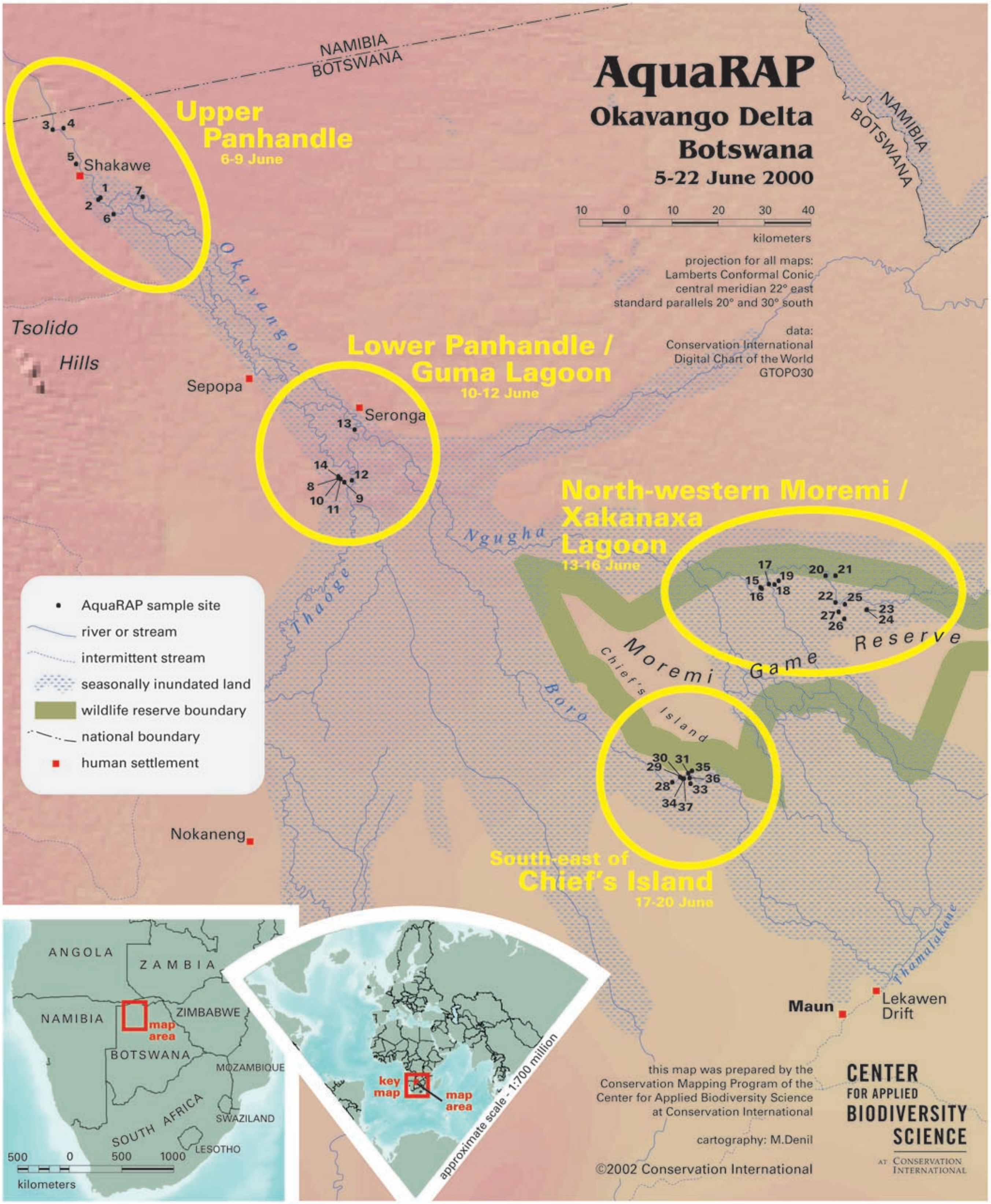
AquaRAP fish team samples along the Okavango River in the Upper Panhandle.


Lani Asato

Jane Prince-Nengu samples plankton.


Lani Asato

Chris Appleton collects aquatic invertebrates from a sieve.



AquaRAP
Okavango Delta
Botswana
5-22 June 2000
10 0 10 20 30 40
kilometers
projection for all maps:
Lamberts Conformal Conic
central meridian 22° east
standard parallels 20° and 30° south
data:
Conservation International
Digital Chart of the World
GTOPO30
NAMIBIA
BOTSWANA
Upper Panhandle
6-9 June
Shakawe
Okavango
Tsolido Hills
Sepopa
Lower Panhandle / Guma Lagoon
10-12 June
Seronga
North-western Moremi / Xakanaxa Lagoon
13-16 June
Ngugha
Thaoge
Moremi Game Reserve
Chief's Island
Boro
South-east of Chief's Island
17-20 June
Nokaneng
Maun
Lekawen Drift
Thamalakane
AquaRAP sample site
river or stream
intermittent stream
seasonally inundated land
wildlife reserve boundary
national boundary
human settlement
ANGOLA
ZAMBIA
NAMIBIA
ZIMBABWE
map area
BOTSWANA
MOZAMBIQUE
SOUTH AFRICA
SWAZILAND
LESOTHO
500 0 500 1000
kilometers
key map
map area
approximate scale - 1:700 million
this map was prepared by the
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cartography: M.Denil
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Leeanne Alonso

The giant sedge *Cyperus papyrus* (papyrus, *koma;* left bank in view) and *Phragmites mauritianus* (common reed, *letlhaka;* right bank) dominate plant communities along the Okavango River in the Upper Panhandle.

Leeanne Alonso

The floating leaves of the water lily *Nymphaea nouchali* (blue water lily; *tswii*) covered much of the open water areas in the seasonal swamps of the Chief's Island focal area.

Leeanne Alonso

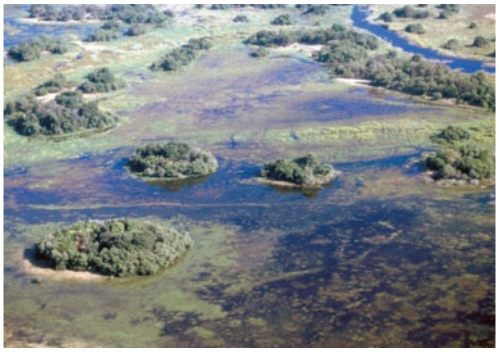
In Guma Lagoon, dissolved oxygen concentrations were often low, likely due to the floodwater flushing organic matter from beneath the extensive *Cyperus papyrus* (papyrus) mats, which results in low fish diversity and natural annual fish kills.

Denis Tweddle

Riparian forests concentrate and focus large quantities of salts, acting as purification filters that remove salts from the water column. This ensures the maintenance of fresh surface water within the Okavango Delta.

Leeanne Alonso

The vegetation in the Xakanaxa/Moremi focal area changes constantly, eventually leading to the establishment of a short emergent bog community in which species richness is high and there are no dominant species.



Lani Asato

The termite *Macrotermes michaelseni* is important in initiating island growth as plants establish on the mounds amidst the floodwaters.

Leeanne Alonso

Plants, particularly *Cyperus papyrus* (papyrus; *koma*), play an important role in catching and accumulating sediments, thereby promoting high landscape heterogeneity and diversity.

Leeanne Alonso

Moremi Game Reserve contains many isolated fresh-water fed pools that have high salinity. These pools contain unique plants and animals.

Clare Nielsen

Gadikwe Lagoon in Moremi Game Reserve is an important breeding site for at least 14 bird species.

Leeanne Alonso

Alien weeds such as *Salvinia molesta* pose a threat to the floristic diversity of aquatic habitats. Control of their introduction and spread should continue to be enforced.

Lani Asato

The AquaRAP team found healthy water conditions throughout the Delta except for dissolved oxygen concentrations, which were fairly low, especially in the Lower Panhandle.

Roger Bills, SAIAB

The tigerfish, *Hydrocynus vittatus*, was found only in the main channel of the Okavango River in the Upper Panhandle and not in the lower Delta.

Chris Appleton

Waterbugs (*Appasus* spp.) are active swimmers and voracious predators. They breathe air and so must come to the surface to replenish their air supply.

Roger Bills, SAIAB

Squeakers or *Synodontis* catfishes, including *Synodontis macrostigm,* were collected only in the Upper Panhandle and Chief's Island areas.

Annelise Gerber

Caridina nilotica is a common shrimp in the Okavango Delta, abundant in marginal, submerged and floating vegetation in many habitats.

Roger Bills, SAIAB

The yellowbelly bream or nembwe, *Serranochromis robustus,* and other large bream species are highly sought after by both tourist anglers and commercial fishermen.

Dai Herbert

Biomphalaria pfeifferi is a medium-sized, aquatic snail commonly found crawling on submerged vegetation. This species is the intermediate host of *Schistosoma mansoni,* the parasite causing intestinal bilharzia (schistosomiasis).

Executive Summary

THE OKAVANGO DELTA

The Okavango Delta ecosystem is a critical resource for the people and wildlife of Botswana and surrounding countries, containing unique terrestrial and aquatic species, intricate connections between water and land, and dramatic seasonal flooding cycles. In addition to acting as a water regulator in an arid land, the Delta attracts large-scale migrations of megafauna and is home to many endangered species, making this a wilderness of global biological significance. The Okavango Delta is a key regional resource, with a catchment spanning three countries and supporting over 150,000 people. The aquatic ecosystems provide freshwater, food, transportation, and habitat for local and regional communities as well as for wildlife. Many fish species migrate long distances along the river system between Angola, Namibia, and Botswana.

Most international and local research and conservation efforts in the region have focused on terrestrial and big game issues and have virtually ignored the real backbone of the Okavango Delta, the aquatic ecosystems and their inhabitants. Pollution, introduced species, low flood levels, fishing, a growing tourism industry, increasing local human populations, and widespread insecticide spraying have been increasingly impacting the aquatic ecosystems of the Okavango Delta over the last few years, creating an urgent need to assess the status of the aquatic ecosystems throughout the Delta. Possible plans to divert water from the Okavango River upstream from the Delta, and to develop impoundments for the generation of hydroelectric power, could pose threats that would drastically change the ecosystem.

THE OKAVANGO AQUARAP SURVEY

The Conservation International Aquatic Rapid Assessment Programme (AquaRAP) Expedition to the Okavango Delta system in northwestern Botswana took place from 5 to 22 June 2000. The expedition comprised a multi-disciplinary team of some 20 scientists and graduate students, complemented by staff drawn from two Botswana Government Departments (Water Affairs and Fisheries), as well as staff from the local Harry Oppenheimer Okavango Research Centre and Conservation International's U.S. and Botswana offices.

The AquaRAP survey team conducted rapid surveys of organisms associated with the aquatic ecosystems, including fish diversity, fisheries issues, invertebrates (benthic organisms that live in or on the bottom sediments or are associated with submerged and marginal vegetation, and planktonic organisms that live in the water), plants, and birds. The AquaRAP team also evaluated water quality and water levels, and conducted surveys and assessments of the perceptions and concerns of residents regarding environmental problems and threats that face the Okavango Delta.

OBJECTIVES OF THE OKAVANGO AQUARAP SURVEY

The specific aims of the Okavango AquaRAP Survey were to:

1. Derive a brief but thorough overview of the existing diversity and integrity of the main ecological systems making up the Okavango Delta ecosystem;

2. Compare the information collected during this expedition with available information from earlier surveys, and evaluate any changes that had taken place;

3. Highlight and publicize the biodiversity and unique features of the Okavango Delta ecosystem to members of the general public in Botswana and elsewhere, with a view to increasing awareness of this unique ecosystem and promoting its conservation;

4. Provide soundly-based recommendations for any additional studies that may be required to investigate specific issues within the Okavango Delta ecosystem;

5. Provide recommendations for conservation priorities with a view to influencing local, national, and international conservation policies relating to the Okavango Delta;

6. Expand awareness and interest amongst local communities, tourism operators, tourists and scientists by disseminating information and involving individuals from these sectors in discussions and debates; and

7. Provide useful "on-site" training for graduate students under the guidance and mentorship of experienced field ecologists.

STUDY SITES

The Okavango AquaRAP team undertook a multi-disciplinary survey at 37 georeference points (see below) in four focal areas within the Okavango Delta between June 5 and 22, 2000, with the aim of providing an integrated baseline analysis of biodiversity and conservation status of the unique mosaic of aquatic ecosystems of the Delta.

The four focal areas sampled were:

1. Upper Panhandle (centred around Shakawe/Mohembo): 6-9 June, 2000

Sampling of water quality parameters, aquatic and terrestrial plants, fishes, and invertebrates was conducted around seven georeference points from the town of Mohembo at the Botswana-Namibia border, south to the town of Shakawe, and then on to approximately three kilometres south of Drotsky's Cabins.

2. Lower Panhandle (centred around Guma Lagoon): 10-12 June, 2000

Seven georeference sampling points were sampled, particularly in and around Guma Lagoon (Ngquma Lebida) and in the small channel (Thaoge Channel) connecting Guma Lagoon to the Okavango River. Water quality characteristics, aquatic and terrestrial vegetation, fishes and invertebrates were studied at each of these sampling points.

3. North-western Moremi Game Reserve (around Xakanaxa Lagoon): 13-16 June, 2000.

Thirteen georeference points were sampled in order to assess the variety of aquatic habitats at this site, which included several important lagoons as well as land-locked pools within the reserve. The team investigated water quality, vegetation, fishes, invertebrates, and aquatic birds in small and medium-sized channels, lagoons, permanently and seasonally flooded pools, and saline pools.

4. South-east of Chief's Island along the Boro River: 17-20 June, 2000

Nine georeference points were sampled. Since motor boats are prohibited at this site, all sampling was conducted from mokoros (dug-out canoes) or from land, which was much more challenging and did not always allow for complete access to all habitat types. Small channels, lagoons, seasonal pans and pools, and a borrow pit were sampled at this site.

GEOREFERENCE POINTS

One of the unique aspects of an AquaRAP survey is that different teams sample a variety of taxonomic groups during the same time frame and at the same sites. To take full advantage of this, AquaRAP scientists sample around common georeference points during each survey. While additional sampling can be conducted wherever individual researchers feel it is appropriate for their taxonomic group, all groups attempt to sample together several georeference points in each focal area. The specific location of each georeference point is selected to maximize the diversity of habitats surveyed in each area. The number of georeference points sampled at each site depends on the length of time available in each focal area.

During the AquaRAP expedition to the Okavango Delta, a total of 37 georeference points were sampled, with a range of 7-13 points in each focal area so as to provide a representative coverage of all the available habitats (Appendix 1). At each georeference point, a variety of field measurements, collections, and observations were made for water quality, vegetation, fishes, and invertebrates. Each group sampled within a 0.5 km radius of the georeference point, in most cases in the same exact location. The georeference points were numbered sequentially from the first site (OK1-1) at Mohembo (Upper Panhandle) to the final site (OK1-37), which was located approximately in the middle of the western banks of Chief's Island.

The precise position of each georeference point (and any additional samples taken) was recorded with a Garmin-12 Geographical Positioning System (GPS). See Appendix 1. These data will allow future investigators to re-visit selected sites if required.

SUMMARY OF RESULTS

Water Quality

Several water quality variables were measured on site: temperature, electrical conductivity (EC, a measure of the salinity or total dissolved salts), pH (an indicator of the water's acidity or alkalinity), dissolved oxygen, and water clarity. All of the measurements apart from dissolved oxygen reflected benign and healthy conditions throughout the Delta. Dissolved oxygen concentrations were often low (representing concentrations that were below 50% saturation), especially in deeper lagoon waters of the Lower Panhandle section of the upper Delta. This can be attributed to natural flood-induced flushing of accumulated organic matter from beneath *Cyperus papyrus* (papyrus) mats into these lagoons. This is undoubtedly the cause of the natural annual fish kills experienced at Guma Lagoon.

The team found, with localized exceptions, a progressive "downstream" increase in dissolved oxygen levels within the main channels. This trend is probably caused by the increased numbers of submerged and emergent aquatic plants, as well as algae, that produce oxygen during photosynthesis. Water temperatures reflected a corresponding trend, with surface water values rising from approximately 17°C in the faster-flowing upper region, to values around 19°C in the shallower and quieter lower reaches of the Delta. At the Upper Panhandle section, the main channel of the Okavango River averaged some 200 metres in width and 4 metres in depth, with current velocities averaging 0.9 metres/second. The channel dimensions declined as the Okavango River gradually became narrower along its length, reaching some 60-70 metres in width and 2 metres in depth at the Lower Panhandle. Here, current velocities had also declined to around 0.3-0.4 metres/second. As the river channels diverged and split up further in the upper reaches of the deltaic fan, channel dimensions reduced to between 5 and 10 metres in width and 1.4-1.8 metres in depth. Similarly, water velocities continued to reduce, reaching some 0.2-0.3 metres/second. This pattern of progressive shallowing of the river channels and declining water flow velocities reflects the increasing quantities of water that flow through the permanent and seasonal swamps outside of the main distributary channels.

Low salinity values are characteristic of the Okavango system. However, EC increased almost three-fold along the hydraulic axis of the system, from values around 30 µS/cm in the upper reaches to slightly over 80 µS/cm around Chief's Island. This increase is attributed to the evaporative concentration of salts along the system's hydraulic axis, associated with evapotranspiration of both aquatic plants (reeds, grasses, and sedges) and the riparian vegetation complex found on the multitude of islands. Greatly elevated salinity values were recorded at certain confined locations, particularly in isolated rain-fed pools. However, this gradual evaporative concentration of salts along the length of the Okavango Delta does not account for the entire load of solutes that enter via the Okavango River. Instead, studies have shown that fringing riparian vegetation concentrate and focus large quantities of salts, acting in effect as purification filters that remove accumulating salts from the water column. These salts accumulate in the soils under islands and give rise to locally important saline pools.

The pH of water throughout the Delta was at or near neutral, apart from localized areas that exhibited slight acidity (a natural consequence of the dissolution of natural humic compounds derived from decomposing organic material) and fewer areas exhibiting slight alkalinity. A range of additional water quality determinations will require laboratory analysis, including major anions and cations (sodium, potassium, magnesium, chloride, sulphate, carbonate, etc.), plant nutrients, and concentration of total and organic suspended solids.

Plankton

Micro-crustaceans, comprising a wide variety of small animals including water-fleas (cladocerans), copepods (a diverse group to which the legendary "Cyclops" belongs), and seed shrimps (ostracods), were studied at selected georeference points. The samples yielded a considerable diversity of micro-crustacean species with strong faunal affinities apparent between the "entomostracan" fauna (a collective grouping of micro-crustaceans) of the Okavango Delta and that of the Bangweulu swamps of Zambia. A possible new species of *Eucyclops* was collected. All taxa collected from permanent waters of the Okavango swamps, or waters seasonally connected thereto, are small-bodied. This logically reflects the severe size-selective impact of fish predators on this assemblage. The almost transparent open channel waters favour fish and other predators that rely on sight to locate their "prey" items, whilst the darker stained humic waters associated with the floating mats of papyrus favour fish that rely on electro-sensory organs to locate their food. The only large-bodied taxa (notably calanoid copepods) were restricted to isolated and/or ephemeral waters. The persistence or demise of such large-bodied taxa in waters subjected to seasonal flooding and colonization by cohorts of opportunistic juvenile fish from adjacent permanent swamp and lagoon habitats merits consideration.

Invertebrates

Selected invertebrate taxa, including Hirudinea, Decapoda, Heteroptera, Ephemeroptera, Odonata, Gastropoda, and Bivalvia, were collected semi-quantitatively in four focal areas of the Okavango Delta. The invertebrate fauna was found to be rich but relatively uniform in all four areas, and there was little evidence that it changed as habitat diversity increased from the Panhandle to the seasonal part of the Delta. A largely different fauna was found in ephemeral rainpools isolated from the deltaic habitats in the Moremi and Chief's Island areas. One possible new species of *Appasus* (Belastomatidae) was found and several new mollusk records for the Delta (and the Okavango system as a whole) were documented. Except for the introduced biocontrol weevil, *Cyrtobagus salviniae*, no invasive invertebrates were collected. More species would probably have been recorded had the expedition taken place during the summer months, i.e., November to March, when the water would have been warmer and the depth shallower.

Aquatic and Terrestrial Vegetation

Semi-quantitative vegetation surveys were undertaken at a total of 122 sample plots within the four focal areas. The overall floristic diversity of the Okavango Delta is exceptionally high, and it should be viewed as having a high value from a biodiversity perspective. A high proportion (about one-quarter) of the approximately 1250 plant species known from the Delta were encountered during this brief cool-season survey. At least 77 plant species were recorded from the Upper Panhandle, 131 species from the Guma Lediba (Lake) area, 154 species from Moremi Game Reserve/ Xakanaxa, and 108 species from the Chief's Island area.

The surveys revealed an increase in local-scale plant species richness (*alpha* diversity) from the Upper Panhandle to the lower reaches of the Delta. In addition, the primarily aquatic assemblage in the upper reaches, dominated by the grasses *Vossia cuspidata* (hippo grass; *mojakubu*) and *Echinochloa pyramidalis* (Limpopo grass), sedges such as *Cyperus papyrus* (papyrus; *koma*), rushes such as *Typha capensis* (bulrush; *tsita*) and reeds such as *Phragmites mauritianus,* changed to a much more patchy mosaic of aquatic, semi-aquatic, and terrestrial habitats and species in the lower reaches.

Nine distinct plant communities were recognized in this study, of which seven were wetland communities ranging from permanently flooded marsh to seasonally inundated floodplain. A further two communities that were identified were riparian woodlands that are not flooded but which contain species that have their roots in the water table in both the permanent and seasonal swamps.

The distribution of wetland plant communities identified in this study is related primarily to the hydrological regime (such as the depth, duration, and timing of inundation), to processes associated with nutrient and sediment supply and sediment deposition, and to the nature of the substratum. The distribution of riparian woodland communities was related to soil and groundwater salinity.

Plants, particularly papyrus, play a very important role in focusing incoming sediments to within-channel areas, promoting aggradation in papyrus-lined channels. This leads to natural large-scale changes in the distribution of water within the ecosystem that promotes high landscape level heterogeneity and therefore diversity. The integrity of this interaction needs to be maintained by ensuring a sediment supply as well as the integrity and vigour of the papyrus community, in order to promote the overall diversity of the system.

Riparian forests promote the focusing of dissolved solutes beneath islands, a process that ensures the maintenance of fresh surface water within the wetland system. Failure of this mechanism of solute disposal within the Okavango system would be catastrophic, potentially leading to widespread salinisation of surface water and major changes in the wetland flora and fauna.

Fishes

A total of 64-66 species out of the 71 species previously recorded from the system were identified in 74 collections in this brief survey, indicating that sampling methods and selected sites effectively covered the diversity of Delta habitats. There were differences between the four focal areas (Upper Panhandle, Lower Panhandle, Moremi Game Reserve, and Chief's Island) and these indicate real differences in community diversity, although as the focal areas were at different phases in the flood cycle, this may have affected our collection efficiency.

The highest diversity was at Shakawe (Upper Panhandle), where the 54+ fish species recorded included predominantly rheophilic species in the main river. The apparent absence of tigerfish, *Hydrocynus vittatus*, from the other three sampling areas is a striking example of the difference between the main river fauna and the smaller stream habitats downstream. Other species common at Shakawe and absent from catches in the other areas in the AquaRAP survey were *Barbus radiatus* Peters, *Labeo cylindricus* Peters, *Nannocharax macropterus*, and *Chiloglanis fasciatus*.

Guma Lagoon had the lowest diversity, due in large part to the absence of riverine habitats with well-defined banks that could be effectively sampled. The low oxygen levels in the area because of floodwater flushing under the extensive papyrus mats probably also have an impact. At Xakanaxa (Moremi Game Reserve), a broad range of habitats was available for sampling, resulting in high diversity. One undescribed species of *Aplocheilichthys* was collected at several sites at Xakanaxa. The variety of habitats available for sampling was lower in the Chief's Island area, resulting in a lower total species count, but the diversity in the individual samples from the well-vegetated riverine and flow-through lagoon habitat was very high. Noteworthy was the presence of five of the six *Serranochromis* species occurring in the Delta in a single gillnet catch.

The addition of several new distribution records for the Delta in the present survey shows that scientific knowledge of finer scale distribution patterns within the Panhandle and Delta is still incomplete. No exotic fish species were found in the system.

There are conflicts of interest between commercial fishermen and the recreational/tourist fishery, but these are not a result of overfishing. Tourist lodges and commercial fishing sites are adjacent to one another and the two groups share the same fishing grounds and compete for the same fish resource, particularly the large cichlid species. The issues at stake are economic, social, and environmental, and the impacts of commercial fishing and angling tourism need to be considered. See below for conservation and management suggestions.

Aquatic Birds

Ad-hoc aquatic bird surveys were conducted at the four focal areas by the entire AquaRAP team. The aquatic avifauna appeared less diverse than expected, though some species (e.g., Fish Eagle, *Halietus vocifer*) were more abundant in the Upper than in the Lower Delta region, while the reverse was true for other species such as Reed Cormorant *(Phalacocorax africanus)*. Additional studies should evaluate the possible reasons for these trends.

Sixty-three aquatic bird species were recorded during the survey (Appendix 15). One site in particular, the breeding colony at Gadikwe Lagoon at Xakanaxa, was an important observation. This heronry was occupied by 14 species, including African Spoonbill, Sacred Ibis, several species of egrets (Great White, Yellowbilled, Black) and herons (Grey, Rufousbellied, Greenbacked), and Reed Cormorants. In addition, two species of rare and endangered aquatic birds were recorded breeding here: the Yellowbilled Stork and the Slaty Egret. The team's observations confirm that Gadikwe Lagoon represents an important breeding site for these species in southern Africa. It is notable that the breeding activity at Gadikwe Lagoon took place earlier than most years, perhaps because of the unusually heavy rains experienced throughout the region.

Monitoring

A summary of suggestions from the AquaRAP scientists for developing a long-term aquatic monitoring program aimed at local schools, communities, and tourist camps, is presented. The methodologies have been written as simply as possible so that non-scientists can follow them. Simple methodologies are presented to monitor water quality parameters such as channel depth, water flow, visibility, pH, temperature and water colour, invertebrates, aquatic weeds and plants, cranes, skimmers and bird breeding sites, climate and channel dynamics, and fishes. These methodologies need to be field tested and refined in order to formulate a standard aquatic monitoring plan for the Okavango Delta.

CONSERVATION CONCERNS AND RECOMMENDATIONS

The chapters in this report document a high diversity of unique aquatic organisms in the Okavango Delta. These animals and plants are essential parts of the Okavango ecosystem, which supports not only a vast mosaic of closely linked terrestrial and aquatic system components, but also a high diversity of megafauna and birds that draw international attention and tourists to the region. The aquatic ecosystem also supports the human population, providing clean drinking water, transportation, and livelihoods.

Overall Recommendations:

- **Protect aquatic diversity throughout the Delta:** The diversity and abundance of aquatic organisms varied between the four focal areas studied. Therefore, the aquatic organisms and the dynamic hydrological systems throughout the Delta must be protected to conserve the wide variety of habitats and species, as well as the wide range of ecological processes that rely on these organisms.

- **Protect the Panhandle and Upper Delta:** The Panhandle and upper part of the Delta should be a conservation priority. They are extremely important in shaping the entire Okavango Delta ecosystem, as this is where most of the water dispersal and sedimentation processes that drive the system take place.

- **Limit water abstraction (extraction):** The abstraction (extraction) of surface water from the Okavango Delta and the river system supplying it with water is by far the greatest threat to the ecosystem. Offtake should be closely regulated and be carried out in ways that do not jeopardize the ecological functioning of the system. Any proposals to modify the flow regime of the Okavango River should be carefully scrutinized to evaluate their potential for adverse impacts on the Okavango Delta ecosystem.

- **Ensure sediment supply to the Delta is not interrupted:** Dramatic year-to-year changes in the distribution of water over the surface of the Okavango Delta are essential to its long-term survival, and efforts to stabilize or alter flow patterns within the system directly threaten its integrity. Channel change relies on the input of sediment into the system from the Okavango River. Structures such as dams or weirs that impede sediment supply to the system should not be constructed on the Okavango River in Angola, Namibia, or Botswana. The papyrus community is also important in promoting channel change and its integrity must be protected within the Okavango Delta.

- **Protect riparian woodlands:** Riparian woodlands are responsible for much of the water loss that takes place from the Okavango ecosystem, and this leads to the disposal of toxic solutes in a way that maintains exceptionally high water quality of surface waters. Riparian woodlands should therefore be considered as particularly important habitats worthy of special protection throughout the Okavango Delta.

- **Conserve hippos:** In view of their importance in promoting channel change and of ensuring rapid delivery of water to the lower reaches of the system, hippo warrant attention from a conservation perspective.

- **Develop a management strategy for fisheries:** Conflict exists between tourist lodges and commercial fishermen because the two groups share the same fishing grounds and compete for the same fish resources. Options for management include setting and enforcement of regulations to protect stocks and/or segregation of fishing areas to separate commercial fishing and angling tourism.

Specific Recommendations

Specific conservation concerns and recommendations for the Okavango Delta are listed below. More details can be found in the individual chapters of this report.

Issues affecting Water Quality

1. **Garbage disposal practices in the Upper Panhandle zone.** Domestic garbage has been dumped in unsightly heaps along the Okavango River near Shakawe and Mohembo. This type of garbage disposal practice is contrary to normally accepted methods of garbage disposal, has the potential to contaminate nearby water supplies, and promotes the spread of diseases, as well as being very unsightly.

2. **Contamination by agricultural chemicals in the Lower Panhandle zone.** An agro-chemical mixing tank (fertilizers and pesticides) at an irrigated agricultural area downstream from Shakawe should be moved away from the water's edge since any leakage will have a negative effect on the water quality of the nearby channel.

3. **Channel clearing operations.** Formal channel clearing operations produce a lot of decaying plant material, which allows plant nutrients to return rapidly to the water and could lead to enhanced growth of aquatic plants in or near these dumps. While most effects will be localised, the conditions along many of these channels are favourable for papyrus growth. Therefore, channel clearing would need to be done continuously.

4. **Nutrient and bacteriological contamination of surface waters from tourist camps.** It is strongly recommended that the authorities ensure that all septic tank sanitation systems at or near tourist facilities are properly designed and constructed so as to promote effluent flows away from the open water areas. This may be achieved by appropriate location of septic systems and French drains.

5. **Possible hydro-carbon contamination near boat launching points.** The Botswana authorities should regulate the number of such boat launching points and provide firm guidelines for all boat servicing and refueling activities. This will help to reduce or eliminate the risks associated with spilt fuel and oil.

Issues affecting Plants

6. **Invasive aquatic plants.** The Botswana Department of Water Affairs should continue their long-term programme of biological control against *Salvinia molesta* and other aquatic invasive plants. Failure to control the spread of this weed would allow it to colonize other pool, lagoon, and channel areas with potentially enormous adverse consequences for the ecological structure and functioning of the Okavango Delta ecosystem.

7. **Pesticide effects on termites.** The termite *Macrotermes michaelseni* is important in initiating island growth. The use of persistent insecticides that threaten the activities of this species should be prohibited.

Issues affecting Fishes and Fisheries

8. **Conflicts of interest between commercial fishermen and the recreational/tourist fishery.** Before management decisions can be taken, a thorough review of all issues is needed, including not just fisheries aspects, but other users of the Panhandle resources. Management options to address the conflict between tourist lodges and commercial fishermen because they share the same fishing grounds and compete for the same fish resource include:
   A. Develop and enforce regulations for the commercial fisheries, including:
      - Licensing with strict sets of conditions,
      - Prohibition of use of nets blocking lagoon entrances,
      - Limitation of effort,
      - Closed seasons,
      - Limitations on mesh sizes,
      - Limitations on night-time fishing activities.

   B. Divide fishing areas between commercial and tourist operations either locally or regionally.

9. **Fish farming.** If there are serious attempts to introduce fish farming into the region, the species used should be native to the Okavango Delta. Exotic species such as *Oreochromis niloticus* should NOT be permitted under any circumstances.

10. **Unrestricted use of motorboats.** The Botswana Government should set in place a series of principles and policies to control the number and types of motorboats used on the Okavango Delta. Motorboat traffic along the main river channel in the Upper Panhandle zone should be carefully controlled, and nocturnal boat traffic should be completely prohibited. Motorboat use in narrow and shallow channels should be restricted completely.

Issues affecting Birds

11. **Protect the heronry at Gadikwe Lagoon.** Motorboats should not be allowed to enter sensitive Gadikwe Lagoon, except for official business. Tourism to the area should be carefully regulated, with particular care taken during the height of the breeding season.

FUTURE RESEARCH RECOMMENDATIONS

See also the individual chapters in this report for more recommendations and details.

1. **Investigate the seasonal changes in water quality and diversity of organisms.** An aquatic survey should be carried out during the low water season, to complement and compare to the results reported here during high water levels. Data on the natural range of variation of important water quality and diversity parameters provide a firm basis for management decisions regarding the possible causes of these changes and allow us to evaluate the potential influence of human activities.

2. **Investigate the distribution and transmission of schistosomiasis (bilharzia) in the Delta.** Populations of the snail, *Biomphalaria pfeifferi*, which is the intermediate host of intestinal schistosomiasis (caused by *Schistosoma mansoni*), and incidents of the disease should be closely monitored throughout the Delta.

3. **Study fisheries issues including:**
   - The economic viability of the commercial fisheries,
   - The economic status of the angling tourism industry, including the feasibility of introducing angling concession areas,
   - The scale of the subsistence fisheries sector and its role in the nutritional status of villages in the area,
   - The extent of the fishable area in relation to the overall area in the Panhandle,
   - Continuation of the Fisheries Unit's stock assessment research,
   - Collection of data on angling catches,
   - Further ecological research,
   - Environmental impacts of tourism and commercial fisheries operations,
   - Fish biodiversity and distribution,
   - Impact of fish kills on the fish populations,
   - Fish farming.

4. **Conduct additional invertebrate surveys.** The invertebrate groups studied during this AquaRAP survey barely scratched the surface of the aquatic invertebrate groups present in the Okavango Delta. Further studies of the diversity and ecology of other groups are needed to obtain a more comprehensive picture of the invertebrate fauna of the Delta.

5. **Study the ecology of hippos.** Research into hippo numbers, behavior, and their role within the ecosystem should be encouraged.

6. **Evaluate the impacts of motorboat traffic.** Collect information on the extent and frequency of motorboat use, types of boats and motors, frequency and duration of trips, areas most frequently visited, the types of boat users concerned, and details of their launching / docking sites. This will allow the Botswana authorities to draw up a coherent set of policies and controls to regulate the use of motorboats and minimize their adverse consequences on the Okavango Delta.

7. **Evaluate the potential impacts of nutrients and salts from sanitation systems.** Study whether the septic tank sanitation systems at tourism camps and lodges are contributing nutrients and salts to the Okavango Delta as a basis for the development of guidelines for the selection of appropriate sites, optimal system designs, and construction of septic tank soak-away systems so that the potential adverse effects can be minimized.

8. **Evaluate the potential impacts of irrigation return flows.** Conduct ground and surface water sampling and analysis, combined with a local soil survey, to verify whether the irrigation scheme downstream from Shakawe poses potential water quality problems for the Okavango River.

9. **Evaluate the sediment-water exchange of nutrients and salts.** Carry out experimental field measurements in selected ecosystem zones (cut-off lagoons, flow-through lagoons, open channels) to determine the extent and importance of the exchange of nutrients and salts between the water and sediments in the Okavango Delta. This would provide extremely useful information upon which to base any management decisions regarding the sensitivity and vulnerability of these ecosystem components.

10. **Evaluate the evidence for pesticide residues.** Conduct a carefully structured sampling and analysis program to determine whether or not pesticide residues from Tsetse Fly spraying are present and, if so, the degree to which they pose an ecological threat to the structure and functioning of the Okavango Delta ecosystem. This information will provide extremely useful evidence to answer the many uninformed claims of lingering, widespread ecological damage caused by earlier Tsetse Fly control programmes. In addition, it would also form a cornerstone for the design of possible future Tsetse Fly control programmes.

Chapter 1

Introduction to the Okavango Delta and the AquaRAP Expedition

Peter J. Ashton, Lee-Ann Nordin, and Leeanne E. Alonso

IMPORTANCE OF THE OKAVANGO DELTA

The Okavango Delta has long been recognized as a unique and valuable ecosystem and has been cited frequently as being extremely vulnerable to external influences (Wilson and Dincer 1976; IUCN 1993; Ellery and McCarthy 1994; Gieske 1996; CSIR 1997; Pallett 1997; McCarthy et al. 1998, 2000; Ashton and Neal 2002; Gumbricht et al. 2002). The Botswana Government has also recognized that the Okavango Delta is an exceptionally important resource, particularly in terms of its conservation and tourism value (MGDP 1997; Ramberg 1997), and through the provision of a wide variety of ecosystem goods and services to local residents (FAO 2000).

The diversity of water users in the three countries making up the Okavango River basin, together with their current and future needs, provides an ideal example of the complex and conflicting demands between human development interests and ecological interests (Ashton 2000, 2001, 2002). In particular, considerable local and international attention has been focused on the distinctive mosaic of ecosystems that make up the Okavango Delta, as well as the possible consequences that may adversely affect these ecosystem components if the basin's water resources are not managed sensitively and cautiously (Greenpeace 1991; IUCN 1993; Ramberg 1997). Clearly, both human and ecosystem perspectives must be taken into account if an equitable and sustainable solution is to be found (Ellery and McCarthy 1994; Ashton 2000, 2001, 2002).

It is vitally important that the water resources of the Okavango River basin are managed in a sustainable way so that the current and projected future needs of the three basin states (Angola, Botswana, and Namibia) can be met in an equitable and sustainable manner, whilst still retaining and conserving the diverse array of ecosystem services and goods that are derived from the system. In order to achieve this, it is extremely important to understand the hydrological, social, economic and political setting within which the Okavango Delta is located (Ashton and Neal 2002). This setting provides the framework for rational management and decision-making that will allow each country comprising the Okavango River basin to meet the legitimate needs for water posed by their growing populations and economies, whilst conserving the ecological integrity of the Okavango River and Delta ecosystem.

THE OKAVANGO DELTA

General Description

The Okavango Delta is situated in north-western Botswana (see Map) and fluctuates in area from 6,000-8,000 km^2 during the dry season to over 15,000 km^2 during the flood season. The Okavango River rises as two main tributary systems, the Cubango and Cuito rivers in the central highlands of Angola, and flows in a southeasterly direction along the border of northern Namibia before entering Botswana and emptying into the Okavango Delta in Botswana. Along its course from the foothills of the Angolan highlands to the Okavango Delta, the Okavango River and its major tributaries function as a "linear oasis" in a progressively more arid area

(Ashton 2000). During years of exceptionally high flows in the Okavango River, outflows from the Okavango Delta feed the Boteti River and, ultimately, these flows may reach the Makgadikgadi Pans (Wilson and Dincer 1976). The Makgadikgadi Pans are also fed by seasonal and episodic flows from the Nata River in western Zimbabwe. Other, smaller tributary rivers rise in north-eastern Namibia but have not carried surface flows into the Okavango River or Okavango Delta in living memory (Bethune 1991; CSIR 1997; Ashton and Manley 1999; Ashton and Neal 2002).

The Okavango River enters Botswana as a single broad river, approximately 200 m wide and 4 m deep, that meanders within a broad floodplain in the Panhandle before branching out to form the Okavango Delta, a large alluvial fan of 15,844 km^2 in extent during high floods (see Map), with a shallow gradient of approximately 1:3 500 and gently undulating local topography.

The Okavango Delta itself consists of a series of permanent river channels, semi-permanent drainage channels, lagoons, and floodplains that link up and then separate again during the course of an annual flood. Several habitats can be recognised in the Okavango Delta, including permanent swamps that are permanently flooded, seasonal swamps that are dominated by seasonally flooded grasslands, and islands which vary in size from several metres to tens of kilometres across (Smith 1976; Ellery and Ellery 1997). Extending into the Okavango Delta from the surrounding Kalahari are a number of extensive savanna habitats known as "sandveld tongues." These are dryland areas contained within the Okavango Delta, particularly in the southern and eastern regions.

Hydrology

The catchment of the Okavango Delta comprises about 413,550 km^2, with an additional 15,844 km^2 contributed by the wetland area of the Okavango Delta plus its islands. Some 53.4% of the catchment area is considered to be "non-functional," since it receives very low rainfall and, because of high potential evaporation rates, contributes no surface runoff or ground water inflows to the Okavango Delta (Ashton and Neal 2002). Recent estimates indicate that direct rainfall onto the Okavango Delta contributes on average an additional 3,205 mm^3 (24.5%) of water to the Okavango Delta with the remaining 9,863 mm^3 (75.5%) provided by surface and ground water inflows via the inflowing Okavango River (Ashton and Manley 1999; Ashton 2000; McCarthy et al. 1998, 2000; Ashton and Neal 2002; Table 1.1). Overall, the Angolan portion of the Okavango catchment provides about 94.5% of the total runoff in the Okavango River, whilst some 2.9% originates in Namibia and the remaining 2.6% is contributed by Botswana (CSIR 1997; Ashton and Neal 2002).

A variety of estimates have been offered for the quantities of water that are lost each year from the Okavango Delta via evapotranspiration, seepage to local ground water and outflows to the Thamalakane River (Wilson and Dincer 1976; IUCN 1993; Gieske 1996; CSIR 1997; Ramberg 1997; Ashton and Manley 1999; McCarthy et al. 1998, 2000). Whilst all of these estimates reflect the high degree of uncertainty and variability that surrounds each component of the Okavango Delta water balance, there is general agreement as to the relative magnitude and importance of the different components (IUCN 1993; Ashton and Manley 1999; McCarthy et al. 2000). The main components of the Okavango Delta water balance are shown in Table 1.1.

Table 1.1. Summarized annual water balance for the Okavango Delta, Botswana, showing relative contributions for each component. (Data taken from Ashton and Manley 1999.)

Water Balance Component	Relative Contribution (%)
Inflows:	
• Okavango River	76 %
• Direct rainfall onto the Okavango Delta	24 %
Outflows:	
• Evapotranspiration	84 %
• Local ground water and riparian vegetation	13 %
• Outflows to the Thamalakane River	3 %

Primary water distribution within the Okavango Delta occurs via channels, which serve as an arterial system supplying water to the permanent and seasonal swamps. The main distributary channel, the Nqoga River, is connected directly to the source channel, the Okavango River, but many channels are not so connected, and arise by leakage from the primary channels. Secondary water distribution occurs mainly via overland flow through vegetated swamp.

Variability in Flood Patterns

The inter-annual variability in river inflows and erratic regional rainfalls across the Okavango catchment has given rise to a highly variable pattern of flooding in the Okavango Delta (see Figure on page 15). The precise pattern of flooding each year is dependent on antecedent conditions (extent and duration of previous floods), as well as the timing and duration of rainfalls in the catchment and direct rainfalls onto the Okavango Delta (Wilson and Dincer 1976; McCarthy and Ellery 1998; Ashton and Manley 1999). In turn, the flooding pattern determines the spatial extent of the different ecosystem components within the Okavango Delta (Ellery and McCarthy 1994; Ashton and Manley 1999; Gumbricht et al. 2002). The approximate average extent of these different ecosystem components is summarized in Table 1.2. In recent years, low rainfall in Angola has led to low water levels and near drought conditions in the Delta. More recently (1998-2002), rainfall and water levels have increased, though these are still below long-term average levels.

Water dispersal within the Okavango Delta is remarkably dynamic, with flow patterns changing dramatically over relatively short time periods. During the last century the major offtake of the Okavango River was the Thaoge River flowing down the western side of the Delta. During the

Table 1.2. Approximate average area of the different flooded ecosystem components within the Okavango Delta. (Data taken from Ashton and Manley 1999.)

Ecosystem Component	Average Area	
	km^2	%
Perennially flooded swamp	4,885	30.8
Regularly seasonal flooding (once each year)	3,855	24.4
Occasional seasonal flooding (once in three/five years)	2,760	17.4
High floods only (once in ten years)	2,502	15.8
Dry land (islands that are never flooded)	1,842	11.6
Total area of Okavango Delta	**15,844**	

latter part of the 1800s this river system started failing, probably as a consequence of sedimentation along its course. This was accompanied by the development of papyrus blockages that accompanied declining flows as channel switching took place, with flow being diverted eastwards into the Nqogha River at that time. During the early part of this century the main supplier of water to the town of Maun was the Nqogha - Mboroga - Santantadibe River system. However, during the 1920s this river system started failing in its lower reaches north-east of Chief's Island. This was accompanied by an increase in flow along the more northerly Maunachira River system. Thus the study site at Guma Lediba and its environs represent a region of the system that has experienced declining flows over the past 150 years or so. The fact that flow is still declining is suggested by current blockage by the giant sedge *Cyperus papyrus* of the link channel between Guma Lediba and the Nqogha River. In contrast, the study site at Xakanaxa in Moremi Game Reserve represents a region of the system that has experienced substantially increased flows over the last 60 to 70 years, as suggested by relatively large areas of shallow open water (lagoons or *lediba*) where plant succession is taking place (Ellery 1987).

Annual Flood Schedule

Depending on the rainfall patterns in the Okavango catchment, annual floodwaters from Angola begin to arrive in the northern Panhandle of the Okavango in January, peaking February-March, then reaching the mid-Delta in March and the Thamalakane River outflow at Maun in June or July. This slow pattern of inundation is due to the extremely low gradient, which causes the water to spread out to form the Delta. The slow flood cycle causes the lower reaches of the Delta to be seasonally flooded during the dry winter season, with waters reaching the southern parts of the Delta during the coldest months when water temperatures are lowest (average June temperature is 11^{o}C).

Nutrient Content

The catchment of the Okavango River is situated primarily on Kalahari sand that represents the distribution of an ancient desert. The catchment is thus sandy with relatively little exposed rock. This has two important consequences for the Okavango system as a whole. Firstly, the concentration of solutes in water entering the Okavango Delta is extremely low due to the lack of weathering of rock taking place in the catchment. Dissolved solids average 30 ppm to give a total annual dissolved solid load of 450 000 t.a^{-1}, the bulk of which accumulates within the ecosystem. Thus, water entering the Okavango Delta is chemically of high quality, with extremely low concentrations of plant macronutrients such as nitrogen and phosphorus. The fraction of the catchment that is not on Kalahari sand comprises granite, and consequently the most important solutes entering the system are silica that is present in by far the highest concentration, followed by calcium, magnesium, and sodium that enter the system as carbonate salts.

Secondly, there is very little suspended clastic sediment (clay and silt) being brought into the system. The small quantity of suspended sediment entering the system is mainly kaolinite with a relatively low exchange capacity, with the bulk of the incoming sediment being fine-grained sand that is transported as bedload. Around 170 000 t.a^{-1} of fine aeolian sand are transported onto the Delta primarily as bed load, with a further 30 000 t.a^{-1} as suspended load consisting mainly of kaolinite.

Fauna and Flora

While most of the large terrestrial mammals of the Okavango Delta are well-known and well-studied, the aquatic organisms of the Delta have received much less attention. Not since 1976, when the Botswana Society held the Symposium on "The Okavango Delta and its Future Utilisation," which focused on aquatic systems (including fishes, crocodiles, plants; Botswana Society 1976), have the aquatic resources of the Okavango Delta been studied in any comprehensive manner.

Fish diversity in the Okavango Delta was studied during the 1980s by the J.L.B. Smith Institute of Ichthyology (JLBSI; Merron and Bruton 1988; Merron 1993). The fishes of the area are covered by a Southern African field guide, which includes 71 fish species from the Okavango Delta (Skelton 1993). The aquatic and terrestrial plants have also been fairly extensively studied, particularly by P.A. Smith, with a field guide published by Ellery and Ellery (1997). Similarly, many of the aquatic birds have been studied and can be found in field guides to the region, such as Maclean (1993). However, few groups of aquatic invertebrates have been studied, and no comprehensive overview of the aquatic biodiversity of the Okavango Delta is available.

THE SOCIO-ECONOMIC AND POLITICAL CONTEXT

In the Okavango River basin, the recent prolonged droughts have resulted in rural communities becoming progressively more impoverished. Consequently, many people have migrated towards urban centres along the Okavango River and the fringes of the Okavango Delta in search of drought relief. There is a clear and pressing need to relieve the problems faced by these people and to provide adequate water supplies for their growing needs. In addition to the need to provide water for domestic purposes, there is also an urgent need to expand the agricultural sector so that additional food can be grown to the meet the needs of the growing population. This situation is particularly acute in Angola (FAO 1995, 1997) where, until recently, the prevailing civil war has prevented any form of organized agricultural development in the Angolan segment of the Okavango catchment.

The northern border regions of Namibia are relatively remote from the main centres of development and population, and Namibia currently uses very little water from the Okavango River (Ashton 2000). At present, the few small-scale irrigation schemes located along the Okavango River in Namibia are insufficient to meet local food needs and will need to be expanded in the future. Namibia has also communicated its intention to withdraw water from the Okavango River along the Namibian border with Angola, to meet the growing water deficits in the Central Areas of Namibia (Heyns 1995a, b; Republic of Namibia 2000). Clearly, any such water abstractions will need to be arranged in collaboration with the other two basin states (Ashton and Manley 1999). Recent Angolan military activities (during 2000 and 2001) along Namibia's northern border with Angola have forced many Namibian communities to leave the Okavango River and move southwards to areas where hand-dug wells provide the main or only sources of water.

Small-scale irrigation developments (approximately 25 hectares in total area) located alongside the Upper Panhandle section of the Okavango Delta near the town of Shakawe in Botswana currently use relatively little water. However, there are plans to expand the irrigated area to over 125 hectares, and possible options are being examined to initiate additional irrigation schemes in areas where suitable soils occur. In addition, more attention is being focused on the use of surface and ground water for domestic purposes in the small towns and communities located around the fringes of the Okavango Delta (MGDP 1997). Clearly, this type of development will be essential if the growing domestic needs for water are to be met in Botswana. Nevertheless, despite the very small quantities of water that are currently used from the Okavango River, the Botswana Government and a variety of non-governmental organizations (NGOs) remain concerned that proposals for new water developments in the upper and middle reaches of the Okavango River, as well as those within Botswana, may pose a serious threat to the ecological integrity and functioning of the Okavango Delta (Greenpeace 1991; IUCN 1993; Ramberg 1997).

The Issue of "Water Rights" versus "Water Needs"

International law (ILA 1966; ILC 1994; UN 1997) technically entitles Angola, Botswana and Namibia to develop water systems that flow within or along the boundaries of their territories, provided that such developments do "…not cause appreciable harm" to other states that share portions of the same river basin. This right is confirmed in terms of both the original and revised versions of the SADC Protocol on Shared Water Course Systems (Heyns 1995a; SADC 1995, 2001). As the lowermost basin state, Botswana is in a "vulnerable" position and would clearly like to ensure that its interests are not unduly prejudiced by any developments that may take place upstream in Namibia and Angola (IUCN 1993; CSIR 1997; Ashton and Neal 2002). At present, the quantity of water needed by the Okavango Delta in Botswana cannot be defined precisely, yet represents a very large proportion of the total flows in the Okavango catchment. In effect, therefore, whilst Botswana provides a relatively small quantity of water from within its own territory, the ecosystem "needs" of the Okavango Delta represent the single largest water use in the catchment (Ashton and Neal 2002).

The Governments of Angola, Namibia, and Botswana see the judicious (small-scale) use of water from the Okavango River (Angola and Namibia) or Okavango Delta (Botswana) as entirely legitimate from a territorial sovereignty viewpoint (Republic of Botswana 1990; Heyns 1995b; SADC 1995). To date, none of the proposed water abstraction schemes (UNDP and FAO 1977; SMEC 1987, 1989; Heyns 1995b) have yet been implemented, and each country continues to rely on existing (small-scale) run-of-river abstractions and on the exploitation of nearby ground water supplies (MGDP 1997).

The Government of Botswana has long recognized the value of the Okavango Delta, particularly in terms of its conservation and tourism value (IUCN 1993; Ramberg 1997), and through its provision of a wide variety of ecosystem services and goods to local residents (FAO 2000). Local and international concern to conserve the unique mosaics of ecosystems that make up the Okavango Delta has opposed earlier Namibian plans to abstract water from the Okavango River (Greenpeace 1991; IUCN 1993; Ramberg 1997). Whilst it can be argued that this support has strengthened Botswana's otherwise apparently "unfavourable" position as the lowest riparian state in an international river basin, this strategy also makes it difficult for Botswana to meet the growing needs for water of its own citizens from the water resources of the Okavango (Ashton 2000; Ashton and Neal 2002).

The question of "equity" lies at the centre of almost all debates over water sharing. Essentially, this issue should be the basis upon which waters in a river basin will be shared (UN 1997). However, because the term "equity" is vague and often undefined in international law, it has been applied in a variety of ways, with different degrees of success (Wolf 1999; FAO 2000; van der Zaag et al. 2000). For example, some countries sharing a river basin have argued that water resources should be apportioned on the basis of "the rights of prior (established) use"; other countries take the view that water "shares" should be based on the proportion of runoff contributed by each of the states forming the river basin. The variety of possible positions makes it difficult for individual states to reach agreement. Legal mechanisms, similarly, are seldom available to enforce whatever principles of equity may have been agreed upon by the different parties (Wolf 1999; van der Zaag et al. 2000).

More recently, there is increasing acceptance that the application of the principles inherent in "equity" requires parties to move away from claims for water based on various real or perceived "rights," to one where the parties motivate their "needs" for specific quantities of water. There seem to be several reasons why this move has occurred, but it is important to note that it is far easier for a country to quantify and justify its *needs* for water, than to provide the same level of support for its real or perceived *right*s to water (Wolf 1999; Ashton 2000; van der Zaag et al. 2000).

In summary, the rational and efficient management of the water resources in a shared river basin depends heavily on the joint realization and acceptance by the basin states concerned that water resource management should be fully integrated across the different parties (van der Zaag and Savenije 2000). This relatively simple statement masks a great deal of underlying political, social, economic, ecological, and institutional complexity. Truly integrated water resource management of a shared river basin should be based on a whole basin approach (Heyns 1995b; Savenije and van der Zaag 1998, 2000). In addition, each basin state needs to collaborate closely with its neighbours and reach agreement as to what proportions of the water resource can be equitably and reasonably allocated for specific uses in each country, and how the resource will be managed.

The Road Ahead

In 1994, the Governments of Botswana, Namibia, and Angola jointly launched the tripartite Permanent Water Commission on the Okavango River basin (OKACOM) to investigate ways in which the legitimate water needs of each of the three countries could be accommodated in a sustainable manner without prejudicing the needs of neighbouring riparian states (OKACOM 1994). This Commission seeks to develop an integrated water management strategy for the entire Okavango River basin. Several investigations have already been launched to provide the basis for estimates of water availability and patterns of current use (OKACOM 1995).

The existing institutional arrangements, in the form of the OKACOM commission, provide the most logical framework for initiating discussions and negotiations between the basin states. Clearly, these discussions and negotiations will require extreme care and tact because of the enormous sensitivities that have developed over the issue of using water from the Okavango River (e.g., Greenpeace 1991; Ramberg 1997).

The OKACOM institutional structure also provides the logical starting point for the development of a formal River Basin Organization (RBO) to manage the water resources of the Okavango system on behalf of the three basin states (Taylor and Bethune 1999; Ashton 2000). At present, the OKACOM Commission consists of government-nominated representatives from the three basin states (Angola, Botswana, and Namibia) and has been given the mandate to provide the information necessary to develop a formal management plan for the Okavango basin (OKACOM 1994). If the entire Okavango basin has to be managed as a single unit in future, this will only be possible if the individual basin states agree to set up a single independent authority to be responsible for overall management (Ashton and Neal 2002).

An important cautionary note that should be borne in mind is that advice from other multi-state river basin organizations in other parts of the world should be carefully scrutinized and evaluated before it is accepted. This is because, to date, none of the multi-state river basin organizations elsewhere in the world has been able to prevent disputes over competing uses or abuses of the water in their areas of jurisdiction. This fact alone should alert the parties concerned to be extremely careful in all aspects of their deliberations. A final point that is worth noting is that once riparian states agree on the extent and justification of their needs for water, and then confirm these in a river basin agreement, these needs will then become formalized as the "rights" of each country in law (Ashton 2000). At this point, each signatory to such an agreement shares a mutual responsibility to uphold both the spirit and intention of the agreement.

THE OKAVANGO AQUARAP SURVEY

The Aquatic Rapid Assessment Program (AquaRAP)

The Aquatic Rapid Assessment Program (AquaRAP) was founded in 1996 by Conservation International (CI) and the Field Museum (Chicago, USA) to collect biodiversity data for freshwater aquatic ecosystems to successfully influence and guide conservation actions. International teams of experienced tropical biologists from both foreign and host country institutions work together to quickly collect, analyze, and disseminate information on poorly known but important biodiversity conservation sites. Taxonomic groups surveyed include fishes, macro-crustaceans, aquatic insects, aquatic plants, and plankton (limnology). Water chemistry and hydrology are also studied. Whenever possible, AquaRAP focuses on entire watersheds, studying the biological diversity, degree of endemism, uniqueness, ecological connections, and the degree of risk of extinction of the area on national and global scales. AquaRAP is designed to be "rapid." Field expeditions typically last 3-4 weeks while data analysis and report preparation is expected within 6-8 months after the expedition. For more detailed information on AquaRAP, see http://www.biodiversityscience.org/rap.

THE OKAVANGO AQUARAP STUDY SITES

In order to provide the widest possible coverage of the different habitat types present in the Okavango Delta, four focal areas were selected and surveyed by the AquaRAP team. These areas are listed here and described below (see also Gazetteer):

1) Upper Panhandle (centred around Shakawe)

2) Lower Panhandle (centred around Guma Lagoon)

3) North-western Moremi Game Reserve (around Xakanaxa Lagoon)

4) South-east of Chief's Island along the Boro River

Upper Panhandle

At the entry to the Upper Panhandle zone of the Okavango Delta, the entire flow of the Okavango River is confined to the main channel at the point marked by the Department of Water Affairs' flow-gauging site. Immediately downstream of Mohembo, the Panhandle zone broadens out and the main channel is flanked by increasingly wider zones of permanent swamp that are fringed on their outer edges by narrow areas of seasonal swamp. The Okavango River meanders down the length of the Panhandle, and the Upper Panhandle zone has very few lagoons and side channels.

At high river flows, water flows almost constantly down the centre of the elevated main channel and flows sideways off the higher meander ridge. The meander ridges become too elevated to sustain permanent flooding due to steep hydraulic gradients away from the ridge. In the Upper Panhandle, vegetation distribution is entirely a product of the fluvial processes of erosion and deposition.

A general feature of the Upper Panhandle zone is the absence of islands and lagoons, probably as a result of fluvial processes associated with meandering rivers. Islands have been flattened (eroded) whilst lagoons have been filled in by depositional processes, giving rise to the low diversity of habitats. Backwater areas are remote, being set well away from the meander ridge, and the snapshot of the area is one of low habitat diversity.

A second general feature of note in the upper Panhandle area is the widespread occurrence of shallow surface clay deposits on underlying sand. There is little peat present, although organic detritus is widespread, varying in character between different plant communities. For example, coarse organic detritus is present in *Echinochloa* and *Vossia* backswamps, whilst the organic detritus is predominantly fine-grained in open water areas such as backwaters and lagoons.

A few kilometres downstream of Mohembo, near Shakawe, the main channel carries approximately one-quarter to one-third of the water that flows down this zone of the Okavango Delta. The balance of the water travels through the papyrus and phragmites swamp, becoming "filtered" in the process. Water flow rates are high, up to 0.9 m/sec in the main channel. From the main channel, the water flows sideways and outwards into and through the perennial swamps of this zone. Water flow rates amongst the flooded grasses and reeds of this zone are usually below 0.1 m/sec. Overall, it is this continual flow of water that shapes and forms the perennial swamps and "drives" these ecosystem components and their associated ecological processes.

The Lower Panhandle

Between the Upper Panhandle sites and the Lower Panhandle, the Okavango River meanders widely across the floodplain and the main channel becomes noticeably narrower with increasing distance down the Panhandle. Throughout its length, the main channel is fringed by dense permanent swamp, which grades gradually into more seasonal swamp vegetation with increasing distance from the main channel. There is increasing evidence of the extent of these meanders in the form of old ox-bow lagoons that have been separated from the present channel and now remain as isolated lagoons of varying sizes (such as Guma Lagoon). Narrow channels still link several of these old ox-bow lagoons with the main channel, though they receive water primarily as "underflows" from their fringing swamp areas and not as direct inflows from the main channel.

Moremi Game Reserve/Xakanaxa

Between the Lower Panhandle zone and Xakanaxa Lagoon in Moremi Game Reserve, the water of the Okavango River spreads out into numerous smaller (narrower and shallower) channels and hippo paths through the papyrus, as well as flowing through and under the papyrus *(Cyperus papyrus)* and *Phragmites* mats. These channels tend to become progressively smaller with increasing distance from the base of the Panhandle.

The large lagoons that have a channel flowing through them (so-called "flow-through lagoons") are well oxygenated and the organisms within these lagoons benefit from the constant flow-through of nutrients. In contrast, lagoons that are isolated from flow-through channels (so-called "cut-off lagoons") usually have high accumulations of organic debris, low pH values, and low levels of dissolved oxygen. These lagoons are often subject to seasonal deoxygenation and associated fish kills whenever floodwater brings in new loads of organic matter. In both nutrient-poor (e.g., Xakanaxa) and nutrient-rich (e.g., Gadikwe) lagoons, there is often an imbalance between the quantities of the nutrients nitrogen and phosphorus, resulting in the development of nitrogen-fixing blue-green algae. These are commonly seen as small to large gelatinous balls that are attached to the submerged stems and leaves of aquatic plants.

Another feature of the middle and lower reaches of the Okavango Delta is the gradual reduction in the size of *Cyperus papyrus* plants, decreasing from some 3.5-4.0 metres in the Upper and Lower Panhandle zones, to between 1.5–2.0 metres in the Okavango Delta itself. In addition to this reduction in the size of the papyrus plants, the plants also tend to show a gradual change in colour from bright green to yellowish green. This also suggests that there is a progressive decrease in the nitrogen available for plant growth.

Chief's Island

Between the Moremi and Chief's Island zones, the channels become narrower, shallower and more numerous as the Okavango waters spread out further into the deltaic fan. The aquatic vegetation changes from a dominance by papyrus and *Phragmites* to a range of emergent and submerged species occupying channels, lagoons, and flooded grasslands. The impression gained is that whilst the same groups of plant species occurs, they are grouped into a wider range of combinations that gives rise to a greater variety of habitats.

With increasing distance down the length of the Okavango Delta, it appears that hippos perform an important role in keeping channels open by breaking down or removing packed plant material, helping the lateral spread of water, and creating new aquatic habitats. There are also considerable quantities of epiphytic green and blue-green algae present in the flooded grassland areas. The stems and leaves of submerged vegetation also provide support for a wide variety of small invertebrate organisms and act as efficient filters for the water passing through them.

Several shallow (< 3 metres deep) lagoons occur in the vicinity of Chief's Island and most of these lagoons support dense populations of water lilies. The floating water lily leaves often cover over 40% of the total water surface. In the Chief's Island zone, several saline pools also occur on islands.

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Chapter 2

Water quality of the Okavango Delta, Botswana

Peter J. Ashton, Hilary Masundire, Rob Hart, Jane Prince-Nengu, Oikantswe Botshelo, Merepelo Lekhuru, Mandla Mehlomakulu, and Innocent Tylol

INTRODUCTION

During the 2000 AquaRAP biodiversity survey of the Okavango Delta, the Water Quality Team was responsible for field measurements and observations on all aspects relating to water quality at the different sampling sites in four sampling focal areas (see Map). In addition to the field measurements, a series of water samples were collected for more detailed chemical analysis in the Water Affairs analytical laboratories in Gaborone. As indicated in the introductory section of the AquaRAP Expedition Report (Chapter 1), the water quality investigations provide essential background and contextual information for the individual investigations on different aspects of the biodiversity of the Okavango Delta.

This report on the water quality issues investigated during the AquaRAP Expedition has been divided into eight sections for convenience. The report opens with a brief introduction and rationale, followed by a description of the sampling methods and choice of sampling locations. This is followed by an overview of the results obtained and observations made in each of the four sampling areas. The final five sections of the report comprise an assessment of the training aspects undertaken, some overall impressions of water quality issues in the Okavango Delta, followed by a list of conservation concerns, and a list of recommendations for future investigations.

THE AQUARAP WATER QUALITY TEAM

The eight team members responsible for the water quality component of the AquaRAP Expedition were drawn from five different organizations in Botswana and South Africa. The team included Prof. Peter Ashton, Prof. Rob Hart, Prof. Hilary Masundire, Ms. Jane Prince-Nengu, Ms. Oikantswe Botshelo, Mr. Innocent Tylol, Mr. Meropelo Lekhuru, and Mr. Mandla Mehlomakulu. In addition, two post-graduate students from the University of Botswana, Ms. Tumi Mothibi and Ms. Masego Kruger, joined the team on certain days to gain familiarity with water quality sampling protocols. In addition to water quality issues, the team also examined a selection of geomorphology and hydrology issues at each of the sampling sites.

SAMPLING AND MEASUREMENT METHODS

The June 2000 AquaRAP Expedition coincided with the arrival of the annual floods from the upper Okavango catchment in Angola, where the floodwaters were superimposed on minor, but widespread flooding caused by earlier, unusually heavy rains that had fallen across the entire Okavango Delta. This combination of conditions led to somewhat unusual conditions of higher-than-normal water levels in certain areas (for this specific time of year) and the overall impression created was that a "good flood year" had occurred.

Choice of sampling locations

In order to provide the widest possible coverage of the different habitat types present in the Okavango Delta ecosystem, four focal areas were chosen for examination. The specific focal areas were:

- Upper Panhandle (centred on the town of Shakawe);
- Lower Panhandle (centred on Guma Lagoon);
- North-western Moremi Game Reserve (centred on Xakanaxa Lagoon); and
- South-east of Chief's Island (centred on Oddball's Camp).

A variety of geo-referenced sampling sites were selected in each focal area so as to provide a representative coverage of all the available habitats. At each geo-referenced sampling site, a variety of field measurements and observations were made. The geo-referenced sampling sites were numbered sequentially from the first site (OK1-1) at Mohembo, to the final site (OK1-37) that was located near Oddball's Camp. The locations of the sampling sites chosen within each of these focal areas are shown in Figures 2.1 – 2.4.

"Spot" sampling is recognized as being notoriously inadequate when attempting to characterize a river or lake. Accordingly, at each geo-referenced site, samples were collected at three to seven points along a transect across the river channel or lagoon. At each point along the transect, a vertical profile of water current speeds was recorded at 50 centimetre intervals, whilst dissolved oxygen and water temperature measurements were also taken. Other parameters (pH and electrical conductivity) could only be measured in the surface waters due to the very short cables available for these instruments.

Field measurements

Prior to any field measurements of sample collection, the precise position of each sampling site was noted with a Garmin-12 Geographical Positioning System (GPS). These site location data (Appendix 1) will allow future investigators to re-visit selected sites if so required.

A variety of standard water quality measurements were carried out at each sampling site, using specific field instruments. These measurements consisted of:

- Current speed at 50-centimetre intervals from the water surface to the bottom sediments;
- Water temperature, using a Yellow Springs Instruments (YSI) Model 85 hand-held meter;
- Dissolved oxygen, using a YSI Model 85 hand-held meter;
- pH (a measure of how acidic or alkaline the water is) using a YSI Model 60 hand-held meter;
- Electrical conductivity (a measure of the salinity, or quantity of total dissolved salts present in the water) using a YSI Model 85 hand-held meter; and

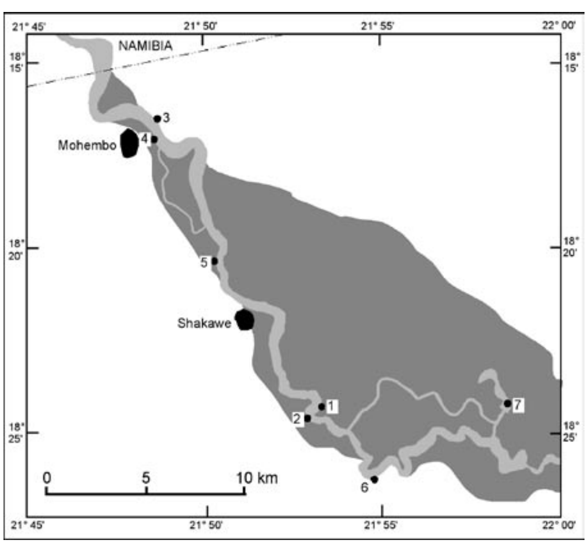

Figure 2.1. Sketch map of Focal Area 1, located in the Upper Panhandle zone of the Okavango Delta, showing the positions of seven sampling sites in relation to the Okavango River and the nearby towns of Mohembo and Shakawe.

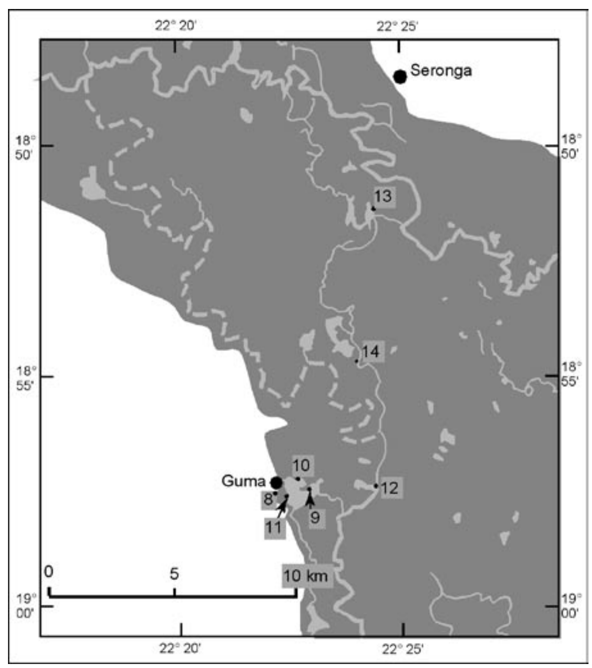

Figure 2.2. Sketch map of Focal Area 2, located in the Lower Panhandle/ Guma Lagoon zone, showing the positions of seven sampling sites in relation to the different channels and lagoons, as well as the town of Seronga and Guma Fishing Camp.

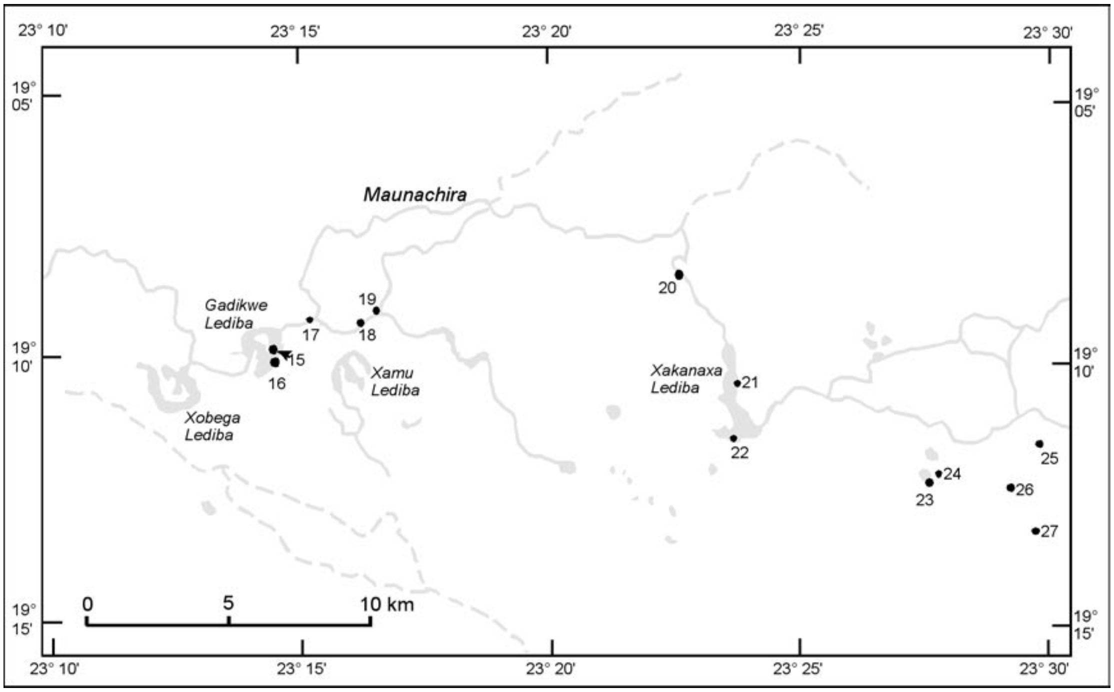

Figure 2.3. Sketch map of Focal Area 3, in the Moremi Game Reserve area, showing the locations of the thirteen sampling sites in relation to nearby channels and lagoons.

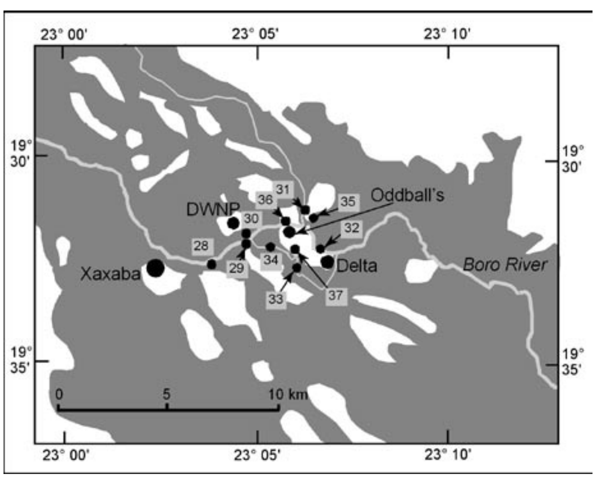

Figure 2.4. Sketch map of Focal Area 4, in the Chief's Island zone, showing the locations of the ten sampling sites in relation to the Boro River and the nearby tourist lodges Xaxaba, Delta Camp, and Oddball's.

- Light penetration (an estimate of the water clarity, or the approximate depth to which incident light is able to penetrate the water).

At each sampling site, a 50-µm-mesh plankton net with a 30-centimetre orifice was used to sample a vertical profile of the water column in order to collect any planktonic organisms that might be present. All plankton samples were preserved with 5% formaldehyde for microscopic analysis on return to the laboratory in Gaborone (Prof. Hilary Masundire) and Pietermaritzburg (Prof. Rob Hart).

In addition to the field measurements, a 500-millilitre sample of surface water was collected at selected sampling sites for detailed chemical analysis in the Department of Water Affairs laboratories in Gaborone. All water samples were kept cool and stored in the dark prior to analysis. No chemical preservatives were used for the water samples and it was recognized that any nutrient analyses (the different forms of nitrogen and phosphorus) would therefore not be accurate. Despite these potential inaccuracies, the nitrogen and phosphorus analyses can be used to provide general indications of the nutrient status of sites where samples were collected.

Laboratory analyses

The laboratory analyses conducted by the Botswana Department of Water Affairs Laboratory in Gaborone on each water sample consisted of the following analyses:

- pH
- Electrical conductivity (E.C.)
- Total dissolved salts (TDS)
- Calcium (Ca)
- Magnesium (Mg)
- Sodium (Na)
- Potassium (K)
- Chloride (Cl)
- Sulphate (SO_4)
- Fluoride (F)
- Carbonate (CO_3)
- Bicarbonate (HCO_3)
- Manganese (Mn)
- Iron (Fe)
- Nitrate (NO_3-N)
- Nitrite (NO_2-N)
- Orthophosphate (PO_4-P)

In addition to these chemical analyses, the Botswana Department of Water Affairs Laboratory also provided three calculated parameters for each water sample. These parameters were:

- Total Hardness
- Magnesium Hardness; and
- Sodium Absorption Ratio (SAR).

These three values are useful indices for evaluating the suitability of water for domestic use and in irrigation agriculture. The hardness indices reflect the likelihood that water will require special treatment prior to use, whilst the SAR value indicates whether or not the water will cause compaction or dispersion in soils that are irrigated.

RESULTS AND OBSERVATIONS

The results and observations presented here have been divided according to the four focal areas that were sampled during the AquaRAP Expedition (see Map and Figures 2.1-2.4), and provide an overview and summary of the main features and characteristics of each focal area. The specific water quality results have been listed in the data tables (Tables 2.1 to 2.6) whilst the individual results and field observations have been discussed in the "results" sections that deal with the four different focal areas that were sampled. In addition, the expedition database contains the precise listings of all measurements and locations where samples were collected during the AquaRAP Expedition (see http://rapdb.conservation.org).

In addition to the water quality data and results obtained during the AquaRAP Expedition in June 2000, water quality data published by earlier investigators have also been included for comparative purposes. Though these data are very scanty, they do provide some additional information regarding the water quality status of the Okavango system.

Upstream reaches of the Okavango River

A few water quality data are available for the Okavango River upstream of the Botswana-Namibia border; these are shown in Table 2.1. The general water quality of these reaches is very good, with low concentrations of total dissolved salts and circum-neutral pH values (Smith 1976). Along the middle reaches of the Okavango River where it forms the north-eastern border of Namibia, the cations are dominated by calcium, followed by magnesium, sodium and potassium, whilst the anions are dominated by carbonate-bicarbonate, followed by chloride. Sulphate concentrations are below the detection limit of the analytical technique used. There are some signs of slight enrichment with inorganic nitrogen and phosphorus, probably as a result of return flows from small areas of irrigation and the discharge of treated sewage effluent at the town of Rundu (Bethune 1987, 1991; CSIR 1997).

Focal Area 1: Upper Panhandle

A total of seven geo-reference points were chosen within this focal area (Map, Figure 2.1). These were located in a variety of different habitats situated between the town of Mohembo, near the Botswana-Namibia border, southwards to a point some five kilometres downstream of Drotsky's Fishing Cabins, near the town of Shakawe.

General aquatic characteristics of Focal Area 1

At the entry to the Upper Panhandle zone of the Okavango Delta, the entire flow of the Okavango River is confined to the main channel at the point marked by the Department of Water Affairs flow-gauging site. Immediately downstream of Mohembo, the Panhandle zone broadens out and the main channel is flanked by increasingly wider zones of permanent swamp that are fringed on their outer edges by narrow areas of seasonal swamp. The Okavango River meanders down the length of the Panhandle, and the Upper Panhandle zone has very few lagoons and side channels.

At high river flows, water flows almost constantly down the centre of the elevated main channel and flow sideways off the higher meander ridge. The meander ridges become too elevated to sustain permanent flooding due to steep hydraulic gradients away from the ridge. In the Upper Panhandle, vegetation distribution is entirely a product of the fluvial processes of erosion and deposition.

A general feature of the Uupper Panhandle zone is the absence of islands and lagoons, probably as a result of fluvial processes associated with meandering rivers. Islands have been flattened (eroded) whilst depositional processes, giving rise to the low diversity of habitats, have filled in lagoons.

Table 2.1. Water quality analyses for sites along the Okavango River in Angola and Namibia, upstream of the Botswana border at Mohembo. Sources of data are given in footnote to the table. All values in milligrammes per litre, except: pH, E.C. (µS/cm) = Electrical Conductivity in microSiemens per centimetre; Turb. (NTU) = Turbidity in Nephelometric Turbidity Units; and Diss. O_2 (%) = Dissolved oxygen in percentage saturation. - = No data available. Month = Month(s) when samples collected or field measurements made.

Reference:	#1	#1	#1	#2	#2	#3	#3	#3	#3	#3
Sampling Site:	Cubango River headwater in Angola	Middle Cubango River in Angola	Okavango River at Rundu in Namibia	Main channel Okavango River at Mukwe in Namibia	Backwater pools of Okavango River at Katere in Namibia	Backwater floodplain pool near Rundu in Namibia	Above Cuito River confluence at Nyan-gana in Namibia	Cuito River confluence at Katere in Namibia	Braided area near Andara (W. Bank) in Namibia	Western side of Popa Falls in Namibia
Month *	-	-	-	S&W 1984	S&W 1984	Nov. 1996	Nov. 1996	Nov. 1996	Nov. 1996	Nov. 1996
pH	-	-	-	6.8 - 7.2	6.7 - 7.5	8.9	7.6	7.5	7.3	7.5
E.C. (µS/cm)	4.2 - 8.0	21 - 35	36 - 38	30 - 45	45 - 205	50	40	40	30	30
Turb. (NTU)	-	-	-	-	-	39	11	10	11	19
Diss. O_2 (%)	-	-	-	65 - 105	50 - 130	160	108	92	100	100
Na	-	-	-	1 - 3	3 - 10	-	-	-	-	-
K	-	-	-	1 - 2	1 - 3	-	-	-	-	-
Ca	-	-	-	6 - 16	7 - 46	-	-	-	-	-
Mg	-	-	-	3 - 8	6 - 22	-	-	-	-	-
SiO_2	-	-	-	8 - 15	9 - 36	-	-	-	-	-
Cl	-	-	-	0.5 - 1.0	1.0 - 5.6	-	-	-	-	-
SO_4	-	-	-	0	0	-	-	-	-	-
CO_3+HCO_3	-	-	-	10 - 20	20 - 95	-	-	-	-	-
Inorg. N	-	-	-	0.1 - 1.5	0.1 - 6.2	-	-	-	-	-
Total P	-	-	-	0.01 - 0.15	0.04 - 0.37	-	-	-	-	-

Data sources/references: #1: Smith (1976); #2: Bethune (1987, 1991); #3: CSIR (1997).
* S&W = summer and winter months

Backwater areas are remote, being set well away from the meander ridge, and the snapshot of the area is one of low habitat diversity.

A second general feature of note in the Upper Panhandle area is the widespread occurrence of shallow surface clay deposits on underlying sand. There is little peat present, although organic detritus is widespread varying in character between different plant communities. For example, coarse organic detritus is present in *Echinochloa* and *Vossia* back-swamps, whilst the organic detritus is predominantly fine-grained in open water areas such as backwaters and lagoons.

A few kilometres downstream of Mohembo, near Shakawe, the main channel carries approximately one-quarter to one-third of the water that flows down this zone of the Okavango Delta. The balance of the water travels through the *Cyperus papyrus* and *Phragmites* swamp, becoming "filtered" in the process. Water flow rates are high, up to 0.9 m/sec in the main channel. From the main channel, the water flows sideways and outwards into and through the perennial swamps of this zone. Water flow rates amongst the flooded grasses and reeds of this zone are usually below 0.1m/sec. Overall, it is this continual flow of water that shapes and forms the perennial swamps and "drives" and sustains these ecosystem components.

Water quality characteristics of Focal Area 1

Water temperatures in the Upper Panhandle zone ranged from 18°C to 19°C; these values are considered to be normal for this (cool season) time of year. The pH values ranged from 6.1 to 7.5, indicating that the water is neutral to very slightly acidic (Table 2.2). The electrical conductivity (EC) values ranged from 33 to 35 µS/cm, with one value of 37 µS/cm, indicating that very low concentrations of total dissolved salts are present and that the water quality is likely to be excellent. The vertical profiles of dissolved oxygen indicated that dissolved oxygen values varied between 65% and 95% of saturation at all times, again indicating the water quality to be excellent.

The only minor exceptions to these generalizations would be the water quality of small marginal pools and lagoons

Table 2.2. Water quality analyses for sites along the Upper Panhandle section of the Okavango River in Botswana. Sources of data are given in footnote to the table. All values in milligrammes per litre, except pH, E.C. (µS/cm) = Electrical Conductivity in microSiemens per centimetre; Secchi Disc (m) = A measure of water transparency in metres; and Diss. O_2 (%) = Dissolved oxygen in percentage saturation. - = No data available; Month = Month(s) when samples collected or field measurements made.

Reference:	This Study	This Study	#1	#2	This Study	This Study	This Study	This Study
Sampling Site:	Okavango R. channel at Mohembo Pontoon	Side pool opposite Mohembo Pontoon	Opposite DWA boat landing at Shakawe	Opposite DWA boat landing at Shakawe	Okavango R. channel near Drotsky's	Side pool / lagoon above Drotsky's	Irrigation channel downstream of Drotsky's	Xaulethoga Lagoon downstream of Drotsky's
Sample Nos.	OK3C,3E,4	OK3	N/A	N/A	OK1B, 6F	OK2D	Ok6	OK7B
Month	Jun. 2000	Jun. 2000	Aug. 1975	May 1976	Jun. 2000	Jun. 2000	Jun. 2000	Jun. 2000
pH	6.75 – 7.05	6.74	-	6.9	6.60 – 6.85	6.75 – 6.95	6.6 – 6.8	6.5
E.C. (µS/cm)	34 - 35	34	-	33	30 – 35	36	35	37
Secchi Disc (m)	3.2-3.4	3.0	-	-	2.5	2.5	Bottom (1.0)	3.3
Diss. O_2 (%)	85 - 95	85	-	85	80 - 95	15	35	25
Na	1.4 – 1.6	1.6	2.0	-	1.6 –1.7	1.8	1.7	1.7
K	1.3	1.4	1.4	-	1.3	1.5	1.5	1.3
Ca	2.9 – 3.0	2.6	5.0	-	3.0 – 3.5	3.0	2.7	3.0
Mg	0.7 – 1.1	3.3	0.6	-	0.7 – 1.0	1.8	1.6	0.7
SiO_2	-	-	16	5 – 12	-	-	-	-
Cl	0.3 – 0.4	0.5	< 1	-	0.2 – 0.4	0.5	0.4	0.4
SO_4	0	0	< 1	-	0	0	0	0
CO_3+HCO_3	15 – 21	26	22	-	19 – 21	19	19	19
Inorg. N	0.7 – 2.5	1.7	-	-	0.5 – 0.9	1.7	2.4	0
Total P	0	0	-	-	0	0	0	0

Data sources/references: #1: Hutton and Dincer (1976); #2: UNDP and FAO (1977).

where mixing and aeration occurs slowly or water quality is affected by human activities on or near the riverbanks. At these more sheltered sites, water quality characteristics (dissolved oxygen, pH, and electrical conductivity) suggested that the lack of water mixing from the main river channel had not caused adverse water quality effects, whilst human activities at shallow marginal sites have had only minor adverse effects. Field observations near the town of Shakawe suggest that if the current, unsightly practices of garbage disposal on the river banks are continued, these may well lead to a gradual decline in water quality in this area.

The average chemical analysis results for seven sampling sites evaluated in the upper Panhandle zone are shown in Table 2.2, together with the few data that are available from two earlier studies (Hutton and Dincer 1976; UNDP and FAO 1977). There is good correspondence between the historical data and those collected during this study, suggesting that no major water quality changes have taken place. The data from the present study show that this entire zone has relatively low levels of the nutrients nitrogen and phosphorus, with phosphorus concentrations below the level of detection for the analytical technique used.

The cation water chemistry is dominated by calcium ions, followed in dominance by magnesium, sodium and potassium. The dominant anions are carbonate-bicarbonate, followed by chloride. Sulphate ions were usually below detection levels of the analytical technique used. A few earlier analyses showed the presence of moderate amounts of silica. The low concentrations of major ions, as well as their proportions to one another, reflect the geological origin of the Okavango River water and are very similar to those recorded from sites further upstream in Namibia (Table 2.1).

Focal Area 2: Lower Panhandle / Guma Lagoon

A total of seven geo-reference points were chosen within this focal area (Figure 2.2). These were located at a variety of different habitats situated in open pools and lagoons, as well as the narrow channel that links Guma Lagoon with the main channel of the Okavango River.

General aquatic characteristics of Focal Area 2

Between the Upper Panhandle sites and the Lower Panhandle, the Okavango River meanders widely across the floodplain and the main channel becomes noticeably narrower with increasing distance down the Panhandle. Throughout its length, the main channel is fringed by dense permanent swamp, which grades gradually into more seasonal swamp vegetation with increasing distance from the main channel. There is increasing evidence of the extent of these meanders in the form of old ox-bow lagoons that have been separated from the present channel and now remain as isolated lagoons of varying sizes (such as Guma Lagoon). Narrow channels still link several of these old ox-bow lagoons with the main channel, though they receive water primarily from their fringing swamp areas and not as direct inflow from the main channel.

The larger lagoons (e.g. Guma Lagoon) have wide areas that are partially deoxygenated; in most areas the dissolved oxygen concentrations in the lower half to two-thirds of the water column is well below 20% of saturation. This feature appears to be driven by the inflows of large volumes of water that has been either "filtered" through the swamps, or has flowed beneath the mats of vegetation during higher (flood) flows. This water brings with it considerable quantities of dissolved and particulate organic matter that have accumulated beneath the swamp vegetation during periods of low flow. The organic matter decomposes very readily in the presence of oxygen and, in the process, uses up the available oxygen. The primary process whereby the oxygen is replaced in the water is by diffusion from the atmosphere and from photosynthesis by submerged plants in the lagoons. If the delicate balance between oxygen consumption and oxygen production is displaced or disturbed, this could cause a rapid loss of all the dissolved oxygen and this, in turn, would cause a fish kill.

In marginal pools on the floodplain, there is a sharp variation in dissolved oxygen and temperature over a 24-hour cycle. Water temperatures increase very rapidly during the day and this is accompanied by bacterial activity in the flooded grasses that, in turn, uses up large quantities of dissolved oxygen that the few submerged aquatic plants can produce. In these very shallow water situations, this can lead to oxygen stress for the pool-dwelling fish. At night, the reverse occurs, where water temperatures drop rapidly and oxygen saturation increases due to atmospheric diffusion. The net result is that these pools represent a specialized type of habitat for a restricted range of organisms.

Within the open lagoons, there are large quantities of particulate organic matter in suspension and dissolved in the water. Very few planktonic organisms were found, suggesting that plankton do not play an important role in the functioning of these lagoon systems (see Hart et al. 2003). Nocturnal samples for plankton also showed a very low population of plankton and support this hypothesis. Earlier studies in lagoons elsewhere in the Okavango Delta and in the Chobe River in Botswana show that planktonic organisms can be important in the food webs of those systems. Therefore, our observations on Guma Lagoon seem to reflect what is happening during the winter (high flow) months and may be expected to be different during the summer (low flow) months.

Water quality characteristics of Focal Area 2

Daytime water temperatures at all sites in the Lower Panhandle zone ranged from 18°C to 19°C, very similar to those recorded at the Upper Panhandle sites. These values are considered to be normal for this (cool season) time of year. Nocturnal surface water temperatures in Guma Lagoon showed a slight drop of between 3 and 5°C by 21:00.

The pH values of Guma Lagoon surface waters ranged from 4.5 to 5.5 (Table 2.3), indicating that the water is slightly acidic and reflecting the concentrations of dissolved humic compounds that stained the water a pale yellowish-brown colour. In the isolated channel linking Guma Lagoon with the Nqoga Channel, pH values were slightly higher (ranging from 5.3 to 6.2). In the second lagoon located close to the Nqoga Channel, pH values were again slightly higher (6.4 to 7.1), similar to those recorded for the Nqoga Channel.

The electrical conductivity (EC) values for Guma Lagoon and the inter-linking channel were very similar and ranged from 33 to 36 µS/cm, with one value of 37 µS/cm. This indicates that very low concentrations of total dissolved salts are present and that, apart from the low pH values, the water quality is likely to be excellent. The waters in nearby flooded grassland pans had slightly higher electrical conductivity values (36 to 38 µS/cm).

Vertical profiles of dissolved oxygen in Guma Lagoon indicated that dissolved oxygen values varied between 10% and 40% of saturation at all times, with the highest values recorded at the water surface. There was a consistent pattern of decreasing oxygen concentrations with increasing depth, suggesting that decomposition processes in the deeper waters were consuming considerable oxygen. It was noticeable that dissolved oxygen concentrations beneath the fringing *Cyperus papyrus* and *Phragmites* mats were always very low. Since almost all of the water entering Guma Lagoon appears to flow beneath these mats, this would suggest that most of the water entering Guma Lagoon contains very low concentrations of dissolved oxygen that becomes further depleted as organic matter is oxidized during decomposition in the lagoon.

The water quality of the small flooded grassland pools was slightly different to that recorded from Guma Lagoon. These differences can be attributed to the almost complete absence of inflow to these pools and the decomposition of flooded vegetation.

There was no evidence that any of the human activities alongside Guma Lagoon had had a negative influence on any water quality parameter. However, given the very sandy nature of the soils around the shores, it can be expected that some nutrients may enter the lagoon via seepage from sanitation systems.

The average chemical analysis results for five sampling sites evaluated in the Lower Panhandle zone are shown Table 2.3, together with the few data that area available

Table 2.3. Water quality analyses for sites along the Lower Panhandle section of the Okavango River in Botswana. Sources of data are given in footnote to the table. All values in milligrammes per litre, except pH, electrical conductivity, Secchi Disc and Dissolved oxygen. E.C. (µS/cm) = Electrical Conductivity in microSiemens per centimetre; Secchi Disc (m) = A measure of water transparency in metres; Diss. O_2 (%) = Dissolved oxygen in percentage saturation. - = No data available. Month = Month(s) when samples collected or field measurements made.

Reference:	#1	#1	#1	#2	This Study	This Study	This Study	This Study	This Study
Sampling Site:	Okavango River at Seronga	Seronga Lagoon	Dungu Lagoon (near Seronga)	Okavango River at Seronga	Flooded grassland near Guma Camp	Guma Lagoon inflow from Swamp	Guma Lagoon (open water)	Guma Lagoon (Papyrus channel)	Centre of secondary lagoon (near Okavango R.)
Sample Nos.	-	-	-	-	OK8B	OK9A	OK9D, 11	OK12	OK13
Month	Feb. 1986	Feb. 1986	Feb. 1986	Apr. – Sep.	Jun. 2000	Jun. 2000	Jun. 2000	Jun. 2000	Jun. 2000
pH	7.0 - 7.2	5.7	7.6	6.3 – 7.3	5.5	5.6 - 5.8	5.3 - 6.1	6.2	5.65 - 6.85
E.C. (µS/cm)	40 - 51	60	102	48	37	35	33 - 35	35	34 - 36
Secchi Disc (m)	1.2	2.3 - 2.6	> 1.5	-	Bottom (0.2)	Bottom (1.8)	2.5 - 3.0	2.0	3.0
Diss. O_2 (%)	-	20 - 40	65 - 135	-	75 - 80	35	40 - 55	25	30 - 35
Na	-	-	-	2.3	2.3	2.2	1.8 - 2.2	1.8	2.3
K	-	-	-	1.3	1.3	1.4	1.0 - 1.2	1.1	1.1
Ca	-	-	-	3.0	3.0	2.8	2.8 - 3.0	2.7	2.8
Mg	-	-	-	1.1	0.3	0.6	0.6 - 0.9	0.6	0.8
SiO_2	6.9 - 7.3	-	11.4	-	-	-	-	-	-
Cl	-	-	-	1.0	1.6	0.4	0.2 - 0.4	0.2	0.2
SO_4	-	-	-	-	0	0	0	0	0
CO_3+HCO_3	-	-	-	23	19	19	19 - 21	19	21
Inorg. N	0.04	-	0.05	-	0	0.4	0	0	0
Total P	0.06	-	0.11	-	0	0	0	0	0

Data sources/references: #1: Hart (1997); #2: Sawula & Martins (1991).

from two earlier studies (Sawula and Martins 1991; Hart 1997). The data from the present study show that this entire zone has relatively low levels of the nutrients nitrogen and phosphorus, with phosphorus concentrations below the level of detection for the analytical technique used. The low concentrations of major ions are virtually identical to those recorded from the Upper Panhandle zone and do not indicate any significant concentration effect along the length of the Panhandle.

Again, the cationic water chemistry is dominated by calcium ions, followed in dominance by magnesium, sodium and potassium. The dominant anions are carbonate-bicarbonate, followed by chloride. Sulphate ions were usually below detection levels of the analytical technique used. A few earlier analyses showed the presence of moderate amounts of silica. The low concentrations of major ions, as well as their proportions to one another, reflect the geological origin of the Okavango River water and are very similar to those recorded from sites further upstream in Namibia (Table 2.1) and the Upper Panhandle (Table 2.2).

Focal Area 3: Moremi Game Reserve / Xakanaxa Lagoon

A total of thirteen geo-reference points were chosen within this focal area (Figure 2.3). The greater number of sampling sites chosen reflects the wider variety of habitat types present in this area. The sites were located across a number of different habitats situated in open lagoons and the narrow channels that link these lagoons, as well as several isolated (land-locked) pools of different sizes located away from the main aquatic system.

General aquatic characteristics of Focal Area 3

Between the Lower Panhandle zone and Xakanaxa Lagoon in Moremi, the water of the Okavango River spreads out into numerous smaller (narrower and shallower) channels and hippo paths through the papyrus, as well as flowing through the *Cyperus papyrus* and *Phragmites* mats. These channels tend to become progressively smaller with increasing distance from the base of the Panhandle. The water flows in these smaller channels are considerably slower (usually less than 0.3 m/sec) than those recorded in the main channel in the Panhandle zone. The water is noticeably less turbid (contains less suspended material); this is probably because the slower flows cannot transport the same quantities of material, as well as due to the filtering effect of the swamp vegetation. These channels link a series of lagoons of differing sizes that have been formed from old river meanders.

The lagoons that have a channel flowing through them (so-called "flow-through lagoons") are well oxygenated and the organisms within these lagoons benefit from the constant flow-through of nutrients. In contrast, lagoons that are isolated from flow-through channels (so-called "cut-off lagoons") usually have high accumulations of organic debris, low pH values, and low levels of dissolved oxygen. These lagoons are often subject to seasonal deoxygenation and associated fish kills whenever floodwater brings in new loads of organic matter. In both nutrient-poor (e.g., Xakanaxa) and nutrient-rich (e.g., Gadikwe) lagoons, there is often an imbalance between the quantities of the nutrients nitrogen and phosphorus, resulting in the development of nitrogen-fixing blue-green algae. These are commonly seen as small to large gelatinous balls that are attached to the submerged stems and leaves of aquatic plants. Another feature of the middle and lower reaches of the Okavango Delta is the gradual reduction in the size of *Cyperus papyrus* plants, decreasing from some 3.5-4.0 metres in the Upper and Lower Panhandle zones, to between 1.5-2.0 metres in the Okavango Delta itself. In addition to this reduction in the size of the papyrus plants, the plants also tend to show a gradual change in colour from bright green to yellowish green. This also suggests that there is a progressive decrease in the nitrogen available for plant growth.

Water quality characteristics of Focal Area 3

At all the channel and lagoon sites in the Moremi zone, dissolved oxygen levels were noticeably higher (averaging between 65% and 90%) than those recorded at both the Upper and Lower Panhandle zones. Submerged plants produce considerable quantities of oxygen during photosynthesis and also trap and accumulate particulate organic matter around their roots. The larger, deeper lagoons have greater quantities of organic matter accumulated on their bottom sediments, and the decomposition of this material results in low oxygen levels near the sediment surface. The bottom water temperature is 0.2-0.5 C higher than the water above it, possibly due to heat produced by decomposition on the bottom and the almost complete absence of any deeper water currents to dissipate temperature differences. Gas bubbles coming up from the bottom sediments are likely to consist primarily of carbon dioxide and methane from decomposition on the bottom.

Dissolved oxygen concentrations at the margins of the lagoons are usually above saturation (reaching 130%), whilst the pH values are quite variable (ranging from 5 to 7; Table 2.4). It is very likely that large pH changes occur during the day because the chemistry of the pool waters suggests that they are poorly buffered. Electrical conductivity values ranged widely, varying from 54 µS/cm in the centre of the open lagoons to 75µS/cm in the weed-fringed marginal areas. These electrical conductivity values are approximately double those that were recorded at the Lower and Upper Panhandle zone sites, suggesting that a considerable quantity of water has been lost through evapo-transpiration processes in the swamp vegetation.

The Moremi zone also has a wide variety of seasonal pools; some of these are connected to other water bodies, whilst others are completely isolated and receive only rainwater. Water quality measurements in the seasonal pools that are connected to the channels revealed that they could contain up to at least six times the salt concentration of the water in the main channel. Part of the reason for this increase in salt concentrations is the nutrients and salts that are liberated during the decomposition of flooded terrestrial vegetation. In the isolated pools, salt concentrations can rise to some 25-fold higher than those in the main channels, usually due to the "evaporative pumping" process of terrestrial vegetation.

The *Salvinia* pool was isolated by a dense stand of aquatic vegetation and the water appeared to be poorly mixed. Whilst this feature would have contributed to the relatively poor quality of water in this pool, the pool also appeared to be used frequently by elephants. The addition of elephant dung and urine would certainly have contributed to poor water quality in this pool. Several of the isolated pools had higher concentrations of total dissolved salts compared to the main channels and lagoons. The higher salinity levels in the pools would enhance the precipitation of clay and other suspended materials and contribute to the formation of a clay "seal" on the bottom of the pool.

Whilst the water quality data collected in the open lagoons and channels have added a lot to our understanding of the area, we have very little information on the structure and functioning of the seasonal pools. Aerial observations suggest that there may be at least five different classes or types of seasonal pools in the Moremi zone, though these classes may also represent different phases from filling through drying. The surfaces of some of these seasonal pools appears to be covered by an algal scum; if this alga is a blue-green alga, it may very well be a toxic form which could pose a threat to wildlife. Ideally, these pool systems need to be studied carefully to assess their significance in the overall functioning of the Okavango Delta ecosystem.

In the larger lagoons (e.g., Gadikwe and Xakanaxa), there is low plankton density that may be due to high predation pressure. However, there is a rich plankton community in the seasonal pools (see Hart et al. 2003). Some of these pools have plankton communities that are dominated by large zooplankton species – other pools seem to be different and contain only small species. There is virtually no plankton in the main channel at Xakanaxa because it is very clear and fish would eat them. Higher plankton densities in the seasonal pools may be due to a combination of the higher nutrient concentrations that have been derived from decaying plants and animal faeces, as well as lower predation due to the presence of fewer fish.

The average chemical analysis results for four sampling sites evaluated in the Moremi zone are summarized in Table 2.4. These data show that this entire zone has very low levels of the nutrients nitrogen and phosphorus. The concentrations of major ions are slightly higher than those recorded from the Upper and Lower Panhandle zones and indicate a slight concentrating effect between these two zones.

For comparison, the chemical analysis of a water sample collected from an isolated pool in the Paradise Pools area of Moremi is also shown in Table 2.4. These data clearly reveal the very large increase in total dissolved salt concentrations that has taken place.

Focal Area 4: Chief's Island

A total of ten geo-reference points were chosen within this focal area (Figure 2.4). Once again, the number of sampling sites chosen reflects the wider variety of habitat types present in this area. The sites were located among a wide variety of different habitats situated in small channels and open lagoons, as well as a few isolated (land-locked) pools and one borrow pit. All sampling of the open water aquatic sites was conducted from dugout canoes (mokoros) since motorboats are prohibited in this area.

General aquatic characteristics of Focal Area 4

Between the Moremi and Chief's Island zones, the channels become narrower, shallower and more numerous as the Okavango waters spread out further into the deltaic fan. The aquatic vegetation changes from a dominance by *Cyperus papyrus* and *Phragmites* to a range of emergent and submerged species occupying channels, lagoons and flooded grasslands. The impression gained is that whilst the same groups of plant species occur, they are grouped into a wider range of combinations that gives rise to a greater variety of habitats.

Water flows become progressively lower and rarely exceed 0.2 m/sec; numerous hippo paths act as connectors between areas of different habitats. The water is very clear and appears to carry almost no suspended material; this suggests that most suspended material has been trapped by aquatic vegetation. Indeed, throughout the Okavango Delta ecosystem, aquatic plants act as very efficient filtering systems and

Table 2.4. Water quality analyses for sites in the Moremi Sector of the Okavango Delta in Botswana. Sources of data are given in footnote to the table. All values in milligrammes per litre, except pH, electrical conductivity, Secchi Disc and Dissolved oxygen. E.C. (µS/cm) = Electrical Conductivity in microSiemens per centimetre; Secchi Disc (m) = A measure of water transparency in metres; Diss. O_2 (%) = Dissolved oxygen in percentage saturation. - = No data available. Month = Month(s) when samples collected or field measurements made.

Reference:	#1	#2	#3	This Study	This Study	This Study	This Study	This Study
Sampling Site:	Fringe of small island next to Khiandiandavhu Channel	Fringe of island to north of Xugana Lagoon	Fringes of islands along Maunachira Channel	Fringe of heronry in Gadikwe Lagoon	Open water of Gadikwe Lagoon	Channel between Gadikwe and Xakanaxa lagoons	Open waters of Xakanaxa Lagoon	Large saline pool in Paradise Pools area
Sample Nos.	-	-	-	OK14	OK14D	OK17	OK20B	OK26
Month	Jan. 1987	-	Oct. 1990	Jun. 2000	Jun. 2000	Jun. 2000	Jun. 2000	Jun. 2000
pH	-	7.4	6.3 - 6.9	6.7 - 7.0	6.5 - 6.9	6.5 - 6.95	6.55 - 7.05	9.25
E.C. (µS/cm)	-	-	64 - 138	65 - 71	66 - 68	66 - 79	66 - 67	405
Secchi Disc (m)	-	-	-	1.6	2.5	Bottom (1.7)	2.65	< 0.2
Diss. O_2 (%)	-	-	-	50 - 65	60 - 75	75 - 85	70 - 80	160
Na	2.9	5	6 – 9	3.3	3.1	3.2	6.4	64.0
K	2.7	3	4 – 7	2.1	2.2	2.0	2.9	15.8
Ca	4.4	6	5 – 7	4.3	4.2	3.4	4.9	14.7
Mg	0.8	1	1 – 3	1.0	1.0	0.6	1.1	5.5
SiO_2	19.3	13.3	10 – 29	-	-	-	-	-
Cl	1.2	5	< 5	1.2	0.9	1.0	2.6	17.8
SO_4	0.3	5	< 5	0	0	0	0	1.2
CO_3+HCO_3	-	37	32 – 57	31	31	24	38	220
Inorg. N	-	-	-	0	0	0	0	0
Total P	-	-	-	0	0	0	0	0

Data sources/references: #1: McCarthy and Metcalfe (1990); #2: McCarthy et al. (1991); #3: McCarthy et al. (1993).

are extremely effective at removing detritus and nutrients from the water flowing through and around them.

Flows decline gradually along the length of the Panhandle and Delta as water is dispersed laterally into an ever-widening area and increasing quantities of water are lost via evaporation from open water surfaces and through transpiration by plants. These processes result in a gradual increase in the concentrations of total dissolved salts along the length of the Panhandle and Delta; electrical conductivity values at the Chief's island sites were approximately double those measured at the Upper Panhandle zone.

Water quality characteristics of Focal Area 4

In areas that receive continual inflows of water, dissolved oxygen levels normally remain high as a result of diffusion from the atmosphere and from photosynthesis by submerged plants. With increasing distance down the length of the Okavango Delta, it appears that hippos perform a more important role in keeping channels open by breaking down or removing the packed plant material, helping the lateral spread of water and creating new aquatic habitats. There are also considerable quantities of epiphytic green and blue-green algae present in the flooded grassland areas. The stems and leaves of submerged vegetation also provide support for a wide variety of small invertebrate organisms and act as efficient filters for the water passing through them.

Several shallow (< 3 metres deep) lagoons occur in the vicinity of Chief's Island and most of these lagoons support dense populations of water lilies. The floating water lily leaves often cover over 40% of the total water surface and act as very efficient "stabilizers," preventing wind mixing of the surface waters and thereby reducing the aeration of the lagoon waters. In these lagoons, dissolved oxygen levels are often below 50% saturation. The oxygen produced by photosynthesising aquatic plants and epiphytic algae appears to be insufficient to completely counter-balance the oxygen consumed by decomposition of the organic detritus that accumulates at the bottom of these lagoons.

When flood waters enter the terrestrial grasslands at the onset of flooding, the terrestrial species die down and, in the process of decomposing, cause a rapid loss of dissolved oxygen whilst liberating considerable quantities of nutrients and other salts. These, in turn, are rapidly taken up by the new growth of submerged and emergent aquatic plants that take advantage of the newly created flooded habitats. In this process, the concentrations of total dissolved salts in the water increases and reaches levels that are approximately double those recorded in the Panhandle zone. The water is also stained a light brown or yellowish colour by the presence of dissolved humic compounds that have been derived from the decomposing vegetation. The combination of aquatic plants and epiphytic algae growing on their stems and leaves results in high levels of dissolved oxygen via photosynthesis.

In the Chief's Island zone, several saline pools occur on islands. In these systems, the water is becoming progressively more saline as salts accumulate due to the evaporative pumping effects of the terrestrial vegetation on the islands. In addition, the water in these pools is stained a dark brown colour from dissolved humic compounds and pH values are often slightly acidic.

The average chemical analysis results for five sampling sites evaluated in the Chief's Island zone are shown in Table 2.5, together with the few data that area available from three earlier studies (Hutton and Dincer 1976; Sawula and Martins 1991; McCarthy and Ellery 1994). The data from the present study show that this entire zone has relatively low levels of the nutrients nitrogen and phosphorus, with both phosphorus and nitrogen concentrations below the level of detection for the analytical technique used. The concentrations of major ions are slightly higher than those recorded from the Lower Panhandle zone and indicate a very slight concentration effect along the length of the Panhandle and Okavango Delta.

Once again, the cationic water chemistry is dominated by calcium ions, followed in dominance by magnesium, sodium, and potassium. The dominant anions are carbonate-bicarbonate, followed by chloride. Sulphate ions were usually below detection levels of the analytical technique used. A few earlier analyses showed the presence of moderate amounts of silica. The proportions of the major ions to one another continue to reflect the geological origin of the Okavango River water and are similar to those recorded from sites further upstream in Namibia (Table 2.1) and the Upper Panhandle (Table 2.2).

Additional sampling sites on the lower Boro River

In addition to the four focal areas that were sampled June 5-21, 2000, two sets of samples and measurements were collected at a fifth site on the lower Boro River by a few local members of the AquaRAP team. Despite the reduced sampling intensity, these sites can be referred to as the fifth focal area.

General aquatic characteristics of Focal Area 5

Downstream from Chief's Island, the Boro River provides the major outflow from the Okavango Delta and its waters enter the Thamalakane River that flows past the town of Maun, the capital of Ngamiland District where the Okavango Delta is situated. According to oral history and earlier published records (e.g., Smith 1976), the Boro River became the major outflow to Maun in the 1950s. Since these earlier times when high flows were regular and reliable, river flows have declined and, frequently, have stopped altogether. The Boro River is now regarded as a seasonal or episodic river, where flows only occur if upstream flooding occurs.

A dredging operation was conducted along a section of the lower Boro River in the 1970s as a means to increase the outflow of surface water from the Okavango Delta to the Thamalakane River and the town of Maun, as well as to supply water required for the diamond mining operations at Orapa. The straightening, bunding (by raising and protect-

Table 2.5. Water quality analyses for sites in the Chief's Island and Lower Boro River Sectors of the Okavango Delta in Botswana. Sources of data are given in footnote to the table. All values in milligrammes per litre, except pH, electrical conductivity, Secchi Disc and Dissolved oxygen. E.C. (µS/cm) = Electrical Conductivity in microSiemens per centimetre; Secchi Disc (m) = A measure of water transparency in metres; Diss. O_2 (%) = Dissolved oxygen in percentage saturation. - = No data available. Month = Month(s) when samples collected or field measurements made.

Reference:	#1	This Study	This Study	This Study	This Study	This Study	#2	#3	This Study
Description of Sampling Site:	Island fringe near Xaxaba Lagoon	Narrow channel downstream from Xaxaba Lagoon	Main channel of Boro River (Near Parks Camp)	Centre of lagoon opposite Oddball's Camp	Fringe of lagoon behind Oddball's Camp	Surface of lagoon behind Delta Camp	Lower Boro River near Maun	Lower Boro River near Maun	Banks of lower Boro River along dredged section of channel near Maun
Sample Nos.	-	OK28	OK29	OK31	OK33	OK34	-	-	-
Month *	Aug. 1992	Jun. 2000	Jun. 2000	Jun. 2000	Jun. 2000	Jun. 2000	Aug. 1975	Apr. - Sep.	Jun. 2000
pH	-	6.5	6.5 - 6.6	6.4	6.3	6.2	-	7.7	5.6 - 7.0
E.C. (µS/cm)	90 - 110	66	68 - 70	67	68	68.2	-	95	104.5
Secchi Disc (m)	-	Bottom (1.9)	2.5	Bottom (1.8)	Bottom (1.8)	Bottom (1.8)	-	-	-
Diss. O_2 (%)	-	75	75 - 85	36	45	52	-	-	-
Na	6 - 8	3.7	3.5	-	-	-	6.5	5.9	6.5
K	6 - 7	1.7	1.7	-	-	-	4.3	3.3	1.4
Ca	8	5.2	6.7	-	-	-	9.0	6.1	9.46
Mg	2	1.4	1.2	-	-	-	2.0	1.7	3.2
SiO_2	44 - 47	-	-	-	-	-	35	38	-
Cl	-	0.3	0	-	-	-	< 1	1.1	0.23
SO_4	-	0	0	-	-	-	< 1	< 5	0
CO_3+HCO_3	52 - 53	38	38	-	-	-	-	44	71.9
Inorg. N	-	0	0	-	-	-	-	-	0
Total P	-	0	0	-	-	-	-	-	0

Data sources/references: #1: McCarthy and Ellery (1994); #2: Hutton and Dincer (1976); #3: Sawula & Martins (1991).

ing the river banks) and dredging (deepening) of the original channel have reduced the fringing wetland areas around the current channel.

Two sampling sites were selected along the dredged portion of the lower Boro River. The channel bottom at both sites was observed to consist mainly of unconsolidated sand, with small pockets of mud and silt. The majority of the aquatic vegetation in the channel is located along the recently flooded fringes and in areas where organic sediments and silt have accumulated. The sandy portions of the channel support little or no aquatic vegetation. Flow rates varied from less than 0.1 m^3/sec during periods of low flow, to approximately 0.6 m^3/sec during high flows (DWA files, Maun).

Water quality characteristics of Focal Area 5

Surface water temperatures at the two sampling sites along the lower Boro River varied from 17°C to 18°C, which is considered normal for this time of year. The pH values ranged from 5.6 to 7.0 indicating the water to be neutral to slightly acidic (Table 2.5). The electrical conductivity (E.C.) values averaged 104.5 µS/cm, indicating a somewhat higher concentration of total dissolved salts than that recorded at the other focal areas. This higher dissolved salt concentration is most probably caused by evaporative concentration as well as evapo-transpiration by trees and other vegetation lining the river channel.

The average chemical analysis of samples collected at the two sampling sites is shown in Table 2.6. The cations are

Table 2.6. Average results for water quality analyses of samples collected at two sites along the lower Boro River, Okavango Delta, Botswana (June 2000).

Ca	Mg	Na	K	SO_4	Cl	CO_3+HCO_3	N	P
9.46	3.2	6.5	1.4	0	0.23	71.9	0	0

once again dominated by calcium, followed by magnesium, sodium and potassium, whilst bicarbonate is the dominant anion, followed by chloride. Sulphate concentrations were below the limit of detection of the analytical technique used.

TRAINING ASPECTS

Throughout the AquaRAP Expedition, close attention was paid to ensuring that recent graduates, researchers, and officials from the Botswana Government Departments were fully involved in all aspects of the sampling and information interpretation. This aspect was considered to be extremely important as it provided the younger students and researchers with an excellent opportunity to interact closely with experienced field ecologists and benefit from their expertise and experience.

At each sampling site, scientists demonstrated the use of the various measurement techniques and instruments and stressed the importance of detailed field observations. Each member of the water quality group had the opportunity to use all of the field instruments and each participated in the recording of field data.

All interpretations of field measurements and observations were explained to the scientists and students forming the water quality team. An informal discussion and "report back" was held at the completion of sampling at each of the four focal areas, so that the information, insights, and possible problem issues identified at the focal area could be shared with all of the expedition members. This also allowed team members to identify linkages with the observations and measurements made by each of the other groups.

OVERALL IMPRESSIONS OF WATER QUALITY ISSUES AND POTENTIAL CONSERVATION CONCERNS

Arising from the field measurements and observations of water quality, as well as discussions with other expedition members and local tourism operators, several impressions and potential areas of concern can be recorded. Each of these issues is discussed briefly below.

Garbage disposal practices in the Upper Panhandle zone

Field observations in the Upper Panhandle zone revealed several sites near the towns of Shakawe and Mohembo where domestic garbage appears to have been dumped in unsightly heaps at varying distances from the bank of the Okavango River. It would appear that no attempt has been made to prevent this garbage from being washed into the Okavango River during floods, or to dispose of the material in suitable disposal sites. This type of garbage disposal practice is contrary to normally accepted methods of garbage disposal and cannot be condoned by the local authorities. The disposal sites are extremely unsightly and have the potential to contaminate nearby water supplies.

Contamination by agricultural chemicals in the Lower Panhandle zone

A 25-hectare area of irrigated agriculture is located on the west bank of the Okavango River a short distance downstream from the town of Shakawe. Irrigation water is drawn from a side channel of the Okavango River and a variety of vegetable crops grown for the local market are irrigated by a centre-pivot overhead spray system. Discussions with the farm manager and visiting irrigation specialists revealed that there are plans to expand the irrigated area to approximately 125 hectares. Clearly, this would cause a significant increase (approximately 5-fold) in the volume of water drawn off for irrigation each year.

The irrigation pump house is located a few metres from the channel bank and the general site appears to be in need of improved maintenance and should be cleaned up. The mixing tank for agro-chemicals (various fertilizers and pesticides) is located alongside the pump-house and there are clear signs that chemicals have been spilt onto the ground and washed into the channel. No attempt appears to have been made to prevent the inflow of these chemicals to the channel and, whatever their nature, these chemicals will have a negative effect on the water quality of the nearby channel. In addition, some of the water used for irrigation will also enter the local ground water and flow back towards the river channel. Given the sandy soils of this area, this return flow can be expected to occur rapidly. If the proposed plans to expand the irrigated area are approved, the adverse effects can be expected to increase.

Channel clearing operations

Formal channel clearing operations are carried out at several points in the Okavango Delta such as near Guma Lagoon, and along the Pete Smith Channel that links the Maunachira Channel to the Xakanaxa and Gadikwe Lagoon systems. These channel clearing operations have the obvious benefit of enabling and facilitating transportation and communication. However, the cleared plant material (usually papyrus plants) is simply dumped at the sides of the channels and left to decay. The decay and decomposition process will allow plant nutrients to return to the water, leading to a deterioration in water quality through eutrophication, and this could lead to enhanced growth of aquatic plants in the immediate vicinity of these dumps. Possible adverse water quality effects will be very localized and are unlikely to cause widespread water quality problems because of the rapidity with which the remaining aquatic plants would be able to take up any available nutrients.

However, field observations suggest that the clearing of papyrus plants that block channels may only provide a temporary respite. The hydraulic conditions along many of these channels are favourable for papyrus growth and it seems that their continued growth is almost inevitable. Therefore, it would appear that if a decision were taken to continue with these channel-clearing operations, it would be necessary to continue this indefinitely. In turn, this could lead to a continual release of plant nutrients (especially nitrogen and phosphorus) from the cleared plant material. The obvious adverse effects that these "additional" nutrients could have should be weighed carefully against the advantages to be gained by increasing boat access through cleared channels.

Nutrients in seepage from tourist camps

All of the tourism operators in the Okavango Delta have located their establishments and tourist accommodation close to the main river channels or lagoons. Whilst this has the obvious advantage of enabling visitors to view the exceptional scenery of the areas concerned, there is a strong possibility that nutrients and salts from sanitation systems are entering the aquatic ecosystem. All of the tourism operations visited make use of septic tanks and soak-away systems in the predominantly sandy soils of the area. These soils are highly permeable and will easily allow salts and nutrients (especially nitrogen) to pass through them. It is strongly recommended that the authorities ensure that all such septic tank sanitation systems are properly designed and constructed so as to promote effluent flows away from the open water areas.

Invasive aquatic plants

The invasive aquatic plant *Salvinia molesta* (Kariba Weed) has long been known to occur in the Paradise Pools area of the Moremi zone in the Okavango Delta. The Botswana Department of Water Affairs has conducted a long-term programme of biological control against this weed and has successfully restricted the spread of this plant in other parts of the Okavango Delta. The programme co-ordinators should be congratulated for their efforts to ensure the very welcome success of this control programme and it is strongly recommended that the programme should be continued in the future. Failure to check the spread of this weed would allow it to colonize other pool, lagoon and channel areas with enormous adverse consequences for the ecological structure and functioning of the Okavango Delta ecosystem.

In particular, *Salvinia molesta* mats are known to cause deoxygenation of the underlying waters, causing adverse water quality effects that effectively eliminate most plant and animal species or prevent them from entering such areas. The deoxygenated water beneath *Salvinia molesta* mats has also been shown to act as a "chemical barrier" to the up- and downstream movement of fish and aquatic insects.

Unrestricted use of motorboats

Boats are an essential form of transportation throughout the Okavango Delta. However, during the AquaRAP Expedition, participants gained the impression that the use of motorboats was not restricted except in the area around Chief's Island. This impression was based on observations that motorboats were widely used by tourist operators, local residents and commercial fishermen, as well as by Botswana Government authorities, in all areas of the Okavango Delta.

Nocturnal motorboat traffic was relatively frequent in the Upper and Lower Panhandle zone. No evidence of safety lights was noted. In view of the large population of hippos and crocodiles in the Okavango Delta, it can be concluded that the use of boats at night poses a serious risk for boat users, who also run the risk of fatal boat collisions. Even in areas such as Chief's Island, where the use of motorboats is restricted, motorboats were seen on several occasions.

Motorized boat traffic has two important adverse effects on water quality, namely the emission of fuel and fuel wastes in the cooling water stream, and accelerated "stirring" of sediments in shallow areas. Both of these aspects lead to a loss of dissolved oxygen and cause a reduction in water quality; in addition, the petrol and oil components of fuel are toxic to aquatic life. These aspects are especially important in those areas that experience frequent boat traffic and can be particularly accentuated in areas where boats land for loading and refuelling.

It is strongly recommended that the Botswana Government set in place a series of principles and policies to control the number and types of motorboats used in the Okavango Delta, as well as the areas in which such boats may be used. Motorboats should not be allowed to enter sensitive ecological areas such as Gadikwe Lagoon, except for official business. Similarly, motorboat traffic along the main river channel in the Upper Panhandle zone should be carefully controlled, and nocturnal boat traffic should be completely prohibited. In particular, boat types (shallow, flat hull versus deep-vee hull), motor sizes, and travel speeds need to be restricted to reduce the erosive effects on exposed sandbanks and islands. These island sites contain some of the very few known breeding sites of the African skimmer, a rare and endangered bird species. The narrow and shallow channels that are characteristic of the lower reaches of the Okavango Delta are also particularly susceptible to damage from motorboats and it is extremely dangerous to antagonize the local hippo populations in this area. Motorboat use in this region should be restricted completely.

Possible hydro-carbon contamination near boat launching points

There are a large number of boat launching points in the Okavango Delta; these are located close to tourism operations and fisheries sites. At each site, boats and motors are cleaned and serviced, and fuel tanks are re-filled. Inevitably, accidental spills of oil and fuel occur and this fuel ends up in the water. This spilt fuel is toxic to many forms of aquatic life and, as a result, could cause unacceptable ecological changes in the areas surrounding these boat launching points.

It is strongly recommended that the Botswana authorities regulate the number of such boat launching points and provide firm guidelines for all boat servicing and refueling activities. This will help to reduce or eliminate the risks associated with spilt fuel and oil.

Possible pesticide contamination from Tsetse Fly control operations

There has been considerable controversy surrounding the earlier Tsetse Fly control programme that was conducted in the Okavango Delta. Accusations and claims of possible ecological damage caused by the use of insecticides continue to the present day. For the most part, these accusations are based on incomplete or incorrect information and emotional rhetoric.

During this AquaRAP Expedition to the Okavango Delta, no attempt was made to carry out specialized water quality sampling and analyses to detect pesticide residues or break-down products due to the short-term nature of the study. Therefore, the expedition was not able to provide any substantive evidence for or against the presence of pesticide compounds, or their possible effects on ecosystem components. It must be stressed that casual, short-term observations of the abundance and diversity of ecosystem components such as aquatic birds do not provide sufficient evidence on which to base any deductions regarding the possible effects of pesticides in the Okavango Delta.

RECOMMENDATIONS FOR FUTURE INVESTIGATIONS

Arising from the field studies carried out during this short AquaRAP Expedition to the Okavango Delta, and the conclusions drawn as to the major water quality issues and concerns, a series of recommendations can be made for future investigations.

Investigate the seasonal changes in water quality

Very little information is available on the seasonal changes in water quality that take place along the length of the Okavango Delta. Information on the natural range of variation of important water quality parameters will provide a firm basis for management decisions regarding the possible causes of these changes and the potential influence of human activities. In addition, this information will provide key insights into the likely consequences of water abstraction from the Okavango Delta.

Evaluate the impacts of motorboat traffic

As described above, extensive use is made of motorboats in almost every area of the Okavango Delta. This traffic poses a number of potential threats to the structure and functioning of this unique wetland ecosystem that is also the core of Botswana's tourism industry. Whilst it is important to carefully regulate the use of motorboats within the Okavango Delta, it is also important that any control be soundly based on firm evidence. Therefore, it is considered to be very important that accurate information should be collected on the extent and frequency of motorboat use, together with details of the types of boats and motors, frequency and duration of trips, areas most frequently visited, the types of boat users concerned, and details of their launching/docking sites. This will allow the Botswana authorities to draw up a coherent set of policies and controls to regulate the use of motorboats and minimize their adverse consequences on the Okavango Delta.

Evaluate the evidence for pesticide residues

It is important that an accurate picture be obtained as to the situation regarding the possible presence of pesticide residues in different components of the Okavango Delta ecosystem. This will require a carefully structured sampling and analysis programme to determine whether or not pesticide residues are indeed present and, if so, the degree to which they pose an ecological threat to the structure and functioning of the Okavango Delta ecosystem components. This information will provide extremely useful evidence to answer the many uninformed claims of lingering, widespread ecological damage caused by earlier Tsetse Fly control programmes.

Recently, a second large-scale Tsetse Fly control programme using Deltamethrin was conducted in the Okavango Delta in June 2001. Further (repeated) Deltamethrin spraying will likely be carried out in future months. Whilst this synthetic pyrethroid insecticide is reported to be extremely effective on Tsetse Fly, it could also have adverse effects on other invertebrate, and possibly vertebrate, fauna in the Okavango Delta. This spraying programme should be monitored carefully, using the water quality and other data presented in this AquaRAP report as a baseline.

Evaluate the potential impacts of nutrients and salts from sanitation systems

There is considerable uncertainty surrounding the issue of whether or not the septic tank sanitation systems at tourism camps and lodges are contributing nutrients and salts to the Okavango Delta. A structured sampling and analysis programme can resolve this issue once and for all across the range of tourism facilities located in the Okavango Delta. In addition, it would be desirable for firm guidelines to be produced that aim to help select appropriate sites, optimize system designs, and guide the construction of septic tank soak-away systems so that the potential adverse effects can be minimized.

Evaluate the potential impacts of irrigation return flows

Based on field observations, the existing irrigation scheme downstream from Shakawe poses a few small-scale water quality problems for the Okavango River. It is important that these observations be verified, particularly if the irrigation scheme also makes use of pesticides and soil conditioners. If the existing plans to expand this irrigation scheme from 25 hectares to 125 hectares are approved, it is very likely that additional adverse effects would arise. A careful programme of ground and surface water sampling and analysis, combined with a local soil survey, would provide appropriate guidance on the potential effects that such activities could have on the Okavango River.

Evaluate the sediment-water exchange of nutrients and salts

Very little information is available on the extent and importance of the exchange of nutrients and salts between the water and sediments in the Okavango Delta. These exchange processes are known to be important in other wetland ecosystems and it can be expected that they control much of the cycling and retention of nutrients within the ecosystem. A programme of experimental field measurements in selected ecosystem zones (cut-off lagoons, flow-through lagoon, open channels) would provide extremely useful information upon which to base any management decisions regarding the sensitivity and vulnerability of these ecosystem components.

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Chapter 3

A Brief Commentary on Okavango Delta Micro-Crustacea

Rob C. Hart, Nancy A. Rayner, and Hilary Masundire

INTRODUCTION

From June 5-22, 2000, micro-crustaceans were studied as part of a rapid biodiversity survey (AquaRAP) of the aquatic resources of the Okavango Delta system in northwestern Botswana. Micro-crustaceans comprise a wide variety of small animals including water-fleas (cladocerans), copepods (a diverse group to which the legendary "Cyclops" belongs), and seed shrimps (ostracods), among others. Adult sizes generally range from about 0.2 mm to around 2 mm. These animals inhabit a range of different aquatic habitats – from open water (planktonic forms) to bottom sediments and surfaces (burrowing or surface-dwelling epibenthic forms). Well-vegetated swamp ecosystems are understandably dominated by "epiphytic" taxa – organisms intimately associated with aquatic hydrophytes.

The majority of micro-crustaceans are fine particle feeders, living off live organisms (plant or animal) and/or dead organisms with (or without) their associated decomposing microbes. Feeding modes include the filtration of suspended food particles, or the scraping of mostly single-celled organisms like algae and bacteria attached to various inorganic (sand, mud) and/or organic surfaces (living plants), through to raptorial predation. Many micro-crustaceans rely on detritus, and accordingly serve an important nutrient regeneration function in wetlands. And in turn, they serve as vital nutritional sources ("protein packages") for larger animals, including juvenile fishes in particular.

The small size and limited taxonomic knowledge/expertise for this group limits the practicality of including micro-crustaceans in RAPid inventories. However, their ecological significance warranted inclusion at least of the best-known subset – the planktonic forms. The primary objective of the AquaRAP Expedition was to collect scientific data on the diversity and status of the aquatic ecosystems of the Okavango Delta in order to make recommendations regarding the conservation and management of these critical resources.

METHODS

Samples of planktonic animals were collected (by RCH and HM) with a 53 µm mesh aperture plankton net raised vertically through the water column (sometimes towed horizontally) at various focal area sites during the June 2000 Okavango AquaRAP survey. Appendix 1 gives descriptions and locations of the relevant sampling sites (OK1: 1-37). Planktonic rather than epiphytic or epibenthic forms were specifically targeted in view of their better known taxonomy and more reliable identification. Samples were preserved with formaldehyde (10% final strength) and later identified in Durban (by NAR).

RESULTS

The samples yielded a considerable diversity of micro-crustacean species. The following is a list of the copepod and cladoceran micro-crustaceans collected according to site localities surveyed during the June 2000 Okavango AquaRAP. Table 3.1 summarizes the distributional ranges of specific taxa across sampling sites.

OK1-2a Permanent quiet water, weeded lagoon, northern panhandle. 7.06.2000

Cladocera:

Euryalona colleti (Sars, 1895)

OK1-3 Permanent off-channel lagoon connected to Okavango River. 8.06.2000

Copepoda:

Mesocyclops major Sars, 1927

Microcyclops varicans (Sars, 1863)

Table 3.1. Systematic list of crustacean zooplankton collected during the Okavango AquaRAP survey in June 2000, indicating sites at which named taxa were recorded. See Appendix 1 for descriptions and locations of sampling sites.

TAXON	SITES PRESENT
COPEPODA	
Cyclopoida	
Eucyclops euacanthus (Sars, 1909)	OK1-13; -20; -30; -31
Eucyclops (Afrocyclops) gibsoni (Brady, 1904)	OK1-24
Eucyclops serrulatus (Fischer, 1851)	OK1-9
Eucyclops n.sp.?	OK1-30
Mesocyclops major Sars, 1927	OK1-3; -31; -36
Microcyclops ?crassipes (Sars, 1927)	OK1-23
Microcyclops rubelloides Kiefer, 1952	OK1-7; -20; -21; -24; -31
Microcyclops varicans (Sars, 1863)	OK1-3
Paracyclops ?fimbriatus (Fischer, 1853)	OK1-14; -22
Thermocyclops neglectus (Sars, 1909)	OK1-9; -10; -23; -24; -26; -36
Calanoida	
Tropodiaptomus capriviensis Rayner, 1994	Near OK1-26
Tropodiaptomus kraepelini (Poppe & Mrázek, 1895)	OK1-36
Tropodiaptomus longispinosus	OK1-22
Tropodiaptomus schmeili	OK1-27
CLADOCERA	
Alona affinis (Leydig, 1860)	OK1-10; -22; -30
Bosmina longirostris (Muller, 1785)	OK1-9; -10; -21; -22; -30
Chydorus sphaericus (Muller, 1785)	OK1-10
Diaphanosoma brachyurum (Lieven, 1848)	OK1-9; -22; -27; -36
Echinisca capensis Sars, 1916	OK1-36
Echinisca tenuicornis (Jurine, 1820)	OK1-10
Euryalona colleti (Sars, 1895)	OK1-2; -9
Graptoleberis testudinaria (Fischer, 1848)	OK1-30
Moina brachiata (Jurine, 1820)	OK1-10
Moina reticulata (Daday, 1905)	OK1-24; -26; -36
Pleuroxus aduncus (Jurine, 1820)	OK1-21; -30; -36
Simocephalus serrulatus (Koch, 1841)	OK1-20; -22; -31; -36

OK1-7a - e Permanent lagoon roughly opposite Xaro. 9.06.2000
Copepoda:
Microcyclops rubelloides Kiefer 1952

OK1-9d Flooded grassy levy weakly connected to Gumu lagoon (night sample). 11.06.2000
Copepoda:
Eucyclops serrulatus (Fischer, 1851)
Thermocyclops neglectus (Sars, 1909)
Cladocera:
Diaphanosoma brachyurum (Lieven, 1848)
Bosmina longirostris (Muller, 1785)
Euryalona colleti (Sars, 1895)

OK1-10 Guma lagoon, permanent water. 11.06.2000
Copepoda:
One C5 male calanoid
Two *Microcyclops* species unidentified
Cladocera:
Bosmina longirostris (Muller, 1785)
Alona affinis (Leydig, 1860)
Chydorus sphaericus (Muller, 1785)

OK1-10d Guma lagoon permanent water (daytime sample). 11.06.2000
Copepoda:
Thermocyclops neglectus (Sars, 1909)
Cladocera:
Moina brachiata (Jurine, 1820)
Bosmina longirostris (Muller, 1785)
Echinisca tenuicornis (Jurine, 1820)

OK1-13b Lagoon, permanent water (roughly opposite Seronga) (net haul in Trapa bed). 12.06.2000
Copepoda:
Eucyclops euacanthus (Sars, 1909)

OK1-14 Gadikwe Lagoon, (permanent heronry). 12.06.2000
Copepoda:
Paracyclops ?fimbriatus (Fischer, 1853)

OK1-20b Lagoon through-flow channel (Xakanaxa). 15.06.2000
Copepoda:
Microcyclops rubelloides Kiefer, 1952
Eucyclops euacanthus (Sars, 1909)
Cladocera:
Simocephalus serratus (Koch, 1841)

OK1-21 Xakanaxa "hippo-catch" gill net site. 14.06.2000
Copepoda:
Microcyclops rubelloides Kiefer, 1952
Cladocera:
Bosmina longirostris (Muller, 1785)
Pleuroxus aduncus (Jurine, 1820)

OK1-22c Cladocerans dominant. Xakanaxa. 15.06.2000
Copepoda:
Tropodiaptomus longispinosus Einsle, 1971
Paracyclops fimbriatus (Fischer, 1853)
Cladocera:
Diaphanosoma brachyurum (Lieven, 1848)
Simocephalus serratus (Koch, 1841)
Bosmina longirostris (Muller, 1785)
Alona affinis (Leydig, 1860)

OK1-23 Xakanaxa. 15.06.2000
Copepoda:
Thermocyclops neglectus (Sars, 1909)
Microcyclops ?crassipes (Sars, 1927)

OK1-24 Xakanaxa. 15.06.2000
Copepoda:
Microcyclops rubelloides Kiefer, 1952
Thermocyclops neglectus (Sars, 1909)
Eucyclops (Afrocyclops) gibsoni (Brady, 1904)
Cladocera:
Moina reticulata (Daday, 1905)

OK1-26 Recently flooded mopane depression. 16.06.2000
Copepoda:
One male C5 calanoid
Thermocyclops neglectus (Sars, 1909)
Cladocera:
Moina reticulata (Daday, 1905)

OK1 – unnumbered (near 26). Isolated, rain-filled "scum pool" hollow in Mopane woodland. 16.06.2000
Copepoda:
Tropodiaptomus capriviensis Rayner, 1994

OK1-27 Jessie's pool, flooded depression, copepods very numerous. 16.06.2000.
Copepoda:
Tropodiaptomus schmeili (Kiefer, 1926)
Cladocera:
Diaphanosoma brachyurum (Lieven, 1848)

OK1-30a Okavango River channel near Oddballs. 18.06.2000
Copepoda:
Eucyclops euacanthus (Sars, 1909)

OK1-30b Quiet lily pond near Oddballs. 18.06.2000
Copepoda:
Eucyclops euacanthus (Sars, 1909)
Eucyclops n.sp.? very heavily armoured, inner setae very long
Cladocera:
Bosmina longirostris (Muller, 1785)
Pleuroxus aduncus (Jurine, 1820)
Graptoleberis testudinaria (Fischer, 1848)
Alona affinis (Leydig, 1860)

OK1-31 Okavango side channel, flowing vegetated. 19.06.2000
Copepoda:
Eucyclops euacanthus (Sars, 1909)
Mesocyclops major Sars, 1927
Microcyclops ?rubelloides Kiefer, 1952
Cladocera:
Simocephalus serrulatus (Koch, 1841)

OK1-36a Floodplain wetland, rainfilled, tenuous connection to Okavango River (Oddballs camp) airstrip. 20.06.2000
Copepoda:
Tropodiaptomus kraepelini (Poppe & Mrázek, 1895)
Mesocyclops major Sars, 1927
Thermocyclops neglectus (Sars, 1909)
Cladocera:
Diaphanosoma brachyurum (Lieven, 1848)
Simocephalus serrulatus (Koch, 1841)
Moina reticulata (Daday, 1905)

OK1-36b Rain-filled wetland - floodplain location. 20.06.2000
Copepoda:
Tropodiaptomus kraepelini (Poppe & Mrázek, 1895)
Mesocyclops major Sars, 1927
Thermocyclops neglectus (Sars, 1909)
Cladocera:
Simocephalus serrulatus (Koch, 1841)
Echinisca capensis Sars, 1916

OK1-36c Copepods dominant. Rain-filled wetland in floodplain, Oddballs Airfield. 20.06.2000
Copepoda:
Tropodiaptomus kraepelini (Poppe & Mrázek, 1895)
Mesocyclops major Sars, 1927
Cladocera:
Diaphanosoma brachyurum (Lieven, 1848)
Simocephalus serrulatus (Koch, 1841)
Echinisca capensis Sars, 1916
Pleuroxus aduncus (Jurine, 1820)

DISCUSSION

Several notable points emerge from this cool season survey:

1. Strong faunal affinities are apparent between the ‘entomostracan’ fauna (a collective grouping of micro-crustaceans) of the Okavango Delta and that of the Bangweulu swamps, a considerable distance away in the Luapula River basin of Zambia. Given the sparse collecting effort previously devoted to micro-crustaceans in the Okavango Delta, the absence of obviously new taxa is notable. All taxa encountered - apart from a possible new species of *Eucyclops* collected at OK1-30(b) - are attributable to formerly described species. However this interpretation merits qualification with recognition that morphological similarities may not be matched in respect to molecular genetic attributes and identities.

2. All taxa collected from permanent waters of the Okavango swamps, or waters seasonally connected thereto, are small-bodied. This logically reflects the severe size-selective impact of fish predators on this assemblage. The only large-bodied taxa (notably calanoid copepods) were restricted to isolated and/or ephemeral waters. The persistence or demise of such large-bodied taxa in waters subjected to seasonal flooding and colonization by cohorts of opportunistic juvenile fish from adjacent permanent swamp and lagoon habitats merits consideration.

3. The former observation (see 2 above) has profound practical implications for further studies on the biodiversity and functional ecology of the Okavango Delta. Coarse-meshed nets cannot be used to collect ‘entomostracans’ without both seriously under-representing the taxonomic diversity of this faunal assemblage, and grossly deflating its importance in the ecological structure and functioning of this diverse wetland ecosystem.

4. The occurrence of only one genus of calanoid copepods (*Tropodiaptomus* - Diaptomidae: Diaptominae) is a curious paradox in relation to predation refugia (see 2 above). Representatives of this subfamily of diaptomids generally occupy permanent waters, while those of the sister subfamily Paradiaptominae are more characteristic of ephemeral waters, in view of their general ability to produce resting eggs.

5. Not surprisingly, a considerable proportion of the water-fleas (cladocerans) collected are characteristically epiphytic or epibenthic rather than truly planktonic elements. Parallels in this respect may apply in respect of the cyclopoid copepods– but information in respect of the taxa recorded is presently insufficient to corroborate this conclusion.

Chapter 4

Freshwater Invertebrates of the Okavango Delta, Botswana

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CHAPTER SUMMARY

Selected invertebrate taxa, including Hirudinea, Decapoda, Heteroptera, Ephemeroptera, Odonata, Gastropoda, and Bivalvia, were collected semi-quantitatively in four focal areas of the Okavango Delta. The invertebrate fauna was found to be relatively uniform in all four areas and there was little evidence that it changed as habitat diversity increased from the Panhandle to the seasonal part of the Delta. A largely different fauna was found in ephemeral rainpools isolated from the deltaic habitats in the Moremi and Chief's Island areas. More species would probably have been recorded had the expedition taken place during the summer months, i.e. November to March, when the water would have been warmer and the depth shallower. Several new species and new records for the Delta were found.

INTRODUCTION

Few studies have been made of the aquatic macro-invertebrate fauna of the Okavango River Delta (e.g. Appleton 1979, Bilardo and Rocchi 1987, Brown et al. 1992, Curtis 1997). The 2000 AquaRAP survey thus provided an opportunity to assess the species richness of selected components of this fauna using semi-quantitative sampling techniques and to look for associations between species richness and habitat heterogeneity in four focal areas within the Panhandle and Delta proper. Habitat heterogeneity, as determined by hydrological processes and vegetation, is lowest in the Upper Panhandle but increases as one moves towards the seasonal part of the Delta and one might therefore expect the species richness of invertebrates to show a similar trend.

It should be emphasized that because the survey was carried out in June, one of the cooler winter months, species with seasonal life-cycles or which reach their greatest population densities in summer (November to March) might have become scarce or have disappeared and would not have been recorded. The species richness of taxa such as the Odonata (dragonflies) and Ephemeroptera (mayflies) would certainly have been higher had the expedition taken place earlier in the year.

METHODS

Invertebrate sampling was conducted in four focal areas within the Okavango Delta: Upper Panhandle (UPH), Lower Panhandle and Guma Lagoon (LPH), Moremi Game Reserve (MGH), and Chief's Island (CHI) (see Map), from 5-22 June 2000. Detailed descriptions of the 37 AquaRAP geo-reference sites and the macro-invertebrate sampling localities are given in Appendices 1 and 2. Additional information on water quality, flow dynamics, dissolved oxygen (DO) concentrations (mg/l), electrical conductivity (EC; S/cm) and pH of each geo-reference site is provided in Chapter 2 (this volume). A description of the aquatic vegetation of each site is provided in Appendix 6.

Macro-invertebrates were collected from marginal, floating and submerged vegetation using a long-handled scoop net (2 mm mesh) and a bag net (1 mm mesh) for a fixed time, usually 30 minutes, by the same two people (i.e. CCA, LEA at the Upper Panhandle (UPH) and Lower Panhandle (LPH) sites and CCA, BAC at Moremi Game Reserve (MGR) and Chief's Island (CHI) sites). A third person was on hand with specimen bottles containing 70% ethanol for arthropods and water for molluscs and leeches which were removed manually using forceps. The latter were relaxed overnight in petri-dishes containing river water and a few menthol crystals and preserved the next morning. Bottom sediments in *Cyperus papyrus* and grass (*Miscanthus* / *Echinochloa*) swamps were sampled with the scoop net and a small van Veen grab with a bite of 300 cm^2 (20 x 15 cm). This was used at Xakanaxa (MGR) and was subsequently lost. Sandbanks were sampled by removing and sieving the sediment within a 1 m quadrat to a depth of 150 mm and replicated several times in water up to 50 cm deep.

Grab and quadrat samples were expressed as numbers of individuals collected/m^2. Net catches were expressed as the number of specimens of a species collected at a site by two people per 30 minutes. A scoring system was used to estimate the relative abundance of the taxa sampled so as to allow inter-site comparisons. This system is explained in Appendix 3.

Taxonomic Groups Targeted

Seven taxonomic groups (three at class level and four at order level) were targeted because they are sufficiently well known taxonomically to be identified to species level in most cases.

- Hirudinea – (Phylum Annelida: leeches): identified by CCA using an unpublished key drawn up by the late J.H. Oosthuizen (Pretoria University);
- Gastropoda – (Phylum Mollusca: snails): identified by CCA and selected species confirmed by D.S. Brown (The Natural History Museum, London);
- Bivalvia – (Phylum Mollusca: mussels): identified by CCA;
- Decapoda – (Class Crustacea: crabs and shrimps): identified by B. Cook (University of Stellenbosch);
- Heteroptera – (Class Insecta: waterbugs): identified by P.E. Reavell (University of Zululand);
- Ephemeroptera – (Class Insecta; mayflies); larvae and adults identified by H. Barber-James (Albany Museum);
- Odonata – (Class Insecta; dragonflies and damselflies); identified by J. Kipping (Anhalt University) and M.J. Samways (University of Natal).

Coleoptera (beetles), especially Dytiscidae (predaceous diving beetles) and Hydrophilidae (water scavenger beetles), were common at many sites although Gyrinidae (whirligig beetles) were seldom seen. None of the beetles collected have yet been identified and are therefore omitted from this report. However, the high species richness of this insect order in the Delta area can be gauged from the checklist of the Dytiscidae of Botswana by Bilardo and Rocchi (1987; Appendix 4). This checklist was compiled from several sources and included records from eight localities within the Okavango Delta and its immediate environs. A total of 70 species was recorded from the AquaRAP 2000 survey area, of which one was undescribed.

RESULTS

A list of the macro-invertebrates collected in the four focal areas during the June 2000 AquaRAP survey is given in Appendix 3. A thorough collection of adult Odonata was made with a handnet at the UPH geo-reference sites but, following the return of JK to Maun on June 9th, only incidental specimens were collected in other focal areas. These records are given in Appendix 5 together with an earlier collection by JK from the HOORC site in the Chief's Island (CHI) focal area. Detailed descriptions of the invertebrate fauna at the major sampling (geo-reference) sites in each focal region are given in Appendix 2.

Some general observations on the invertebrate fauna surveyed during the June 2000 AquaRAP are given here:

OVERALL IMPRESSIONS

Collections made in the Okavango Delta by both this AquaRAP expedition and earlier collectors show the diversity and abundance of the macro-invertebrates to be high though surprisingly uniform in the four focal areas sampled. This is surprising in view of the high habitat diversity for which the system is noted and its isolation in an otherwise arid environment. Ephemeral pools in the Moremi Game Reserve showed somewhat greater diversity, dominated in some cases by individual species.

Heteroptera and Odonata were the most diverse invertebrate taxa with totals of 38 and 48 species recorded from all habitat types respectively. Between seven and 10 species of Heteroptera occurred sympatrically in habitats as different as *Miscanthus junceus* backswamps and floating *Cyperus papyrus* mats. Similarly, 10 or 11 species of adult Odonata (UPH focal area only – see Appendix 5) were collected in individual habitat types as different as the *Vossia cuspidata* backswamp at Mohembo and the marginal vegetation at the pump house downstream of Drotsky's Cabins (OK1-06-INV14). One species of damselfly, *Pseudagrion deningi* (Odonata), was present at most sites and was common at several. Two other species, *P. sjoestedti jacksoni* and the dragonfly *Aethiothemis discrepans* were locally abundant.

Freshwater shrimps (*Caridina africana*) declined strikingly in abundance down the length of the system from the Panhandle to Chief's Island. Analysis of the basis for this decline may be ecologically very informative, in terms of energy sources, and predation pressure. Amongst the molluscs, it is noteworthy that the snails *Biomphalaria pfeifferi* and *Lymnaea natalensis*, intermediate hosts of intestinal schistosomiasis (bilharzia) and fascioliasis (liver fluke disease) respectively, were the most common snail species in all focal areas. This situation may have implications for public and veterinary health if contact with the water by people and domestic stock increases in the future (the issue of schistosomiasis is discussed later in this report).

Although densities of bivalve mollusks were not adequately measured, the data obtained for *Coelatura kunenensis* and *Corbicula fluminalis* in shallow, lotic habitats indicate lower densities, <1/m^2 and 0.5-7/m^2 respectively, than those measured in lentic habitats in 1983 by CCA (included in this report). The densities recorded for the sphaeriid bivalves *Eupera* (0.25/m^2) and *Pisidium* (6.25/m^2) also seem low though few comparable data are available (see Appleton 2002).

In part, the uniformity of macro-invertebrates in a system known for its habitat diversity may be linked to inhospitable conditions (low oxygen levels and/or shade-depressed primary productivity) in much of the papyrus and other swamps and predation pressure by a multitude of opportunistically predatory fishes.

In summary, biodiversity was lowest in flowing main channels, slightly higher in vegetated side channels, and higher still in quiet vegetated backwaters and lagoons. The highest levels of biodiversity were found in some of the isolated and ephemeral pools in MGR and CHI focal areas. No invasive aquatic invertebrates have been reported from the Okavango Delta.

General impressions of the Upper Panhandle sites (OK1: 01-07)

Main Channel and Fringe

Sampling in the marginal vegetation, mostly *C. papyrus*, of the main channel of the river yielded a fauna dominated by a community of Odonata comprised largely of the zygopteran genus *Pseudagrion*, but with several species of Anisoptera as well. The absence of larvae in the samples suggests that these odonatans breed in other types of habitat. Other taxa collected were water striders (Veliidae), two prosobranch snails, *Bellamya capillata* and *Gabiella kisalensis*, one pulmonate, *Lymnaea natalensis*, the cryptic bivalve *Eupera ferruginea* and two crustaceans, the river crab *Potamonautes bayonianus* and the shrimp *Caridina africana*.

Side channels and backswamps

The fauna here was richer than the main channel, with 19 taxa being recorded. Sampling in one flowing side channel demonstrated numerous mayfly (Ephemeroptera) nymphs, notably the oligoneuriid *Elassoneuria* ?*grandis,* in the sandy substratum. Backswamps harboured a rich fauna including the fish-eating spider (*Thalassius* sp.) and a succineid snail, *Oxyloma patentissima,* on emergent grasses just above the water level. The aquatic forms were dominated by the shrimp *C. africana*, surface dwelling Heteroptera, and pulmonate snails while adults of the dragonfly *Aethiothemis discrepans* were locally abundant. The presence in recently flooded areas of large quantities of organic material and numerous midge larvae (Chironomidae) suggested that the sediments and overlying (bottom) water were anoxic or nearly so.

Sand Banks

A few bivalve mollusks (*Corbicula fluminalis* and *Coelatura kunenensis*) and gomphid dragonfly nymphs (Anisoptera) were found at low densities in clean sand containing little or no or organic debris. The inherent instability of these sandbanks may account for the restricted fauna here.

Open Water Lagoons

The fringing vegetation of these lagoons was characterised by a rich heteropteran fauna, several pulmonate snails, especially *Biomphalaria pfeifferi*, *Lymnaea natalensis* and *Oxyloma patentissima* (a semi-aquatic species) and damselflies, notably *Pseudagrion deningi* and *Ischnura senegalensis.* Floating vegetation such as the leaves of the water lilies *Nymphaea nouchali* and *N. lotus* supported a limited fauna characterised by juvenile pulmonate snails and glossiphoniid leeches. Submerged weedbeds (*Ceratophyllum demersum*) typically harboured the shrimp *C. africana,* heteropterans and pulmonate snails, again mostly juveniles.

General impressions of the Lower Panhandle sites (OK1: 08-13)

Relatively few invertebrates were found in and around Guma Lagoon, possibly due to the low pH and reduced oxygen levels in the water and sediments. Chironomid midge larvae were the only burrowing forms found.

Marginal Vegetation of Guma Lagoon and Thaoge Channel

The fauna of marginal vegetation was dominated by mobile (flying) insects, e.g. dragonflies, heteropterans (e.g. the corixid *Micronecta acutellaris*) and beetles but these latter were not identified. Mollusc diversity was poor, perhaps because the pH was low, below 5.5. Nevertheless, the small bivalves, *Sphaerium* spp., were found to be quite common in crevices between *C. papyrus* rhizomes. The expected low diversity in recently burnt *C. papyrus* was not observed.

Open Water Lagoons

Only one open water lagoon was sampled and this was situated close to the main river channel. The fauna amongst the *Typha, C. papyrus* and *Hibiscus* along the margins was rich in heteropterans and pulmonate snails – and the pH was above 6.2, higher than in Guma Lagoon and the Thaoge Channel. The bivalves *Sphaerium* spp. were again found in the cavities between *C. papyrus* rhizomes. A similar fauna was collected from floating mats of *Pycreus mundtii* and the water chestnut *(Trapa natans)*.

Compared to other focal areas, submerged stands of *C. demersum* and *Najas horridus* had a lower diversity and abundance of invertebrates. The snail *Biomphalaria pfeifferi* was present but not common. Few shrimps *(C. africana)* were collected, possibly because they require higher oxygen levels.

Flooded grassland

The prosobranch snail *Pila occidentalis* was common in this shallow habitat as were heteropterans, especially notonectids and corixids, and ephemeropteran nymphs.

General Impressions of the Moremi Game Reserve sites (MGR, OK1: 15-27)

Several new mollusc records for the Okavango Delta were made in this focal area, viz. the prosobranch snail *Melanoides victoriae*, the pulmonate snail *Bulinus scalaris*, and the tiny bivalves *Pisidium reticulatum* and *Pisidium* sp. Isolated pools inside Moremi Game Reserve, most of them saline and ephemeral, harboured a largely different invertebrate fauna in terms of diversity and abundance, from the permanent channels and lagoons.

Lagoons

Gadikwe Lagoon contained an interesting invertebrate fauna. The floating mat of *Pycreus mundtii* below the well-known herony harboured a diverse invertebrate fauna. The 17 taxa collected were dominated by the unusual abundance of the shrimp *Caridina africana*, with Odonata, Heteroptera and Gastropoda, both prosobranchs and pulmonate, being common. Three species of bivalve, including the large unionaceans *Coelatura kunenensis* and *Mutela zambeziensis*, and the prosobranch snails *Melanoides victoriae* and *Cleopatra elata* were collected from beneath the *P. mundtii* mat. Submerged stands of *Ceratophyllum demersum* supported a diversity of pulmonate snails.

Backswamp

The *Miscanthus junceus*-dominated backswamp in Xakanaxa Lagoon also yielded a diverse invertebrate fauna with the most common taxa being the shrimp *Caridina africana*, creeping waterbugs (Naucoridae) and scavenger beetles (Hydrophilideae). The large blood-sucking leech *Asiaticobdella buntonensis* made its presence felt here.

Channels

Relatively shallow, sandy-bottomed channels were a feature of this focal area. Invertebrates were scarce and in sunlit stretches were confined by the flow to submerged stands of *Nesaea crassicaulis* and floating *Nymphaea* leaves and to the sediments themselves. Small mayfly nymphs (Ephemeroptera) were the most common but the shrimp *C. africana* and the snails *Biomphalaria pfeifferi* and *Lymnaea natalensis* were present as well. Grab samples from the sediments produced a few chironomid larvae and some *Sphaerium* bivalves. In shaded stretches, the bottom sediments yielded four small bivalve species (*Corbicula fluminalis*, *Eupera parasitica* and two *Pisidium* spp.), a few mayfly nymphs and chironomid larvae. Mesh analyses of the sediments at OK1-18-INV33 are given in Figure 4.1.

Permanent and seasonal pools

In one permanent pool visited, washings of the roots of the invasive aquatic fern *Salvinia molesta* in white trays demonstrated a fauna of small elements, dominated by ephemeropteran nymphs and mosquito larvae. In another, four snail species were found, including the prosobranch *Lanistes ovum*, but the fauna was dominated by Heteroptera, especially the families Notonectidae and Corixidae and the surface-dwelling Gerridae and Veliidae.

Several flooded seasonal pools were visited of which some were acid and markedly saline. The fauna collected was different from that in the deltaic habitats examined inasmuch as several groups were much more common. In addition, individual pools appeared to be dominated by different taxa.

Invertebrate samples from saline pools were dominated by water striders (Veliidae), water boatmen (Corixidae) and scavenger beetles (Hydrophilidae). The fauna of flooded non-saline pools also differed from those in habitats associated with lagoons and channels and contained the pulmonate snail *Bulinus scalaris,* a seasonal pool-specialist not recorded at the deltaic sites. The only other mollusc found here was another member of the genus *Bulinus*, *B. depressus*, which is known to colonize temporary habitats over a wide area of southern Africa (Brown 1994) but is by no means confined to them. Mosquito and chironomid larvae, several heteropteran taxa and hydrophilid beetles were also common.

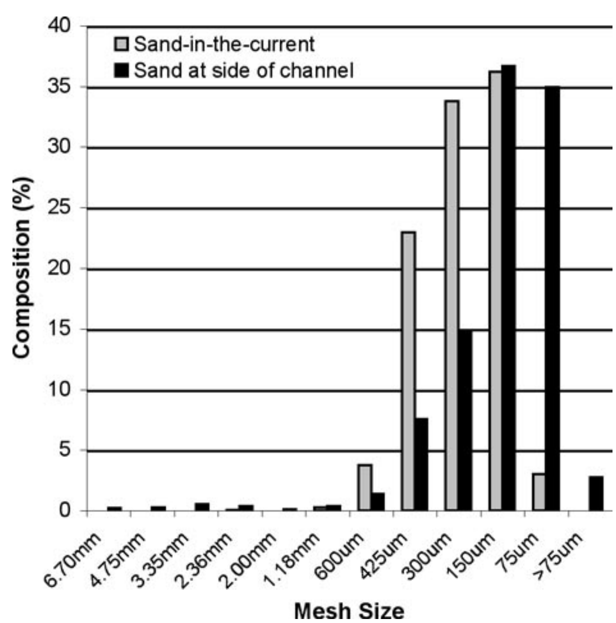

Figure 4.1. Mesh analyses of sand from middle (sand-in-the-current) and side of the Maunichira channel at OK1-18-INV33.

The features of the MGR invertebrate collections were that the fauna of the isolated pools visited differed substantially (i) from that in the lagoons and channels associated with the Delta, i.e. deltaic habitats, and (ii) from one pool to another. The homogeneity of the fauna of the vegetated swamps/mats of the deltaic sites contrasted with the heterogeneity of the fauna of the seasonally rain-filled pools in the area (INV39-42). These pools were the only habitats in which the snail *Bulinus scalaris* was found. In several pools, individual taxa, at either family or species level, were conspicuously dominant (i.e. Fairly Common to Abundant, see Appendix 3) but different groups dominated in different pools. In the deltaic habitats, most taxa fell into the Present-Fairly Common categories (see Appendix 3). The heterogeneity of the fauna of these pools may be related to the frequency of drying, how late in the rainy season each one filled and the fact that each probably has a unique set of physical and chemical characteristics.

General Impressions of the Chief's Island sites (CHI, OK1: 28-38)
Invertebrate sampling was particularly challenging in this focal area, since all collecting was done from mokoros (dugout canoes).

Channels
Although the water in the sandy-bottomed channels was too deep for benthic sampling to be effective, visibility was good and the snail *Lanistes ovum* could be seen at densities of approximately 1 per square metre. The large bivalve *Mutela zambesiensis* was also present but its density could not be estimated. On two occasions we found small trampled platforms of the grass *Vossia cuspidata* located about 40 cm above the water surface. Each of these platforms held 20-30 empty *L. ovum* shells of which 66% had been damaged; a wedge-shaped chip had been taken out of the basal whorl (Figure 4.2). This damage is presumed to have been caused by the Openbill Stork *(Anastomus lamelligerus)* as it breaks the shells with its upper mandible to extract the soft parts with the lower one. These shells were all large, 34-58 mm shell height, and presumably adult. These data will be analyzed elsewhere together with similarly damaged *L. ovum* shells and also bivalves *(Spathopsis wahlbergi)* collected from the Pongolo River floodplain in South Africa.

In the marginal vegetation of these channels, the most common species found were the snail *Lymnaea natalensis,* followed by waterbugs, dragonfly nymphs and another snail, *Bulinus depressus*, all of which were fairly common. Several other species of snails were found. Among fringing clumps of *Miscanthus junceus*, the dominant group found were mayfly nymphs (Fairly Common), *Lymnaea natalensis,* dragonfly and damselfly nymphs, and water scavenger beetles.

The grassy marginal fringe at the mokoro landing site at Oddball's Camp was examined for snails, with particular attention being paid to the large *Croton megalobotrys* leaves that had fallen into the water. The only examples of *Segmentorbis angustus* found during the expedition were collected here.

Figure 4.2. A shell of the snail *Lanistes ovum* showing the typical damage caused to the basal whorl by the Openbill Stork *(Anastomus lamelligerus)*, a species that feeds extensively on molluscs.

Lagoons
The leaves of *Nymphaea* spp. are numerous in these lagoons and cover much of the water surface, up to 40-50% in some cases and, especially their undersurfaces, must constitute an important habitat for invertebrates. Inspection of the undersides of *Nymphaea* leaves in the deeper water of lagoons yielded a fauna of snails, mostly juveniles, such as *Lymnaea natalensis,* mayfly nymphs, waterbugs, weevils, damselfly nymphs, small glossiphoniid leeches (two species) and the limpet *Ferrissia* cf. *victoriensis*. The prosobranch *Lanistes ovum* was occasionally found on these leaves as well. Samples of the sandy bottom sediments revealed the snails *L. ovum* and *Biomphalaria pfeifferi,* zygopteran nymphs and one species of Dytiscidae.

Records from a mollusc collection made in July 2000 by JK from the bank of the Boro River on the western side of Chief's Island (19°32'54.3" S, 23°10'36.1" E) are included here. Species collected were *Pila occidentalis* (juveniles only), *Lymnaea natalensis, Bulinus globosus, B. depressus* and the small bivalve *Sphaerium incomitatum*. The latter was common. By way of contrast, the only mollusc found in a periodically flooded "lagoon" near the Boro River also on the western side of the island (S 19°32'05.8", E 23°11'00.0") was *Bulinus depressus.*

Pools
One rainwater pool sampled produced 17 invertebrate taxa dominated by mosquito larvae (Very Common), water boatmen (Common), pond skaters (Fairly Common) and waterbugs (Fairly Common). The only examples of water scorpions (Nepidae) collected during the entire expedition were found at this site. However, a second seasonal

pool yielded very few invertebrates. Mosquito larvae and pupae were most numerous here with mayflies, dragonflies, damselflies and water scavenger beetles also present. In a saline borrow pit, nine invertebrate taxa were found, with mosquito larvae and backswimmers (*Anisops* sp.) abundant. The other taxa, water boatmen, diving water beetles, water scavengers, marsh treaders, damselflies, dragonflies and midges were present in very low numbers.

DISCUSSION

Several general comments can be made on the invertebrate fauna collected during the expedition:

- The invertebrate fauna in the four focal areas was found to be fairly homogeneous (see below) with high to moderate species richness but low abundance for most groups. The fauna was dominated by mobile insects, i.e. Heteroptera and Coleoptera (the latter not identified). The shrimp *Caridina africana* was found at almost all sites; ephemeropteran larvae were uncommon; no trichopteran larvae were found. Gastropod molluscs were common but bivalves were uncommon though this might have been because they were inaccessible in water too deep to sample.

- Large-scale burning of *C. papyrus* stands is occasionally carried out by local people. We found that these burnt stands supported a similarly structured invertebrate fauna to unburned stands.

- Sediment samples contained large quantities of organic material and, except for chironomid larvae, were generally devoid of invertebrate life. This is suggestive of conditions bordering on anoxia (oxygen-depletion). Indeed, measurements of dissolved oxygen close to these substrata were often around 25% saturation. By extrapolation, these oxygen-depleted conditions must prevail over extensive areas of the Panhandle and Delta.

- There is a rich terrestrial fauna associated with emergent and marginal grasses such as *Vossia cuspidata*. This is dominated by spiders (the fishing spider *Thalassius* is conspicuous), beetles, weevils, and gastropods. Two gastropods, the slug *Elisolimax* sp. and the semi-aquatic snail *Oxyloma patentissima*, were locally common where overhanging leaves were dense and shaded. When these fall into the water, they likely provide a significant food resource for fish and predaceous insects (Hemiptera and Coleoptera).

- The dominant elements of the fauna of rainpools in the MGR and CHI focal areas were different from those of the deltaic habitats and also differed from one pool to another.

- The major limitation experienced in collecting invertebrates was that the water level was very high so that sampling the benthos of the deeper areas of the channels and lagoons was not possible with the equipment available. A van Veen Grab with a bite of approximately 900 cm^2 (i.e. 20 x 15cm) is necessary to properly sample benthic molluscs, especially *Lanistes ovum* and the large unionacean bivalves.

COMMENTS ON INDIVIDUAL TAXA

Hirudinea (Leeches)

Several members of the Family Glossiphoniidae appear to be associated with molluscs. *Batracobdelloides tricarinata* lives inside the mantle cavity of bivalves such as *Spathopsis wahlbergi* (Appleton 1979) and snails such as *Lanistes ovum*, probably as commensals. However *Helobdella conifera* is an obligatory mollusc feeder (Wilken and Appleton 1991, Davies et al. 1997). All three leech species recorded from the Delta were also collected in the adjacent wetlands of Eastern Caprivi (Namibia) by Oosthuizen and Curtis (1990).

Odonata (Damselflies and Dragonflies)

Records from AquaRAP 2000 and JK's unpublished collections are collated in Appendix 5 and list a rich fauna of 47 species, 13 Zygoptera and 34 Anisoptera. More species would probably have been found had the expedition been earlier in the year, i.e. in summer (November to March) or even autumn (April and May). A total of 39 species were recorded by JK from the HOORC site on Chief's Island. Many of these were not collected by JK in the seasonal part of the Delta. Pinhey (1976) reported 81 species (30 Zygoptera and 51 Anisoptera) from the Delta and commented that it is "…. One of the richest and most interesting Odonata ecosystems in southern Africa."

Ephemeroptera (Mayflies)

Two species of adult Emphemeroptera were collected at night using a light trap at Drotsky's Cabins, viz. *Caenis* sp.E (Caenidae) and *Cloeon virgiliae* (Baetidae). Thus the larvae identified as "Caenidae, new genus and species" and *Cloeon* nr *virgiliae* can probably be associated with these adult identifications respectively.

Mollusca (Snails and Mussels)

Brown et al. (1992) recorded 13 species of gastropod from the Okavango Delta, most of them widespread Afrotropical species and Curtis (1997) added two more, *Ferrissia victoriensis* and *Ceratophallus natalensis*. The present survey has added the prosobranch *Melanoides victoriae*, which was known from the Okavango River in Namibia. *Melanoides victoriae* was only collected in Gadikwe Lagoon (at both georeference sites) but if more benthic samples were taken, it may be found to be more widely distributed. As noted by Brown et al. (1992), the Delta represents the southernmost locality in Africa for two prosobranch gastropod species, *Pila occidentalis* and *Gabiella kisalensis. Bulinus scalaris*, which was previously known only from a single locality in the Delta (Brown et al. 1992), is now known to be widespread in ephemeral pools in the seasonal part. The large Ampullariidae (*Lanistes ovum* and *Pila occidentalis)* were most common in seasonally inundated grassland.

The shells of many of the *Lymnaea natalensis* collected during the expedition were noticeably slender, as illustrated by Brown et al. (1992). This feature, together with their pinkish colour, seems typical for the species throughout the Okavango River system. No invasive species have been collected in the Delta but note should be taken of the recent discovery of *Lymnaea columella* and *Physa acuta* in Lake Kariba, Zimbabwe (Anonymous 2000). Their presence here may be linked with the introduction to the lake of the Water Hyacinth, *Eichhornia crassipes,* in 1988, probably from the upper Zambezi and Kafue Rivers (Mhlanga et al. 1999).

The Delta is also the southernmost locality for two bivalve species, *Coelatura kunenensis* and *Aspatharia pfeifferiana* (not found during the present survey). A third large species, *Mutela zambesiensis* (recorded as *Mutela dubia* by Appleton 1979), is common in the Delta and seems to be endemic to southern Africa. The genus *Pisidium* is recorded from the Okavango/East Caprivi wetland system for the first time and is represented by two species, *P. reticulatum* which is also known from Zimbabwe and Madagascar (Kuiper 1966) and a second unidentified species. Although the other sphaeriid genera *Sphaerium* and *Eupera* have been known from the Delta since the 1980s, this is the first time they have been identified to species level. Both *S. capense* and *S. incomitatum* were fairly common in the fine sediments that accumulate in the crevices between *C. papyrus* rhizomes.

Because bivalves constitute the major component of the benthic biomass in sandy substrata, data on their population densities are necessary to give a balanced account of invertebrate abundance and diversity in the Delta. During AquaRAP 2000, some data were obtained for *Coelatura kunenensis* and *Corbicula fluminalis* in the Upper Panhandle but in many habitats the water was too deep for effective sampling. For this reason unpublished density data collected by one of us (CCA) in March 1984 are given below. Although published records (Appleton 1979) show that *C. kunenensis* is the most widespread species in the Delta, quantitative sampling at two sites in March 1984 showed considerable spatial variability (Table 4.1). The sites were (i) the clear-water, gently-shelving Nxaraga Lagoon, Chief's Island, and (ii) a turbid, steeply-shelving pool below Matlapaneng Bridge over the Thamalakane River near Maun.

In terms of grain size, the sand in Nxaraga Lagoon was much coarser than that in the Thamalakane River (Figure 4.3). In the lagoon, 80.2% of grains were between 250 and 500µm diameter, with a mode at 355µm, while in the Thamalakane River, the modal diameter was 180µm (66.6%). *C. kunenensis* and *C. fluminalis* occurred at higher densities in the sediments of the Thamalakane River while *Mutela zambesiensis* was more common in the coarser sand of the Nxaraga Lagoon.

Table 4.1. Mean densities ($m^{-2} \pm SD$) of three bivalve species in shallow water (10-50 cm depth) in Nxaraga Lagoon and the Thamalakane River (n = 24 x 1 m quadrat samples at each site).

Species	Nxaraga Lagoon, Chief's Island	Thamalakane River, Maun
Caelatura kunenensis	3.0 ± 3.2	18.0 ± 17.8
Mutela zambesiensis	0.2 ± 0.4	0.08 ± 0.28
Corbicula fluminalis	None sampled	0.5 ± 0.8

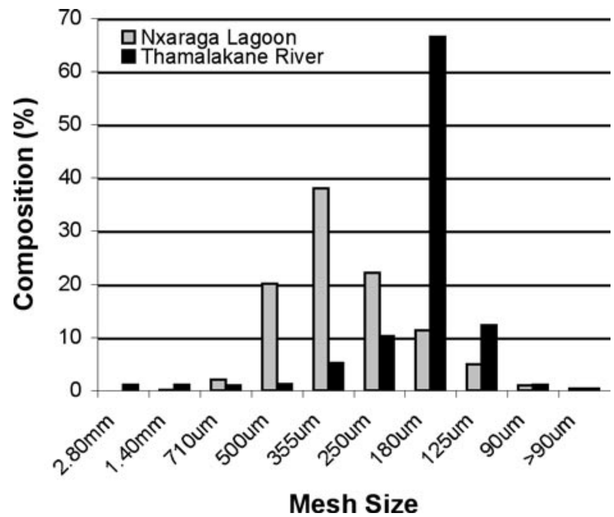

Figure 4.3. Mesh analyses of sand from the sampling sites at Nxaraga lagoon (Chief's Island) and Thamalakane River at Maun.

Few data are available on absolute population densities of freshwater bivalves in southern Africa but when compared to measurements from three other waterbodies in the subcontinent, those from the Okavango Delta are seen to be relatively high for *Coelatura,* average for *M. zambesiensis* and low for *C. fluminalis*. In Zimbabwe, Kenmuir (1980) reported low densities of 0.14-0.50m^{-2} for *Coelatura mossambicensis* but similar values (0.19-0.88 m^{-2}) for *M. dubia* (possibly synonymous with *M. zambesiensis*) in Lake Chivero (formerly called McIlwaine). In Lake Kariba he found *C. mossambicensis* to be more common (17.2-35.4 m^{-2}) with *Spathopsis wahlbergi* at 2.5-5.0m^{-2} and *Mutela dubia* at 0.2-0.8 m^{-2}. Appleton and la Hausse de Lalouviere (1987) reported densities of 2.0-17.8 m^{-2} for *Coelatura framesi*, 0.98-12.0m^{-2} for *Spathopsis wahlbergi* and 13.5-230.5 m^{-2} for *Corbicula fluminalis* on the Pongolo River floodplain in South Africa. While bivalve densities clearly vary spatially, they also vary over time in individual habitats. This is well demonstrated by comparing the above with the earlier estimates for *C. fluminalis* of 1739.1-2608.7 m^{-2} also on the Pongolo floodplain by Pretorius et al. (1975). Neither *S. wahlbergi* nor another mutelid *Aspatharia pfeifferiana*, are known from the Delta although both occur in the Okavango River (Appleton 1979).

Faunal diversity

Table 4.2 compares the numbers of species of the phylum Hirudinea, two arthropod orders (Decapoda and Heteroptera) and two molluscan classes (Gastropoda and Bivalvia) collected from the four focal areas surveyed. Totals for these areas varied between 25 (LPH) and 36 species (MGR) with the major discrepancy being amongst the bivalves. This was because, as noted above, the water level was too high for effective sampling of these molluscs from boats without a grab – except at Gadikwe Lagoon (MGR) where fish nets brought up several species not otherwise collected by the invertebrate team.

Comparable data from three other lentic freshwater systems in southern Africa (Lake Bangweulu in Zambia and the Pongolo River floodplain and Lake Sibaya in South Africa) are available for some of the above taxa (Table 4.3) and help to place the species richness of the Okavango Delta in perspective. If the Okavango River and adjacent wetlands of eastern Caprivi are included, the molluscan diversity rises to 30 species.

The fauna of the Okavango Delta is richer in all cases even if, as seems likely, diversity of the Heteroptera and Dytiscidae in Lake Sibaya has been under-estimated.

A feature of this survey is the finding that the fauna inhabiting seasonal rainpools in the MGR and CHI focal areas was not only different from that in the deltaic habitats, but it was remarkably heterogeneous, differing from one pool to another. Table 4.4 compares the numbers of species of four taxa recorded from MGR and CHI sampling sites (i) associated with the Delta (channels and lagoons) and (ii) the five isolated seasonal pools sampled and (iii) in both categories (i) and (ii). The pools support a restricted fauna that is essentially different (by 9 and 7 species in MGR and CHI respectively) from that in habitats associated with the deltaic channels and lagoons, i.e. habitats fed by the river as opposed to those relying on rainfall. Few species occur in both categories of habitat (5 and 1 species in MGR and CHI respectively). The heteropteran *Appasus ?ampliatus* (Belostomatidae) may be a new species.

Affinities of the fauna

Knowledge of three groups is sufficient to allow comment on the biogeographical affinities of the fauna of the Okavango Delta. Pinhey (1976) noted marked similarities between the Odonata of the Delta and the swamps and swamp-streams of western and northern Zambia and eastern Angola and

Table 4.2. Numbers of species of Hirudinea, Decapoda, Heteroptera, Gastropoda, and Bivalvia identified from samples taken in the four focal areas in the Okavango Delta. UPH = Upper Panhandle, LPH = Lower Panhandle, MGR = Moremi Game Reserve, CHI = Chief's Island.

Taxon	Focal Areas Surveyed				All Four Focal Areas Combined
	UPH	LPH	MGR	CHI	
Hirudinea	2	1	1	3	4
Decapoda	2	1	1	1	2
Heteroptera	12	13	17	13	38
Gastropoda	10	7	9	10	15
Bivalvia	3	3	8	2	8
Total	**29**	**25**	**36**	**29**	**67**

Table 4.3. Comparison between the total numbers of species of seven taxa recorded from the Okavango Delta by AquaRAP 2000 and other collectors and three other wetland systems in southern Africa for which data are available.

Taxon	Okavango Delta	Lake Bangweulu	Lake Sibaya (Allanson et al. 1974)	Pongolo River Floodplain (Pretorius et al. 1975)
Hirudinea	4	-	3	-
Decapoda	3	-	2	-
Dytiscidae	49 (Bilardo & Rocchi 1987)	-	3*	-
Heteroptera	38	-	6*	-
Odonata	78 (Pinhey 1976)	19 (Pinhey 1984)	25	-
Gastropoda	16	7 (Mandahl-Barth 1968)	9	14
Bivalvia**	8	8 (Mandahl-Barth 1968)	3	6

* indicates taxa that have probably not been adequately collected.
** Although not collected by AquaRAP 2000, the mutelid bivalve *Aspatharia pfeifferiana* is included since it was collected by P. Reavell in the Boro River in 1973 (Appleton 1979).

Table 4.4. Number of species of Hirudinea, Decapoda, Heteroptera, Gastropoda, and Bivalvia recorded from deltaic habitats, seasonal pools, and both habitats in the Moremi Game Reserve and Chief's Island focal areas.

Taxon	Moremi Game Reserve			Chief's Island		
	Channels & lagoons	Pools only	Both	Channels & lagoons	Pools only	Both
Hirudinea	1	0	0	3	0	0
Decapoda	1	0	0	1	0	0
Heteroptera	6	8	3	6	6	1
Gastropoda	9	1	2	9	1	0
Bivalvia	8	0	0	2*	0	0
Total	**25**	**9**	**5**	**21**	**7**	**1**

*Two additional species recorded here by Appleton in 1984 (unpublished data) were not collected by this expedition, probably because of the greater depth of water.

inspection of his report suggests that over 90% of the 78 species recorded from the Delta itself have a northerly distribution. He attributed this particularly to past direct connections between the Okavango and upper Zambezi system via a southerly route for the Zambezi route as it flowed through eastern Caprivi and the Linyanti-Chobe swamps to join the Limpopo system. Currently the Chobe River provides intermittent linkages with the Delta when it overflows under high flood conditions via the Selinda Spillway.

The molluscan fauna shows similar affinities (Mandahl-Barth 1988; Brown et al. 1992; Brown 1994). The overwhelming majority of species (approximately 74%) are widespread tropical African forms with a further 21% apparently confined to the Okavango system and the other systems that abut onto it, viz. the Kunene, Chobe-Linyanti swamps and upper Zambezi systems. This distribution pattern mirrors that of the Okavango fish fauna of which 96% also occur in the upper Zambezi (Skelton et al. 1985). Since the larval stages of unionacean bivalves, viz. *Coelatura* and *Mutela*, are obligatory parasites of fish, particularly cichlids, and rely on these host fish for dispersal, similarities should be expected in the distribution patterns of the two groups.

The affinities of the Heteroptera of the Delta are different. According to P. E. Reavell (pers. comm.), the heteropteran fauna of the Delta is similar to that in the warmer parts of South Africa, e.g. Northern Province southwards to the coastal areas of KwaZulu-Natal. Its affinities are thus about 80% subtropical southern African and about 20% Congolian, i.e. further north.

Schistosomiasis (Bilharzia)

Biomphalaria pfeifferi is the most common snail species in both the permanent and seasonal parts of the Delta and is the intermediate host for *Schistosoma mansoni*, the parasite causing human intestinal (rectal) schistosomiasis. The wide distribution of this snail species is clearly of public health importance and it is therefore opportune to briefly discuss the transmission of schistosomiasis within the context of the ecology of the Delta. There was a dramatic increase in transmission in the Maun area during the 1970s and early 1980s and this may have been associated with (i) a parallel increase in the human population, (ii) the shooting out of the crocodile population leading to more extensive contact with water in the Delta, and (iii) the extent of the annual flood. At present transmission is confined to the seasonal part of the Delta where it occurs mainly around the two most heavily populated areas, Maun and Gumare.

Considering the situation in Maun only, no cases were found prior to the early 1960s (Pitchford 1958) but prevalences have risen rapidly since then. Geldenhuys et al. (1967) reported 13.0% in 1965 and Dando (1976) confirmed a disturbing increase in cases between 1973 and 1975. The National Bilharziasis Survey found 24.4% in 1976-1978 (Rudo 1978) and Sibiya et al. (1976) reported 12.9-69.7%. These levels had risen to 80.3% by 1984 (Andersen et al. 1985) and 80.5% by 1986 (Friis and Byskov 1987) and cases of severe morbidity were being found. As a result, the disease was declared notifiable, i.e. all diagnosed cases must be reported to the health authorities. In 1985 a chemotherapy programme was introduced. There has, however, been little transmission over the last decade or so (Dr. E. S. Chapandwe, Senior District Medical Officer, Ngamiland, pers. comm., June 2000) with the health authorities in Maun currently diagnosing about one case/month with the result that notification has been relaxed.

Figure 4.4 shows the annual inflow of floodwater into the Delta at Mohembo and into the Thamalakane River at Maun between 1969 and 1995. It is apparent from this that the rapid increase in *S. mansoni* transmission to prevalences around 80% occurred largely during a period of eight years (1973/4 to 1980/1) when the floodwaters reached the Thamalakane River with discharges of between 300 and 800 million cubic metres measured at Maun. Discharge into the

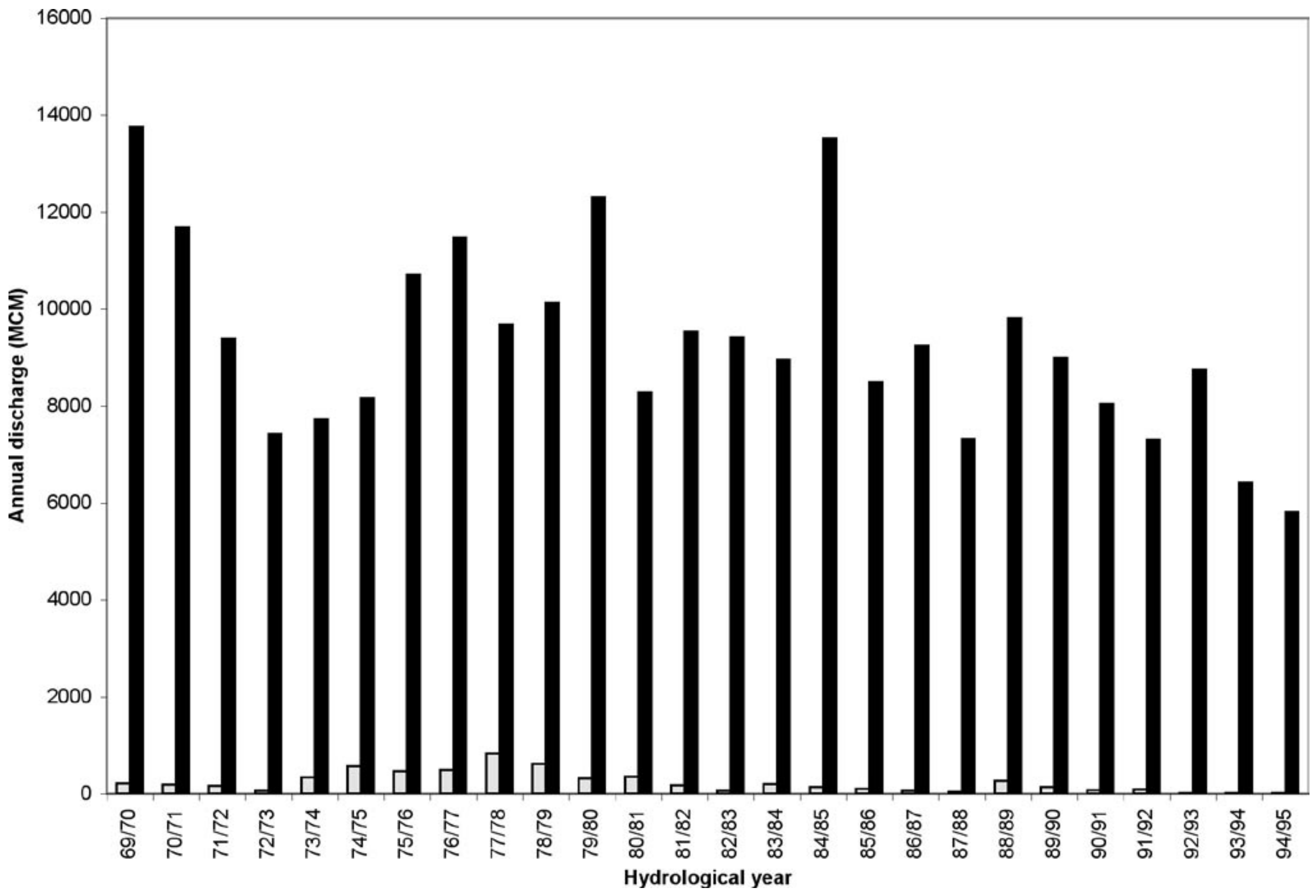

Figure 4.4. Discharge data (in cubic metres/second) for water flowing from the Okavango River into the Delta at Mohembo in the Upper Panhandle (dark bars) and into the Thamalakane River at Maun in the seasonal part of the delta (light bars) from 1969 to 1995.

Thamalakane River since 1981/2 has been lower, sometimes much lower and have not reached Maun, probably restricting transmission. If however future floods reach the Thamalakane River for at least several successive years, the rate of transmission is likely to rise again and schistosomiasis will once more become a notifiable disease.

The snail *Bulinus globosus* is the intermediate host for both human urinary and cattle schistosomiasis, caused by *Schistosoma haematobium* and *S. mattheei* respectively, but there are no reports of either parasite being transmitted in the Delta. This may be because although *B. globosus* is widespread, it is not common enough to facilitate transmission. No schistosomes were found in a survey of the trematode cercariae emerging from snails collected in the Delta (Jansen van Rensburg 2001). The epidemiology of schistosomiasis in the Okavango Delta needs to be investigated.

ACKNOWLEDGEMENTS

We are grateful to the specialists who identified the material collected during the survey and whose names were listed in the “Sampling Methods” section. A special word of thanks must also go to Mr. Patrick Reavell (University of Zululand) for enthusiastic telephonic and email discussions with the senior author on the biology and zoogeography of the collection of Heteroptera and for supplying the list of Dytiscidae recorded from the Delta (Appendix 4). Prof. W. Ellery (University of Natal) kindly supplied the data in Figure 4.4 and Prof. M. J. Samways (University of Natal) helped with literature.

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Chapter 5

Floristic Diversity of the Okavango Delta, Botswana

W. N. Ellery and Budzanani Tacheba

Tribute to Mr. P. A. Smith

A great deal of research has been carried out in the field of the floristic diversity of the Okavango Delta, particularly by Mr. P. A. Smith who lived and worked in the region for much of his professional life. His recent death comes as a great loss to the botanical knowledge of this remarkable system and the herbarium in Maun stands as a fitting tribute to his collection and work. Tribute is paid to him here as he rightfully should have gone on this expedition.

CHAPTER SUMMARY

- Semi-quantitative vegetation surveys were undertaken at a total of 122 sample plots within the four focal areas. The surveys revealed an increase in local scale plant species richness (*alpha* diversity) from the Upper Panhandle to the lower reaches of the Delta. In addition, the primarily aquatic assemblage in the upper reaches, dominated by the grasses *Vossia cuspidata* (hippo grass; *mojakubu*) and *Echinochloa pyramidalis* (Limpopo grass), sedges such as *Cyperus papyrus* (papyrus; *koma*), rushes such as *Typha capensis* (bulrush; *tsita*) and reeds such as *Phragmites mauritianus,* changed to a much more patchy mosaic of aquatic, semi-aquatic, and terrestrial habitats and species in the lower reaches.

- A high proportion (about one-quarter) of the approximately 1250 plant species known from the Delta were encountered during this brief cool-season survey. This was notable since this is a time when many plant species are not reproductive and the above-ground parts of many grasses, sedges and herbs (especially annual herbs) are absent and therefore difficult to locate or identify. At least 77 plant species were recorded from the Upper Panhandle, 131 species from the Guma Lediba[1] (Lake) area, 154 species from Moremi Game Reserve/Xakanaxa, and 108 species from the Chief' Island area. A range of 23-38 sample plots was sampled in each of these focal areas.

- Nine distinct plant communities were recognized in this study, of which seven were wetland communities ranging from permanently flooded marsh to seasonally inundated floodplain. A further two communities that were identified were riparian woodlands that are not flooded but which contain species that have their roots in the water table in both the permanent and seasonal swamps.

- The distribution of wetland plant communities identified in this study is related primarily to the hydrological regime (such as the depth, duration and timing of inundation), to processes associated with nutrient and sediment supply and sediment deposition, and to the

[1] The word "lediba" is the Tswana word for "lake" (plural is "madiba"). The word "lediba" is used in this report as each lake in the Okavango Delta is named "lediba" in the widely used government survey map of the area (at 1:350 000 scale) that is published in English.

nature of the substratum. The distribution of riparian woodland communities was related to soil and groundwater salinity.

- Large scale changes in water flow within the Okavango Delta take place as a consequence of sedimentation on the channel bed that leads to bed aggradation, plant growth in the channel margin that promotes aggradation of the entire channel relative to the surrounding backswamps, and hippos that promote alternative pathways for water flow. Dramatic changes in flow of this kind contribute to a mosaic of habitats in different successional stages, and with different productivities. This process must be preserved, and sediment supply to the Okavango Delta therefore needs to be ensured, the integrity of papyrus swamp needs to be maintained, and hippos should be given increased conservation protection. The greatest threat to the integrity of this interaction is the interruption of sediment supply to the Okavango Delta by construction of weirs along the Okavango River in Namibia or Botswana. This should be avoided.

- The Panhandle and upper part of the fan are particularly important in shaping the entire Okavango Delta ecosystem, as this is where most of the water dispersal and sedimentation processes that drive the system take place. Thus, this area should be a priority for conservation.

- Riparian woodlands are responsible for much of the water loss that takes place from the ecosystem, and this leads to the disposal of toxic solutes in a way that maintains exceptionally high water quality of surface waters. They therefore ensure that Islands function as kidneys within the landscape, and the integrity of this process needs to be maintained. Riparian woodlands should therefore be considered as particularly important habitats worthy of special protection.

- The overall floristic diversity of the Okavango Delta is exceptionally high, and it should be viewed as having a high value from a biodiversity perspective.

- Alien weeds pose a threat to the floristic diversity of aquatic habitats, and steps in place to control their introduction and spread should continue to be enforced.

INTRODUCTION

The conservation of biological diversity has become one of the most important endeavors on the planet at the dawn of the twenty-first century. Many attempts are being made to quantify biodiversity globally as well as in different ecosystems, and to understand the reasons for observed patterns of heterogeneity. Many of the ecological explanations for the diversity that exists within and between natural communities recognize the fact that most environments are characterized by gradients in the distribution of environmental factors (conditions or resources), which are matched by heterogeneity in the distribution of species and communities. Where variation in the distribution of environmental factors is gradual, community level heterogeneity may be difficult to detect, but where environmental factors are patchily distributed, the distribution of species and communities is patchy. Alternatively, organisms themselves modify and diversify the environment, making it suitable for the existence of other organisms.

The diversity within natural communities may be due to a combination of these types of heterogeneity, but ecology has traditionally focused on the relationships between the distribution of natural communities and the underlying variation in the distribution of environmental factors.

The importance of ecosystem engineers

Modification of the natural environment by biota is seldom considered an important source of environmental heterogeneity at the landscape scale. However, many organisms modify the environments in which they occur by altering physical conditions or resource availability, or by modifying the concentrations of toxins in the environment. The consequences of such modification are that the environment supports a different range of species and populations, with different dynamics. This is known as ecosystem engineering. Ecosystem engineering is spatially explicit, and it therefore contributes to heterogeneity at the local and landscape level. If communities and/or ecosystems are organized around the effects of engineers, the disappearance of engineers, for example due to disturbance, may be dramatic. Given this, it is vital to understand the ways in which ecosystem engineers contribute to ecosystem structure and function, in order to adequately conserve local and regional levels of biodiversity.

Contributions of this study

This chapter describes the floristic diversity of the Okavango Delta ecosystem as a means of establishing the value of this ecosystem as a storehouse of biological diversity. It achieves this by examining local and regional patterns of diversity, and by explaining these in terms of the underlying environmental gradients. In many cases the underlying gradients are simply due to variation in abiotic conditions and resources, but in others they are the product of ecosystem engineering by plants and animals. Here we provide evidence that an understanding of the origin of heterogeneity is vital for the adequate conservation of biodiversity.

The approach in this study has been to sample flora in sample plots and to link vegetation distribution to environmental factors in an indirect way based on extensive experience and empirical research in the Okavango by one of the authors (WE). Following this, the floristic diversity of the system as a whole was considered. Further comparison of this system with other biomes in the region helps make the case that the Okavango Delta is an important storehouse of biodiversity in the region, and that this should add to many other reasons for its protection and wise use.

METHODS

Data collected during the AquaRAP survey

The AquaRAP approach was to examine four focal areas within the Okavango Delta; the Upper Panhandle, the upper fan in the region of Guma Lediba (Lake), the lower permanent swamps in the Moremi Game Reserve and the upper seasonal swamps in the vicinity of Chief's Island (Figure 5.1). Within each focal area, as wide a variety of habitats as possible were sampled at goereferenced sample sites (Appendix 6).

At each georeferenced sample site, vegetation was sampled in circular plots of approximately 5m radius for herbaceous communities, and 15m radius for communities with life

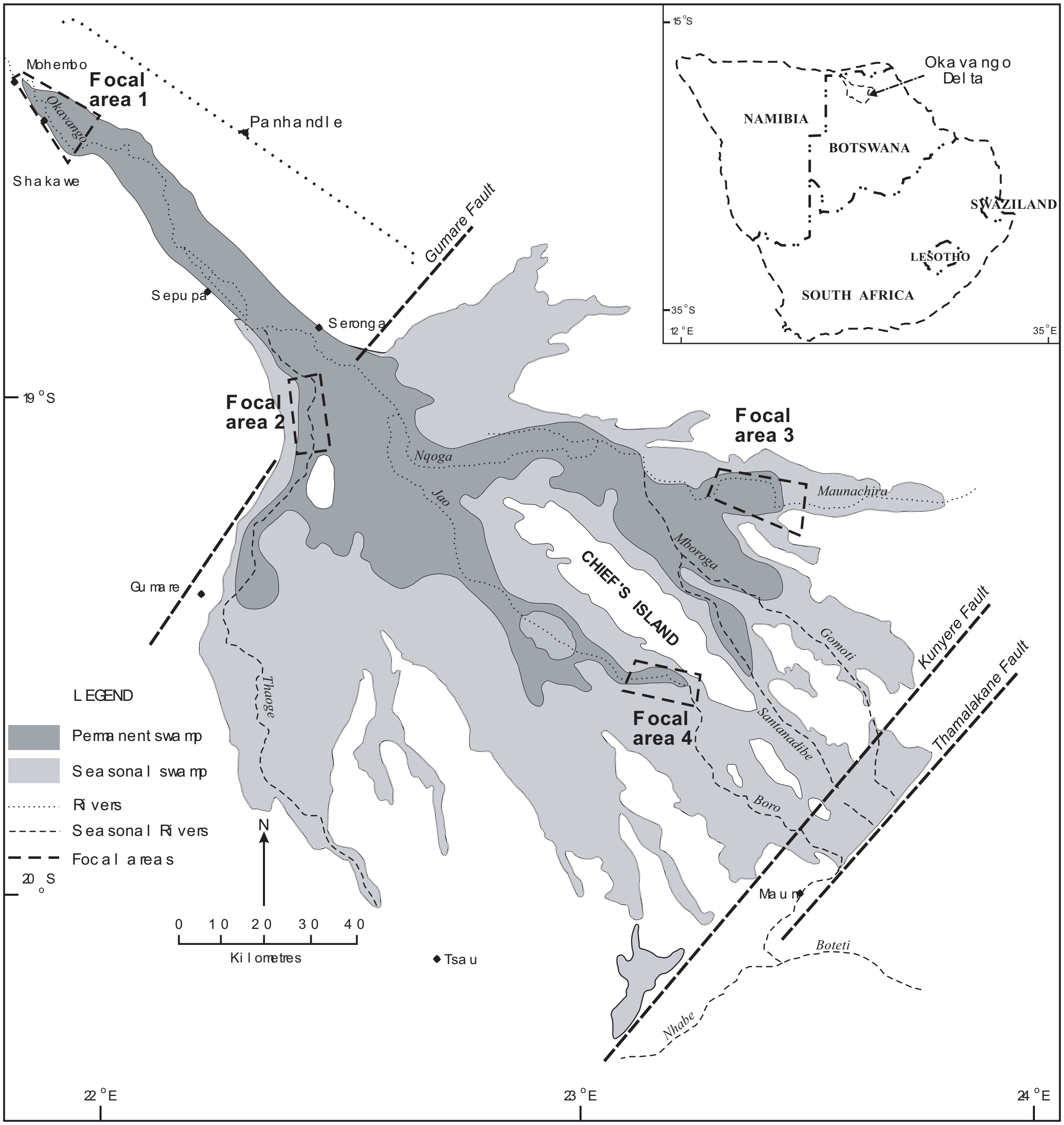

Figure 5.1. Map of the Okavango Delta showing the 5 focal areas.

forms other than herbs. Cover was recorded on a percentage cover scale, with cover intervals of 0-2, 2-5, 5-10, 10-25, 25-50 and >50% cover. These data were used as a basis for providing a general description of habitats in each of the focal areas.

However, in view of the size and complexity of the data set collected during the AquaRAP study, it was necessary to simplify the data in a manner that made it easier to describe and interpret. The widely used cluster analysis algorithm TWINSPAN (Two Way INdicator SPecies ANalysis; Hill 1979) was used for this purpose as it is has been designed specifically for ecological data sets in which the abundance values for each species in each sample are not normally distributed and where there are many zero values (species are absent from many samples). TWINSPAN is a hierarchical divisive technique that divides samples on the basis of their similarity or dissimilarity in terms of species composition. It identifies "indicator species" that are strongly positively associated with samples in one group (occurs in >80% of the samples) and is strongly negatively associated with samples in the other group (occurs in <20% of the samples).

Shannon's Diversity Index was used to calculate the species diversity (a measure of species richness and evenness) of each sample plot, which is considered to provide an index of *alpha* diversity. Shannon's Diversity Index (H) is given as:

$$H = - \sum P_i \ln P_i$$

where P_i is the proportion of total cover of the ith species. Shannon's Diversity Index is presented for each community type identified in this study as well as for the wetland habitats as a whole in each of the four focal areas.

Similarly, Simpson's Diversity Index was used to represent the habitat diversity (*beta* diversity) of communities within each of the four focal areas. Simpson's Diversity Index (S) is given as:

$$S = 1 / \sum P_i^2$$

where P_i is the proportional frequency of the ith community in relation to the total number of communities present in each focal area.

Despite the strong focus by the rest of the AquaRAP team on wetland communities, island communities were also sampled by the botanical contingent, as these habitats are intimately linked to the wetlands themselves. The island fringe vegetation has its roots in the water table and is thus directly affected by flooding conditions and water quality. The island interior communities are solute sinks that represent the end points of evapotranspirational water loss from the system that takes place largely on the island fringes (McCarthy and Metcalfe 1990; McCarthy et al 1991; Ellery et al. 1993).

Data from other sources

Supplementary data on the flora of the Okavango Delta (Appendix 7) were obtained from a list compiled by Mr. P. A. Smith as part of the Okavango Ecozoning Report (SMEC 1989) as well as from data supplied by the National Botanical Institute of South Africa, using data from the National Herbarium and the Pretoria Computerized Information System (PRECIS).

A study entitled "Floristic diversity of the Okavango Delta, Botswana as an endogenous product of biological activity" (Ellery et al. 2000) was published soon after the AquaRAP expedition, having been prepared shortly before the AquaRAP expedition. Some of the material that is presented as part of this report was taken from the publication of Ellery et al. (2000) in view of the extensive overlap between the two studies. However, readers are encouraged to read the publication as it presents a somewhat different perspective on the floristic diversity of the Okavango Delta system than is presented here, particularly in that it provides greater insight into the environmental determinants of landscape level heterogeneity as well as the origin of the underlying environmental heterogeneity of the system.

Throughout the study, nomenclature follows Arnold and de Wet (1993). Whenever possible, the English and Setswana names of plants have also been provided.

RESULTS

Semi-quantitative vegetation surveys were undertaken at a total of 130 sample plots within the four focal areas (Upper Panhandle, Guma Lediba (Lake), Moremi Game Reserve, and Chief's Island; see Appendix 8). The surveys revealed that the number of wetland plant species within each of the focal areas varied between 60 and 73, while the number of species on islands varied between 45 and 83 (Table 5.1). In the cases of both wetland and island vegetation, the greatest number of species was found in the Moremi Game Reserve. A total of 116 plant species was recorded from the Upper Panhandle, 115 from the Guma Lediba (Lake) area, 144 from Moremi Game Reserve, and 110 from the Chief's Island area (Table 5.1). A high proportion (233 species or about 20%) of the approximately 1250 plant species known from the Delta (Ellery et al. 2000) were encountered in the formal vegetation sampling exercise during this brief cool-season survey.

A list of species encountered in each sample plot and estimates of their percentage cover are presented in Appendix 8 and a full list of species encountered in this study is presented in Appendices 7 and 9. No attempt has been made in this study to describe the species composition of each and every sample plot, but a general description of each of the major habitats in each of the four focal areas is provided in the following section.

Table 5.1. Number of wetland and riparian woodland (island) sample plots and plant species encountered in each of the four main study areas of the AQUARAP survey, Okavango Delta.

	Upper Panhandle	Guma Lebida (Lower Panhandle)	Moremi Game Reserve	Chief's Island
No. wetland samples	31	20	30	25
No. wetland species encountered	72	66	73	60
No. riparian woodland samples	3	4	9	8
No. riparian woodland species encountered	45	60	83	58
Total no. species encountered	**116**	**115**	**144**	**110**

VEGETATION SUMMARY WITHIN EACH FOCAL AREA

Upper Panhandle

Background

The Okavango River enters Botswana at the town of Mohembo, and in the stretch between Mohembo and Seronga, the Okavango River is confined in a narrow (15 km wide) depression that is a consequence of faulting. The Okavango is a large river with a mean annual discharge of approximately 11 000 million cubic metres, although annual inflows have varied from approximately 6 000 million cubic metres to approximately 16 400 million cubic metres over the last 60 years (McCarthy et al. 2000).

In its upper reaches within the Panhandle, the Okavango River is meandering, which means that erosion takes place on the concave banks of meander bends (cut banks), while deposition of sediment takes place on the convex banks of meander bends, giving rise to depositional features known as point bars. During especially high flows, deposition on the convex banks leads to the creation of elevated depositional features known as scroll bars that are oriented sub-parallel to the channel margin. As a consequence of this combination of erosion and deposition, the channel gradually migrates across the floodplain. Such migration may lead to the formation of oxbow lakes that are isolated from the main channel.

Migration of the channel across the floodplain is associated with sedimentation over the entire region of the meander belt, leading to the creation of an elevated alluvial ridge along which the river flows. Areas removed from the channel are starved of sediment and they therefore occupy flood basins at lower elevation than the main alluvial ridge where flow and sedimentation take place. This leads to channel instability and may cause the channel to change its course by natural diversion into a region of lower elevation (Smith et al. 1998).

Most of the sediment introduced into the Okavango Delta comprises fine sand that is transported by being rolled or bounced along the channel bed (bedload sediment). Approximately 170 000 tons of bedload sediment is introduced into the system each year. A small proportion of the incoming sediment is clay that is transported in the water column as suspended load (approximately 30 000 tons). The bed-load is deposited along the channel - mainly in depositional features on the convex side of channel bends (point bars). The clay sediment is more widely dispersed across the alluvial ridge.

The disturbance regime that is created by channel migration and sediment deposition means that vegetation in close proximity to the channel is at an early successional stage (Diederichs and Ellery 2000).

Given this background it is appropriate to provide a general description of the habitats and flora of the Upper Panhandle, as seen during the present study.

Description of the focal area

The AquaRAP botanical team made observations of wetland vegetation at 31 sample plots in this focal area and recorded 72 wetland plant species (Table 5.1). The most common plant species encountered (Table 5.2) were *Cyperus papyrus* (papyrus; *koma*; from 14 sample plots), *Vossia cuspidata* (hippo grass; *mojakubu*; 13 plots), *Ipomoea rubens* (12 plots), *Lagarosiphon muscoides* (oxygen weed; 11 plots), *Nymphaea nouchali* (water lily; *tswii*; 9 plots) and *Persicaria senegalensis* (snake root; 9 plots).

In general, plant diversity was not particularly high in the Upper Panhandle, with a mean species richness in each of the wetland samples of 7.5, and a Shannon's Diversity Index of 1.1 (Table 5.3).

Areas flooded to shallow depth were dominated by *Vossia cuspidata* (hippo grass; *mojakubu*). Vegetation in an open-water lediba (lake) included *Nymphaea lotus* (white water lily; *tswii*) and *N. nouchali* (blue water lily; *tswii*) and extensive beds of submerged *Ceratophyllum demersum* (water hornwort). Fringing the ledibas (lakes) were floating mats of sedges dominated by *Pycreus mundii* and *P. nitidus*.

Channels, channel margins, and channel fringes[2]: Channels in the Upper Panhandle were unvegetated due to the high clastic sediment load (sand, silt and clay) that enters the system. It is mainly fine sand that is transported by being rolled or bounced along the river bed ("bed load"). This creates instability that makes colonization of the channel bed difficult.

[2] The term "channel margin" here refers to the region of the channel where water depth decreases.

Table 5.2. Most frequently encountered species in each of the four focal areas and their frequency of occurrence (F = number of plots in which species was recorded).

Upper Panhandle		Guma Lagoon (Lower Panhandle)		Moremi Wildlife Reserve		Chief's Island	
Species	**F**	**Species**	**F**	**Species**	**F**	**Species**	**F**
Cyperus papyrus	14	*Cyperus papyrus*	10	*Miscanthus junceus*	14	*Cyperus articulatus*	25
Vossia cuspidata	13	*Ludwigia leptocarpa*	8	*Leersia hexandra*	12	*Nymphaea nouchali*	22
Ipomoea rubens	12	*Thelypteris interrupta*	8	*Nymphaea nouchali*	11	*Leersia hexandra*	19
Lagarosiphon muscoides	11	*Pycreus mundii*	8	*Eleocharis dulcis*	11	*Schoenoplectus corymbosus*	14
Nymphaea nouchali	9	*Panicum repens*	6	*Pycreus nitidus*	11	*Ludwigia stolonifera*	14
Persicaria senegalensis	9	*Ceratophyllum demersum*	6	*Cyperus articulatus*	8	*Potamogeton thunbergii*	13
Utricularia sp.1	9	*Miscanthus junceus*	5	*Fuirena pubescens*	8	*Najas horrida*	12
Phragmities mauritianus	8	*Cyperus denudatus*	5	*Brasenia schreberi*	8	*Eleocharis dulcis*	11
Ceratophyllum demersum	7	*Trapa natans*	5	*Cyperus pectinatus*	7	*Oryza longistaminata*	11
Leersia hexandra	6	*Hibiscus diversifolius*	5	*Ficus verriculosa*	7	*Lagarosiphon muscoides*	10
Ludwigia stolonifera	6	*Nymphaea nouchali*	4	*Thelypteris interrupta*	7	*Persicaria meisnerianum*	10
Pennistem glaucocladum	6	*Schoenoplectus corymbosus*	4	*Typha capensis*	7	*Paspalidium obtusifolium*	9
Pycreus mundii	5	*Ipomoea rubens*	4	*Utricularia* sp.1	7	*Panicum repens*	7
Aeschynomene fluitans	5	*Cyperus pectinatus*	4	*Ludwigia leptocarpa*	6	*Ottelia ulvifolia*	7
Floscopa glomerata	5	*Typha capensis*	4	*Lagarosiphon muscoides*	6	*Sacchiolepis typhura*	7
Nymphaea lotus	5	*Thelypteris confluens*	4	*Schoenoplectus corymbosus*	4		
Azolla sp.	5	*Vigna luteola*	4	*Potamogeton thunbergii*	4		
Echinochloa pyramidalis	5	*Brachiaria humidicola*	4	*Nymphoides indica*	4		
Persicaria meisnerianum	5			*Thelypteris confluens*	4		

Table 5.3. Mean species richness and Shannon's diversity index (and standard deviations, STD) for wetland habitats within the four study areas of the AquaRAP survey and for island woodlands.

	Upper Panhandle	Guma Lebida	Moremi Wildlife Reserve	Chief's Island	Island Woodlands
Species Richness					
MEAN	7.5	8.7	9.4	11.2	15.8
STD	4.7	4.3	5.3	3.0	8.6
Shannon's Diversity Index					
MEAN	1.1	1.3	1.6	1.7	2.0
STD	0.6	0.6	0.5	0.4	0.6

For much of the Upper Panhandle, the current velocity in the channel fringe was relatively high, and the channel fringe therefore contained many submerged aquatic plants. Where elevated above water level, the tall emergent grasses *Echinochloa pyramidalis* (Limpopo grass) and *Phragmites mauritianus* dominated the plant community. *Pennisetum gaucocladum* (riverbank pennisetum; *lebelebele*) was found growing on elevated clay-rich levees. Higher species diversity was found along the channel fringe than in the backswamps, likely as a consequence of higher habitat heterogeneity within the channel fringe, where local relief and flow conditions are variable. The slow-flowing hippo trails and channels comprised a diverse assemblage of floating-leaved and emergent aquatic plants such as *Ceratophyllum demersum* (water hornwort), *Lagarosiphon muscoides* (oxygen weed), *Nymphaea nouchali* (blue water lily; *tswii*) and the floating legume *Aeschynomene fluitans*. *Nymphaea lotus* (lotus lily) was also a common element. The banks of these habitats were dominated by species such as *Cyperus papyrus* (papyrus; *koma*), *Ludwigia stolonifera* (willow herb), *Persicaria senegalensis* (snake root), *Phragmites mauritianus* and *Vossia cuspidata* (hippo grass; *mojakubu*).

Backswamps: The backswamps tended to be dominated by either the emergent grass *Echinochloa pyramidalis* (Limpopo grass), which formed dense, essentially monospecific stands, or by *Vossia cuspidata* (hippo grass; *mojakubu*). The wild rice *Oryza longistaminata* (wild rice) and vast beds of *Cyperus papyrus* (papyrus; *koma*) rooted in peat deposits were also common in the backswamps. Species richness was relatively low due to the dominance of these species in monospecific stands. The swamp vegetation adjacent to the irrigation off-take was dominated by luxuriant stands of the giant sedge *Cyperus papyrus* (papyrus; *koma*).

Channel islands (sand bars): Dense beds of the reed *Phragmites mauritianus* and *Sacciolepis typhura* (purple hood grass), and emergent grasses *Vossia cuspidata* (hippo grass; *mojakubu*) dominated submerged areas fringing a channel island. *Leersia hexandra* (rice grass; *mokanja*), *Ipomoea rubens, Oryza longistaminata* (wild rice), *Pennisetum glaucocladum* (riverbank pennisetum; *lebelebele*), and *Persicaria meisnerianum* were present with high cover in slightly more elevated areas, while the island itself was dominated by *Acacia hebeclada* (candle thorn; *setshi*), which is typical of early stages of terrestrial vegetation succession.

Scroll bars: Scroll bars are elevated depositional features that occur in the channel fringes on the inner bends of meandering channels. The vegetation zonation of sandy scroll bars reflected the depth and duration of flooding and the age of the bars. Typically the youngest scroll bars occur closest to the channel while older bars occur further away, with a concentric arrangement that is sub-parallel to the inside (concave) bends of the channel. The scroll bar vegetation was dominated by emergent grasses such as *Vossia cuspidata* (hippo grass; *mojakubu*) and *Echinochloa pyramidalis* (Limpopo grass) and, in the case of the youngest vegetated feature, by sedges. Older scroll bars were dominated by the emergent grass *Pennisetum glaucocladum* (riverbank pennisetum; *lebelebele*), with *Acacia hebeclada* (candle thorn; *setshi*) on the oldest bars, which appeared to be several decades old.

Terrestrial islands: Islands in the Upper Panhandle are remarkably diverse, being dominated in places by *Acacia nigrescens* (knobthorn; *mokoba*), but also by *Diospyros mespiliformis* (jackal berry; *mokhutsomu*) and by species of fig (*Ficus* spp.). The baobab (*Adansonia digitata*; *mosu*) was seen on several islands, while trees that occur less frequently included *Berchemia discolor* (bird plum; *motsentsela*) *Croton megalobotrys* (large fever berry; *motsebe*), *Garcinia livingstonei* (African mangosteen; *motsaudi*), *Lonchocarpus capassa* (raintree; *mopororo*), *Phoenix reclinata* (wild date palm; *tsaro*), *Rhus tenuinervis* (Kalahari currant; *morupaphiri*) and *Terminalia prunioides* (purple-pod terminalia; *motsiara*). The understorey includes a variety of shrubs, herbs and grasses. Important shrubs included *Capparis tomentosa* (wooly caper bush, *matowana*), *Combretum mossambicense* (knobbly combretum; *motsweketsane*), *Dichrostachys cinerea* (sickle bush; *moselesele*), *Diospyros lycioides* (blue bush; *letlhajwa*), *Fleuggea virosa* (white-berry bush; *mala-aditlhapi*), *Grewia* spp., *Hippocratea africana* var. *richardiana* (paddle pod), *Pechuel-loeschea leubnitziae* (*mokodi*) and *Ximenia Americana* var a*mericana* (small sourplum; *moretologane*). A wide variety of herbs and grasses were present, with shade tolerant species such as *Enteropogon macrostachyos* (mopane grass), *Panicum maximum* (Guinea grass; *mhaha*) and *Setaria verticillata* (burr bristle grass; *bogoma*) being common in the wooded island fringes, while species that occur in open areas included *Sporobolus* spp., including *S. spicatus* (*tshunga*).

Guma Lediba (Lake or Lagoon)

Background

Guma Lediba (Lake) is situated in the vicinity of the Thaoge Channel that, during the 1800s, was the major distributary channel of the Okavango Delta. This river flowed down the western side of the Delta into Lake Ngami on the southern fringe of the Delta, and when the famous explorer David Livingstone travelled to the lake in 1849 the lake was a vast feature supplied with water via the Thaoge River. The blockage of the Thaoge River (Figure 5.2) is well documented, having been accompanied by natural diversion of water at its head into the Nqoga River via a series of hippo trails (Wilson and Dincer 1976).

However, this channel avulsion was preceded by the gradual blockage of the channel by the giant sedge *Cyperus papyrus* (papyrus; *koma*) that grows from the fringes into the channel. The extent of encroachment is limited by current velocity (Ellery et al., 1995). As papyrus grows into the channel, it is broken off from the margin by the current where velocity is sufficiently high (Ellery et al. 1995). The papyru*s* debris coalesces into large rafts that increase in size as debris drifts downstream. Eventually the size of the rafts approaches channel width, and the channel is blocked. Papyrus grows vegetatively in these debris blockages, and eventually the entire channel is covered and blocked by living papyrus in more-or-less monospeific stands (McCarthy et al. 1986). Blockage of the channel in this way is usually preceded by extensive growth in the channel of the hippo grass *Vossia cuspidata* (hippo grass; *mojakubu*).

The underlying reason for avulsion is sedimentation, as bed-load sediment entering the system is deposited primarily along the bed of major distributary systems. Deposition of sediment in this way causes the bed of the channel to rise (aggrade). Aggradation of the channel is accompanied by aggradation of the channel bank due to the accumulation of peat. This combination of processes reduces the slope of the channel in an upstream direction and increases the hydraulic slope at right angles to the channel axis by creating an alluvial ridge. Blockage of the channel by *Vossia cuspidata* (hippo grass; *mojakubu*) initially, and then by *Cyperus papyrus* (papyrus; *koma*) is therefore a symptom of channel aggradation and failure, with sustained water loss from the channel taking place. The Nqoga River, presently the primary distributary channel in the Okavango Delta, is currently experiencing failure in its lower reaches, with water increasingly being diverted into the Maunachira and Khiandiandavhu Rivers further to the north (Figure 5.2).

Blockage of the Thaoge River happened gradually from the 1870s, and today the Thaoge river seldom flows more than one third of its original length. Drying of the peat deposits flanking the channel resulted in the occurrence of peat fires, which destroy the original plant communities and peat deposits (Ellery et al. 1989). This releases nutrients into the soil, which improves forage quality and, in the case of the Thaoge River, increases utilization of the forage resources by cattle. More recently there has been cultivation of crops

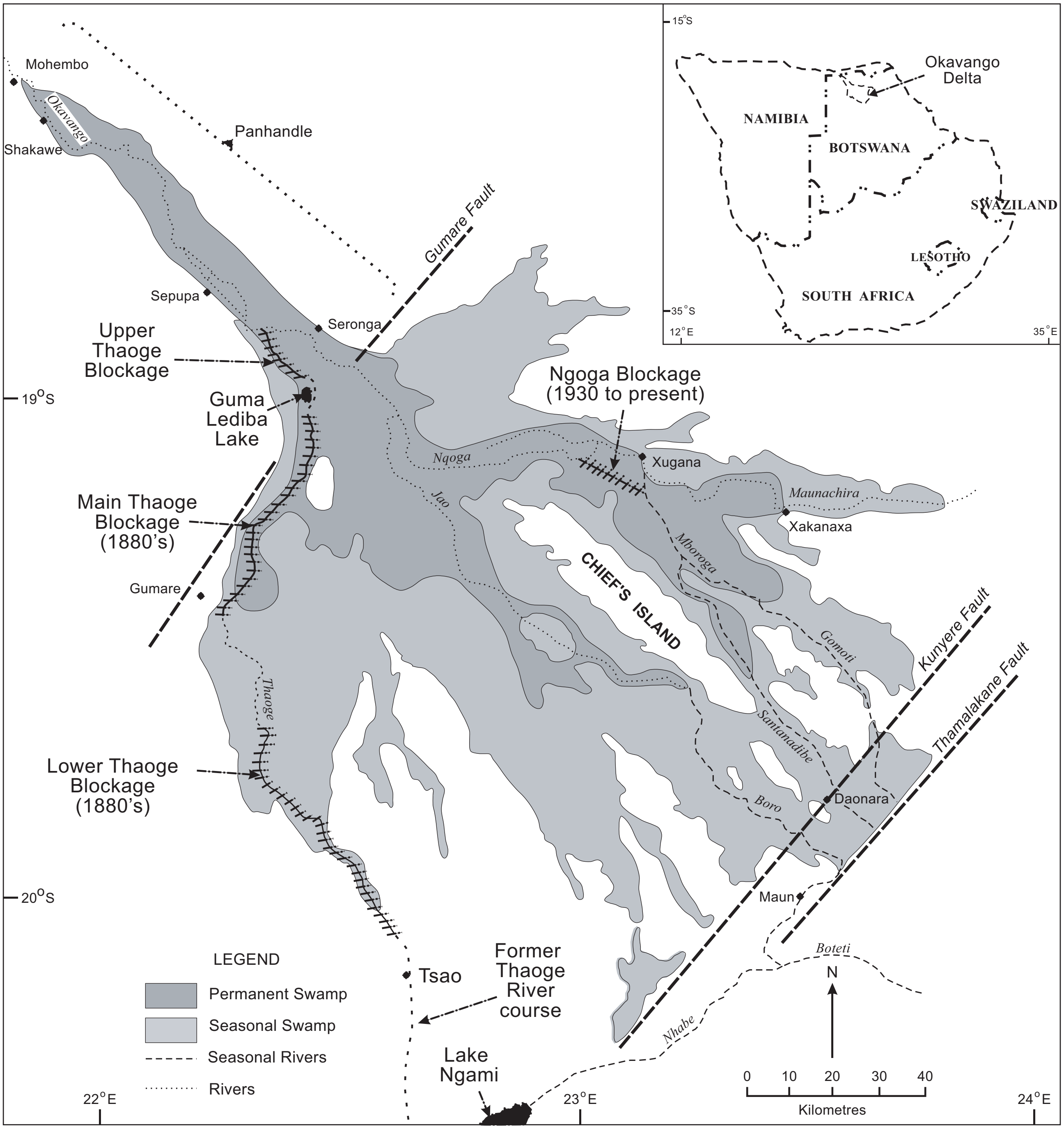

Figure 5.2. Map of the Okavango Delta showing the distribution of the major channel blockages that have occurred over the last 150 years.

such as tropical fruit and sugar cane in this area as a consequence of the elevated soil fertility associated with former burning of peat deposits in such peat fires.

Apart from Maun, people that live on the fringe of the Delta occur on the southern side of the Panhandle and also on the western side of the Delta - west of the Thaoge River. Water shortages in this region as a consequence of the processes described above, have resulted in attempts to restore flow down the western side of the Okavango Delta - along the Thaoge River. There is also pressure from tour operators to do the same. Hence there is ongoing channel clearance in the vicinity of Guma Lediba (Lake). Such channel clearance will have to be ongoing since the gradient along the Thaoge

River is too low to maintain current velocities sufficiently high to prevent papyrus growth.

A second feature that is important from an ecological point of view is that the avulsion of the Thaoge into the Nqoga River is still resulting in local drying and therefore organic matter decomposition of former peat deposits. This leads to oxygen consumption in the shallow backswamps. As a consequence of a gentle southward slope on the water surface in this area, anaerobic water periodically enters ledibas (lakes) from decomposing peat deposits to the north and may lead to high fish mortalities. This is likely to happen most frequently during the time of the incoming floodwaters in April and May.

A sign of large inputs of organic detritus from these backswamps is the presence of the floating leaved *Trapa natans* (water chestnut; *ekota*) on the northern margins of ledibas (lakes) in this area. The distribution of *Trapa natans* is restricted to areas where there is an input of fine organic detritus into open water bodies. It therefore typically occurs where slow-flowing channels and hippo trails enter areas of standing water such as ledibas (lakes). Its widespread occurrence on the northern margins of areas of open water in the vicinities of Guma Lediba (Lake) is a consequence of fine organic detritus entering those areas via shallow southward flow of water across peat-dominated backswamps to the north.

Given this background, it is appropriate to describe the botanical characteristics and range of habitats visited during the AquaRAP study.

Description of the local area

A total of 115 species was recorded from 24 sample plots (Table 5.1) in the vicinity of Guma Lediba (Lake), with 66 species in 20 sample plots in wetland sites and 60 species in 4 sample plots on islands. The most common species (Table 5.2) were *Cyperus papyrus* (papyrus; *koma*; from 10 sample plots), *Ludwigia leptocarpa*, *Pycreus mundii* and *Thelypteris interrupta* (bog fern; *kwena*; all from 8 plots).

Mean species richness per sample was relatively low at 8.7 species per sample and a Shannon's Diversity Index of 1.3 (Table 5.3).

Ledibas (lakes) and open backwaters and their margins: The submerged plant *Ceratophyllum demersum* (water hornwort) was common in areas of open water, while floating-leaved plants were common as water depth declined, particularly the water chestnut *Trapa natans* (water chestnut; *ekota*) that occurred on the northern margins of lakes and deeply flooded backwaters, and the water lily *Nymphaea nouchali* (blue water lily; *tswii*), which was also notable in areas of open water. Floating mats of emergent vegetation were common adjacent to areas of open water, being dominated by the sedge *Pycreus mundii*.

Channels, channel fringes and channel margins: Along the Thaoge Channel, papyrus dominated the fringes and had been recently burned in some areas, while most open-water areas were fringed by papyrus, *Ludwigia leptocarpa,* and *Thelypteris interrupta* (bog fern; *kwena*).

Back swamps: Beyond the locally dominant papyrus fringes of ledibas (lakes) and channels, the permanently flooded backswamp was dominated by *Cyperus denudatus* (*tototwane*), *Miscanthus junceus* (swamp savanna grass; *moxa*) and *Hibiscus diversifolius* (prickly tree hibiscus).

Seasonally inundated floodplains: The grass species *Eragrostis inamoena* and *Panicum repens* (couch panicum) dominated flooded grasslands in the vicinity of the camp at Guma Lediba (Lake). *Crinum* lilies were distributed throughout the floodplain.

Terrestrial islands: Typical island vegetation was recorded at the edge of Guma Lediba (Lake) near the Department of Water Affairs Landing Site, as well as on the island where the campsite is situated. The predominant grass in the open areas was *Cynodon dactylon* (couch grass; *motlhwa*), and trees that were typical included *Phoenix reclinata* (wild date palm; *tsaro*), *Ficus sycomorus* (sycomore fig; *motshaba*) and *Syzygium cordatum* (water berry; *kowa*).

Moremi Game Reserve

Background

The wetland habitats in the vicinities of Xakanaxa and Gadikwe Madiba (Lakes) are in the lower reaches of the permanent swamps in an area that has received greatly increased inundation over the past 60-70 years as a consequence of avulsion of the Lower Nqoga River since the 1930s (Figure 5.2; Smith 1976; Wilson and Dincer 1976). Therefore this region can be considered to represent vegetation succession phases that are anything up to 70 years old, and many areas are subject to unusual successional processes involving the establishment of floating organic rafts and mats that are colonized by a variety of species, particularly by the sedge *Pycreus nitidus* that stabilizes and consolidates the organic mats (Ellery et al. 1990). Later successional phases involve colonization by *Miscanthus junceus* (swamp savanna grass; *moxa*), at which stage the floating mats become anchored to the sandy substratum. Ongoing succession leads to the establishment of a short emergent bog community in which there are no dominant species, and in which species richness is very high (Ellery et al. 1991). This community invariably includes the grass *Imperata cylindrica* (flame grass; *kwenyama*) and *Ficus verruculosa* (water fig; *komoti*)

Because of the fact that this area has been recently inundated, many madiba (lakes) exist in the region, including Xakanaxa, Gadikwe, Gobega and Xhamu. These are connected by a system of channels in which there is little or no sediment movement. As such the channels are well vegetated, usually including the submerged species *Nesaea crassicaulis* and *Rotala myriophylloides* and floating leaved species *Brasenia schreberi* (water shield)*, Nymphaea nouchali* (blue water lily; *tswii*) and *Nymphoides indica* (floating heart). The channel margins are typically dominated by *Miscarthus junceus* (swamp savanna grass; *moxa*)*,* although *Ficus* *verruculosa* (water fig; *komoti*) and *Syzygium cardatum* (water berry; *kowa*) became increasingly common downstream.

Following this brief description of the general characteristics and flora of this focal area, a more detailed description of habitats and this flora is provided.

Description of the focal area

Greatest plant diversity was recorded from this focal area, with 144 species observed at 39 vegetation sample plots (Table 5.1). Of these species, 73 occurred in wetland settings, while 83 occurred in terrestrial settings. The most common plant species encountered included *Miscanthus junceus* (swamp savanna grass; moxa; from 14 sample plots), *Leersia hexandra* (rice grass; *mokanja*; 12 plots), *Eleocharis dulcis* (*moxhitwana*), *Nymphaea nouchali* (blue water lily; *tswii*) and *Pycreus nitidus*, each from 11 plots (Table 5.2).

Species richness of samples was moderate to high in this focal area, with mean species richness per sample of 9.4 and a Shannon's Diversity Index of 1.6 (Table 5.3).

Ledibas (lakes) and open backwaters and their margins: In Gadikwe Lediba (Lake), a heronry was situated in vegetation dominated by *Ficus verruculosa* (water fig; *komoti*), which had extremely high cover. A floating mat of *Pycreus mundii* fringed the dense stand of water fig with a number of species colonizing this mat from the side of the water fig, including *Thelypteris interrupta* (bog fern; *kwena*) and several sedges including *Oxycaryum cubense* and *Pycreus nitidus*.

The open water of Gadikwe Lediba (Lake) was sparsely vegetated, mainly by the submerged aquatic *Ceratophyllum demersum* (water hornwort). Other species in the lake that were present at extremely low densities and with low cover included emergent sedges *Cyperus articulatus* (*moxodwa*) and *Schoenoplectus corymbosus* (mat sedge), as well as the submerged macrophyte *Najas horridus* (saw weed). The vegetation on the eastern side of the lediba (lake) was sparse, comprising a small number of aquatic plants such as the blue water lily *Nymphaea nouchali* (*tswii*), and the water shield *Brasenia schreberi*, as well as the emergent sedges *Cyperus articulatus* (*moxodwa*) and *Eleocharis dulcis* (*moxhitwana*).

The open water habitat gave way to the lake fringe that was very diverse, comprising woody emergent plants *Ficus verruculosa* (water fig; *komoti*) and *Syzygium cordatum* (water berry; *kowa*). *Miscanthus junceus* (swamp savanna grass; *moxa*) was present with high cover, as was the sedge *Fuirena pubescens*.

Xakanaxa Lediba (Lake) was sparsely vegetated with just the submerged species *Ceratophyllum demersum* (water hornwort) and *Najas horridus* (saw weed). Fringing the lediba (lake) in the open water habitat, the floating-leaved plants *Nymphaea nouchali* (blue water lily; *tswii*) and *Brasenia schreberi* (water shield) were present at low cover, together with emergent sedges *Eleocharis acutangular* (*moxhitwana*) and *E. dulcis* (*moxhitwana*). The lediba (lake) fringe was dominated by dense stands of *Miscanthus junceus* (swamp savanna grass; *moxa*), and this gave way to an open community of emergent grasses and sedges, especially *Pycreus nitidus*.

Channels, channel fringes and channel margins: The Maunachira Channel is known to support a diverse flora – both within the channel itself as well as in the channel fringe (Ellery et al. 1990). In some areas, the vegetation along the Maunachira Channel consisted of a few submerged plants (*Nesaea crassicaulis* and *Eichhornia natans*) growing on a submerged sandbank. A few isolated plants of the free-floating aquatic weed *Salvinia molesta* (Kariba weed) and scattered plants of the emergent *Eleocharis dulcis* (*moxhitwana*) were also noted along the channel margins. Where water depth is great and current velocity low, the channel is typically dominated by *Nesaea crassicaulis* and *Rotala myriophylloides*.

The flora of smaller channels was generally similar that of larger channels, with the exception that the submerged aquatic *Rotala myriophylloides* may be present with slightly higher cover than *Nesaea crassicaulis*.

The channel fringes were dominated by *Miscanthus junceus* (swamp savanna grass; *moxa*), giving way in the backswamp to a diverse bog community dominated by *Imperata cylindrica* (flame grass; *kwenyama*) associated with *Miscanthus junceus* (swamp savanna grass; *moxa*).

Shallow pools fringing the mainland: Paradise Pools is an area of open water that is flooded to a fairly shallow depth to the east of Xakanaxa Lediba (Lake). It is apparently the only area within the Okavango Delta where the invasive waterweed *Salvinia molesta* is abundant. The distribution of this plant is locally confined to a relatively small area of densely vegetated grassland and sedge land, with an overhanging fringe of terrestrial trees. Because of these features, most of the water surface in the area where *S. molesta* was most abundant was shaded. *Salvinia molesta* (Kariba weed) did not occur at particularly high densities or at high abundance. According to Dr. Naidoo of the Botswana Department of Water Affairs (pers. comm.), this is due to the introduction of the Brazilian beetle *Cyrtobagus salviniae* that preys exclusively on *Salvinia molesta* and forms the focus of a biological control programme against this invasive waterweed. The indigenous wetland vegetation in the general area of the site is diverse, and comprised over 20 species within a sample area of approximately 20 metres by 20 metres. *Miscanthus junceus* (swamp savanna grass; *moxa*), *Oryza longistaminata* (wild rice) and *Pycreus nitidus* were present with highest cover. A striking feature of the site was the strong smell of urea in the water, and the site seemed superficially to be very productive, as all the plants appeared to be greener and more luxuriant than other similar sites in the area. The presence of abundant green algae growing epiphytically on the submerged stems of aquatic vegetation suggested local eutrophication.

Seasonally inundated floodplains: Seasonally flooded shallow pools and floodplains along the abandoned Xakanaxa airstrip contained a diverse flora, including emergent grasses and sedges. The fringing grassland was dominated by *Imperata cylindrica* (flame grass; *kwenyama*) with high cover, but the vegetation here was a diverse mix of grasses, sedges and herbs, albeit that most species were present with low cover.

Jesse's Pool is a similar shallow seasonal floodplain fringing a series of permanent pools. The inundated portion of the floodplain was relatively species rich, with *Cynodon dactylon* (couch grass; *motlhwa*) being most abundant. The annual *Urochloa mossambicensis* (bushveld signal grass; *phoka*) was locally abundant, as was the sedge *Oxycarium cubense*. The insectivorous bladderwort *Utricularia*, and the aquatic fern *Marsilea* were also found at this site.

An unusual permanently flooded pool contained vast areas of *Colophospermum mopane* (mopane; *mophane*) woodland. The dominant grass was *Cynodon dactylon* (couch grass; *motlhwa*), which had been largely killed by the floodwaters. There was thus a considerable amount of dead and decomposing material in the water. As such, vegetation cover was low, and species diversity was low. However, in contrast to the flooded area, the fringing grassland was very species rich with approximately 30 species encountered within an area of approximately 400 square metres. *Cynodon dactylon* (couch grass; *motlhwa*) was present with highest cover, and other species (mainly herbs) were present at covers of less than 10%.

Terrestrial islands: The islands had a high cover of broadleaved evergreen trees as well as deciduous trees, with no single dominant species. Herbs and shrubs were well represented in the understory. Species that were common in the upper canopy stratum included broadleaved evergreen species closest to the island edge; *Croton megalobotrys* (large fever berry; *motsebe*), *Diospyros lycioides* (blue bush; *letlhajwa*), *Diospyros mespiliformis* (jackal berry; *mokhutsomu*), *Ficus thoinningii* (common wild fig; *moumo*), *Garcinia livingstonii* (African mangosteen; *motsaodi*), *Lonchocarpus capassa* (rain tree; *mopororo*), and *Syzygium cordatum* (water berry; *kowa*). The wild date palm *Phoenix reclinata* (wild date palm; *tsaro*) also occurred close to the island edge. Deciduous species tended to dominate vegetation further towards the centres of islands, including *Acacia nigrescens* (knobthorn; *mokoba*), *Berchemia discolor* (bird plum; *motsentsela*), *Combretum imberbe* (leadwood; *motswere*), *Combretum mossambicense* (Mozambique combretum; *motsweketsane*), *Lannea schweinfurthii,* and *Sclerocarya birrea* (marula). The ivory palm *Hyphaene petersiana* (real fan palm; *mokolwane*) occurred on the interior edge of the riparian woodland, giving way to a relatively barren island interior in which the grass *Sporobolus spicatus* (*tshunga*) is the only species present. Grasses that typically occurre in the shade of the deciduous tree zone included *Panicum maximum* (Guinea grass; *mhaha*) and *Setaria verticallata* (burr bristle grass; *bogoma*), while the outer periphery of the island includes grasses such as *Cynodon dactylon* (couch grass; *motlhwa*), *Setaria sphacelata* (golden bristle grass; *mabele*), and *Sorghastrum friesii* (Fries' grass). The interior regions were characterized by grass species such as *Aristida congesta* (tassel three-awn; *seloka*), *Eragrostis pallens,* and *Eragrostis superba* (sawtooth lovegrass; *mogamapodi*), while *Sporobolus spicatus* (*tshunga*) occurred in the largely barren island interiors.

Saline Pans: A large saline pan was sampled near Paradise Pools, located in the center of an island where "ntsonga" (sodium carbonate and sodium bicarbonate salts) had accumulated as a consequence of the movement of water from the groundwater to the soil surface by capillary attraction and its evaporation from the soil surface. Localized rainfall concentrates these salts locally in depressions in the center of islands, where they occur at sufficiently high concentrations to poison all but the hardiest grasses and sedges, of which *Sporobolus spicatus* (*tshunga*) is the best known.

Chief's Island

Background

The final focal area in the vicinity of Chief's Island is primarily a seasonal swamp habitat – albeit in the upper seasonal swamps. It is an important habitat for wildlife, especially during the dry winter months when the surrounding terrestrial habitats are devoid of surface water. At this time, wildlife tends to concentrate on the seasonal swamps where surface water is present in abundance.

This region of the Okavango Delta has been the focal area of tourism development, primarily for its scenery and wildlife populations, but also because it is relatively easily accessible by air charter from Maun.

Although this area is seasonally flooded, the Boro River is a relatively permanently flooded feature, drying only during exceptionally dry years. However, away from the Boro River, most areas can be considered seasonally inundated.

Perhaps the most notable feature from a botanical perspective is the virtual absence of the wild date palm *Phoenix reclinata* (wild date palm; *tsaro*), which requires permanent flooding in the root zone. However, the ivory palm, which indicates moderately saline conditions, is ubiquitous – occasionally dominating island vegetation completely. This pattern of vegetation distribution reflects the general downstream increase in the concentration of dissolved salts in surface and groundwater in the system as a consequence of evaporative loss of water from the wetlands. However, the increase in solute concentration does not reflect the amount of water loss to the atmosphere by evapotranspiration, because transpiration is the dominant means of water loss (McCarthy et al. 1993).

Following this brief overview of the area, the habitats in this area and their floras will be described.

Description of the focal area

At this site, vegetation distribution is controlled by elevation. Given that water level fluctuations are in the region of 1.5 m in this part of the system, the effects of variation in the depth and duration of flooding on vegetation zonation patterns is striking.

Plant diversity was modest in this focal area, with 110 plant species documented from 33 vegetation sample plots (Table 5.1). Several plant species were common in that they occurred in many sample plots (Table 5.2), but they were seldom present with high cover. These species included *Cype-*

rus articulatus (*moxodwa*; from 25 sample plots), *Nymphaea nouchali* (blue water lily; *tswii*; 22 plots), *Leersia hexandra* (rice grass; *mokanja*; 19 plots) and *Ludwigia stolonifera* (willow herb; 14 plots), *Potamogeton thunbergii* (broad-leaved pondweed; 13 plots), and *Najas horrida* (saw weed; 12 plots).

Local level species richness was high with a mean value of 11.2 species per sample and a mean Shannon's Diversity Index of 1.7 (Table 5.3).

Ledibas (lakes) and open backwaters: Open water areas of ledibas (lakes) (water depth > 1.5 metres) were often dominated by the submerged and floating-leaved species *Najas horridus* (saw weed) and *Nymphaea nouchali* (blue water lily; *tswii*), respectively. Species richness was generally low. The floating leaves of the water lily *Nymphaea nouchali* (blue water lily; *tswii*) covered much of the open water areas, and these plants appeared to be very productive and vigorous, with unusually large and brightly coloured leaves. This was unusual, as the growth of this species at the other three focal areas (Upper Panhandle, Guma Lediba and Moremi Game Reserve) was more typical of the cool season habit where leaves appear senescent and dead as this species typically over-winters by losing its leaves, and re-growth takes place in the spring (October to December).

A shallow entry channel to one lediba (lake), approximately 1.5 metres deep, was colonized by a species-rich flora with relatively high cover (>10%) of the submerged plants *Lagarosiphon muscoides* and *Najas horridus* (saw weed). The floating-leaved plant *Nymphaea nouchali* (blue water lily; *tswii*) and the emergent sedge *Eleocharis dulcis* (*moxhitwana*) were common, each contributing some 5-10% to the total vegetation cover. Between the channel and the adjacent lediba (lake), a diverse assemblage of species was present with *Nymphaea nouchali* (blue water lily; *tswii*) and *Schoenoplectus corymbosus* (mat sedge) present at moderate cover. The lediba (lake) itself supported only five species of plants, with moderate cover of *Najas horridus* (saw weed) and *Nymphaea nouchali* (blue water lily; *tswii*).

Seasonally inundated floodplains: Small channels and flooded grasslands were the predominant habitat type at this focal area, with an average water depth less than 50 cm. Such areas had a high percentage cover of *Imperata cylindrica* (flame grass; *kwenyama*), *Leersia hexandra* (rice grass; *mokanja*), *Miscanthus junceus* (swamp savanna grass; *moxa*), *Panicum repens* (couch panicum), *Paspalidium obtusifolium,* and *Schoenoplectus corymbosus* (mat sedge). Each of these species contributed more than 10% to the total cover. However, there was a general lack of dominance by one or more species.

Saline pans and pools: A moderately saline pan sampled was dominated by a species of the grass *Eragrostis*, and there was low cover by an additional 11 species, including the fern *Marsilea* sp. The pan was fringed by dry grassland with high cover of *Eragrostis viscosa* (sticky lovegrass) and lower cover of *Cynodon dactylon* (couch grass; *motlhwa*). Other grasses and herbs were present at low cover.

An artificial excavation at a borrow pit was devoid of higher plants, and the substratum in the bed of the pit was dominated by a thick mat of blue-green algae. The pit was surrounded by the grass *Sporobolus spicatus* (*tshunga*), indicating the extremely saline nature of the soil.

Terrestrial islands: The terrestrial vegetation on one island adjacent to the floodplain was extremely diverse, comprising a mixture of grasses, herbs, shrubs, and trees, many of which were growing from termite mounds. The dominant tree was the jackal berry *Diospyros mespiliformis* (African ebony; *mokhutsomu*), and a large individual of the sausage tree *Kigelia africana* was present. *Lonchocarpus capassa* (rain tree; *mopororo*) was also present with moderate cover. A total of some 25 species of plants were present at this site.

Several plots were sampled in the vicinity of the campsite, and here *Acacia nigerscens* (knobthorn; *mokoba*), *Hyphaene petersiana* (ivory palm; *mokolwane*) and *Lonchocarpus capassa* (rain tree; *mopororo*) were dominant trees, and once again species richness was high at between 20 and 30 species present in each sample.

Plant Community Classification

The output from the cluster analysis is a dendrogram displayed as Figure 5.3, with the full output table presented in Appendix 10. The divisions started with 130 samples (Group 1) that were split into 2 groups at the first level of division, with 106 samples in the negative group (Group 2 – wetland communities) and 24 samples in the positive group (Group 3 – island communities). There was no indicator species associated with this division although *Cynodon dactylon* (couch grass; *motlhwa*) was strongly preferentially associated with the positive group as it occurred in 75% of the samples in the positive group but only 10% of the samples in the negative group.

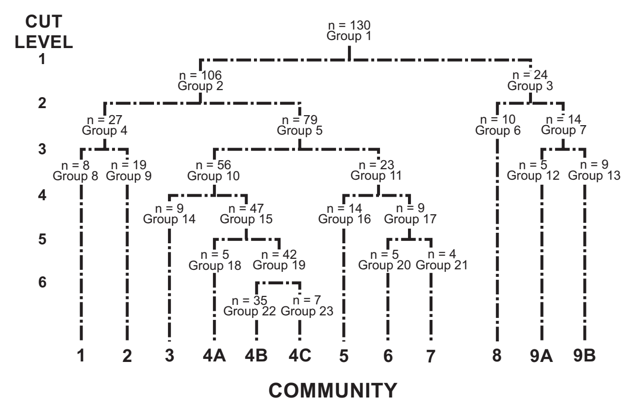

Figure 5.3. Dendrogram showing the hierarchical division of samples into communities.

Wetland communities (Group 2)

The samples of the wetland communities (Group 2; n=106) were divided into two groups at the second level of division in the TWINSPAN cluster analysis, with 27 samples in the negative group (Group 4) and 79 samples in the positive group (Group 5). Once again there were no indicator species associated with this division, although *Cyperus papyrus* (papyrus; *koma*) was strongly associated with samples in the negative group (Group 4), occurring in 75% of the samples and only 4% of the samples in the positive group.

The 27 samples in the negative group of this division (Group 4) were divided into 2 groups at the following (third) level of division, with 8 samples in the negative group (Group 8) and 19 samples in the positive group (Group 9).

The samples in the positive group (Group 9) were indicated by the presence of the giant sedge *Cyperus papyrus* with high cover (>10% cover) while *Ludwigia leptocarpa*, *Pycreus mundii* and *Thelypteris interrupta* (bog fern; *kwena*) were preferentially associated with these samples.

Samples in the negative group (Group 8) were not indicated by any species, although the floating-leaved species *Nymphaea lotus* (lotus water lily; *tswii*) and the emergent species *Persicaria senegalensis* (snake root), *Phragmites mauririanus* (common reed; *letlhaka*) and *Vossia cuspidata* (hippo grass; *mojakuba*) were preferentially associated with these samples.

The samples in these groups (Groups 8 and 9) were not divided further in the analysis in a meaningful way, and they represent the **Lediba and Lediba Margin Community (Community 1) and the *Cyperus papyrus* Primary Channel Fringe Community of the Upper Panhandle (Community 2).**

The 79 samples in Group 5 were divided into 2 groups at the third level of division, with 56 samples in the negative group (Group 10) and 23 samples in the positive group (Group 11). Neither of these groups of samples had any indicator species, although *Nymphaea nouchali* (blue water lily, *tswii*) was associated preferentially with samples in the negative group while *Miscanthus junceus* (swamp savanna grass, *moxa*) and *Pycreus nitidus* were associated preferentially with samples in the positive group.

At the fourth level of division the 56 samples in Group 10 were divided into 2 groups, with 9 samples in the negative group (Group 14) and 47 samples in the positive group (Group 15). Neither of these two groups of samples had any indicator species, but the emergent grasses *Echinochloa pyramidalis* (Limpopo grass), *Pennisetum glaucocladum* (riverbank pennisetum, *lebelebele*) and *Vossia cuspidata* (hippo grass, *mojakubu*) were preferentially associated with samples in the negative group, while *Nymphaea nouchali* (blue water lily, *tswii*) was preferentially associated with samples in the positive group.

Samples in Group 14 were not divided again in a meaningful way at the next level of division, and these samples represent the **Seasonally Flooded Channel Fringe Community of the Upper Panhandle (Community 3)**.

Samples in Group 15 represent a community flooded permanently to relatively shallow depth in areas far removed from primary distributary channels (Community 4). This community is known locally as the "sica" community, being dominated by floating-leaved and submerged plants with low cover of emergent sedges such as *Cyperus articulatus* (*moxodwa*), *Eleocharis acutangula* (*moxhitwana*), *E. dulcis* (*moxhitwana*) and *Schoenoplectus corymbosus* (mat sedge). There are several varieties of 'sica' community as indicated by the division of samples in Group 15 at subsequent levels of division.

At the fifth level of division, samples in Group 15 were divided into two groups, with 5 samples in the negative group (Group 18) and 42 samples in the positive group (Group 19).

The samples in Group 18 were not divided again in a meaningful way at the next level of division and they represent a community that is sparsely vegetated, comprising a **Shallow Open-water Community with Emergent, Floating-leaved and Submerged Macrophytes (Community 4A)**.

The floating leaved species *Nymphaea nouchali* (blue water lily; *tswii*) indicated samples in the positive group (Group 19). Samples in Group 19 were divided again at level 6 of the cluster analysis, with 35 samples in the negative group (Group 22) and 7 in the positive group (Group 23).

There were no indicator species for samples in the negative group, while the submerged aquatic plant *Ceratophyllum demersum* (water hornwort) indicated samples in the positive group. *Nymphaea lotus* (white water lily; *tswii*) was preferentially associated with samples in the positive group (Group 23), while the emergent sedges *Cyperus articulates* (*moxodwa*), *Eleocharis dulcis* (*moxhitwana*) and *Schoenoplectus corymbosus* (mat sedge) were preferentially associated with samples in the negative group (Group 22). The emergent grass *Leersia hexandra* (rice grass, *mokanja*) was also preferentially associated with these samples. These two groups of samples were not divided again, together forming two 'sica' sub-communities; the ***Nymphaea nouchali* Shallow Open-water Community with Emergent Sedges and Grasses (Community 4B)** and the **Shallow Open-water Community with Submerged Macrophytes (Community 4C)**.

The 23 samples in Group 11 were divided into 2 groups at the fourth level of division, with 14 samples in the negative group (Group 16) and 9 samples in the positive group (Group 17).

Samples in Group 16 were indicated by the emergent grasses *Miscanthus junceus* (swamp savanna grass; *moxa*) and *Leersia hexandra* (rice grass; *mokanja*) and the emergent sedge *Pycreus nitidus*, while samples in Group 17 were indicated by the floodplain grass *Panicum repens* (couch panicum). Samples in Group 16 were not divided again in a meaningful way and they represent the ***Miscanthus junceus* / *Leersia hexandra* / *Pucreus nitidus* Permanently Flooded Backswamp Community (Community 5)**.

Samples in Group 17 were divided into two groups with 5 samples in the negative group (Group 20) and 4 samples in the positive group (Group 21). Samples in Group 20 were indicated by high cover of *Imperata cylindrica* (cotton wool grass, flame grass, kwenyama; > 50% cover) while those in Group 21 were indicated by high cover of *Eragrostis inamoena* (>20% cover). Since the samples in these two groups were not divided further in the analysis they represent the ***Imperata cylindrica*** **Floodplain Grassland Community (Community 6)** and the ***Eragrostis inamoena / Pabicum repens*** **Floodplain Grassland Community (Community 7)** respectively.

Island communities (Group 3)

The 24 samples on islands in the Okavango Delta (Group 3) were divided into two groups at the second level of division, with 10 samples in the negative Group (Group 6) and 14 samples in the positive group (Group 7). There were no indicators of the negative group, but the positive group of samples was indicated by the trees *Acacia nigrescens* (knob-thorn; *mokoba*), and *Diospyros mespiliformis* (jackal berry; African ebony; *mokhutsomu*), as well as the herb *Achyranthes aspera* (chaff flower).

The samples in Group 6 were not divided again in a meaningful way at the next level of division, and the samples represent the **Island Interior Grassland and Pan Community (Community 8)**. The samples in Group 7 represent the **Island Fringe Community (Community 9)** comprising broadleaved evergreen trees that generally root to the depth of the water table.

However, the samples in Group 9 were divided into 2 groups at the third level of division, with 4 samples in the negative group (Group 12) and 10 samples in the positive group (Group 13). Samples in Group 12 were indicated by the presence of *Jasminum fluminense* (*motsweketsane*), *Phoenix reclinata* (wild date palm, *tsaro*), *Rhus quartiniana* (river rhus, water currant, *mabele-aditshwene*) and *Syzygium cordatum* (water berry, *kowa*), while those in the positive group were indicated by *Croton megalobotrys* (large fever berry, *motsebe*). Thus there are 2 distinct island fringe subcommunities; the ***Jasminum fluminense / Phoenix reclinata / Rhus quartiniana / Syzygium cordatum*** **Outer Island Fringe Community (Community 9A)**, and the ***Croton megalobotrys*** **Inner Island Fringe Community (Community 9B)**.

WETLAND PLANT COMMUNITY DESCRIPTIONS

The output table from the cluster analysis is summarized in Table 5.4, which includes all of the species that occurred in greater than 40% of the samples in any of the communities.

Table 5.4. Summary of the TWINSPAN output table showing all species that occurred in 40% or more of the samples in any community. See text for descriptions of the communities.

		COMMUNITY											
		1	2	3	4A	4B	4C	5	6	7	8	9A	9B
No	Species	n=8	n=19	n=9	n=5	n=35	n=7	n=14	n=5	n=4	n=10	n=5	n=9
15	*Ceratophyllum demersum*	3	5	1			6						
23	*Lagarosiphon muscoides*	2	2	1	1	14	7						
74	*Pennistem glaucocladum*	1		5									
17	*Ipomoea rubens*	4	7	4									
4	*Cyperus papyrus*	2	18	4		1	1	1					
32	*Persicaria senegalensis*	3	3	4		1							
50	*Nymphaea lotus*	3	1				4						
18	*Pycreus mundii*	1	9	2				3					
12	*Vossia cuspidata*	3	1	6		5	3	1					
5	*Cyperus articulatus*		1			18		6	3				
30	*Cyperus denudatus*		3		2			2		1			
25	*Cyperus pectinatus*		4					7	1				
88	*Echinochloa pyramidalis*			5	1								
8	*Eleocharis dulcis*		1		1	17		4					
20	*Fuirena pubescens*		2		1	1		9	1				
2	*Leersia hexandra*			4		22		11	1				
21	*Ludwigia leptocarpa*		11			1		4		1			
6	*Miscanthus junceus*		6			4		11	2				
13	*Najas horrida*		1		1	12	5	1					
1	*Nymphaea nouchali*	2	1		1	31	3	6		1	1		

continued on following page

Table 5.4., *continued from previous page*

		COMMUNITY											
		1	2	3	4A	4B	4C	5	6	7	8	9A	9B
No	**Species**	n=8	n=19	n=9	n=5	n=35	n=7	n=14	n=5	n=4	n=10	n=5	n=9
22	*Nymphoides indica*				3	5		3		2			
53	*Phragmities mauritianus*	3		3	1	1		1					
16	*Pycreus nitidus*		2			4		12					
75	*Rotala myriophylloides*		1	1	2	1				1			
40	*Thelypteris interrupta*		10			2		4					
102	*Crinum* sp.				1	1			1	2			
57	*Eragrostis inamoena*			1	2				1	4	1	2	
35	*Indigofera* sp.				1					1	6		
158	*Nesaea crassicaulis*			2	3					1	1		
9	*Panicum repens*			2	1	6		5	3	4		2	1
14	*Potamogeton thunbergii*				2	14		2		1			
93	*Rhus quartiniana*			2								4	
94	*Sacchiolepis typhura*					5		6					
7	*Schoenoplectus corymbosus*				2	17		2	1	3			
115	*Sesbania sesban*	1		3	1				3		1		
66	*Aristida congesta*										4	3	
67	*Aristida diffusa*										4	2	
152	*Brachiaria humidicola*				1			1		2		1	
3	*Cynodon dactylon*			2	3	2		1	2	1	6	4	6
34	*Imperata cylindrica*							2	4			1	2
33	*Seteria sphacelata*					2			3	2		3	1
77	*Sporobolus spicatus*				1						5	1	
61	*Syzygium cordatum*		2					2	1	2		4	
64	*Abutilon angulatum*										2	4	5
80	*Acacia erioloba*										1		4
24	*Acacia nigrescens*									1	3	3	8
209	*Acanthaceae* sp.1										1		7
19	*Achyranthes aspera*										2	5	7
56	*Combretum hereroense*											1	6
29	*Croton megalobotrys*								1		1	1	7
28	*Diospyrus mespiliformis*											4	7
46	*Euclea divinorium*											2	6
89	*Ficus sycomorus*											3	2
48	*Garcinia livingstonei*											3	6
192	*Hyphaene petersiana*								1		1	1	4
72	*Jasminium fluminense*											4	2
107	*Kigelia africana*											1	4
58	*Lonchocarpus capassa*								1		1	2	5
92	*Lonchocarpus nelsii*										1		4
59	*Maytenus heterophylla*											4	4
52	*Panicum maximum*											2	7
144	*Phoenix reclinata*											4	1
174	*Protasparagus setaceus*											3	4
187	*Securinega virosa*											1	4
54	*Seteria verticillata*											2	6
116	*Sphaeranthus* sp.										2	1	5

The distribution of the wetland communities in each of the 4 study areas is shown in Table 5.5.

Community 1: Lediba and Lediba Margin Community of the Upper Panhandle

This is a community that is characterized by the presence of submerged and floating species such as *Ceratophyllum demersum* (water hornwort), and *Nymphaea lotus* (white water lily; *tswii*) that typify the open water lake as well as emergent species such as *Ipomoea rubens, Persicaria senegalensis* (snake root), *Phragmites mauritianus* and *Vossia cuspidata* (hippo grass; *mojakubu*) that are associated with the lake margin (Table 5.4).

This community is most common in the upper regions of the system including backwaters that are far removed from the major distributary channels themselves, being typical of open water areas (ledibas/lakes and ledibas/lake margins) in the upper part of the Okavango system (Table 5.5).

The lake and lake margin community has low species richness with a mean value of 4.63 and a value for Shannon's diversity of 0.99 (Table 5.6). The values for species richness and Shannon's Diversity are the lowest of all communities identified in the study, and there is a general lack of dominance by any one species (Table 5.4).

Community 2: Cyperus papyrus Primary Channel Fringe Community

Primary channels are those channels that receive the bulk of their water supply by direct connection to the Okavango River, and include the Okavango River and its direct extension, the Nqoga River. The Thaoge River was a primary channel until late in the last century when its upper reaches failed because of sedimentation. This was accompanied by encroachment of the giant sedge *Cyperus papyrus* (papyrus; *koma*) from the channel fringe into the channel.

Cyperus papyrus (papyrus; *koma*) requires a combination of relatively high nutrient loading in combination with low concentrations of suspended sediment load in order to survive, and it is for this reason that it occurs in the Panhandle of the Okavango Delta and on the Nqoga River (Table 5.5). It still occurs on the Thaoge River where it continues to lead to channel blockage that is regularly being cleared by tour operators in order to promote access to the permanent swamps.

The *Cyperus papyrus* community is relatively species rich with a mean species richness of 8.63 and a value for Shannon's Diversity of 1.10 (Table 5.6). The value for diversity is surprisingly low because of the high cover values of *Cyperus papyrus* and the low cover values of other species, that include mainly *Ludwigia leptocarpa*, *Pycreus mundii* and *Thelypteris interrupta* (bog fern; *kwena*; Table 5.4).

Community 3: Seasonally Flooded Channel Fringe Community of the Upper Panhandle

Due to the deposition of clay in the Upper Panhandle, most of the floodplain communities adjacent to the river are seasonally flooded. The most widespread of these had *Echinochloa pyramidalis* (Limpopo grass), *Pennisetum glaucocladum* (riverbank pennisetum; *lebelebele*) and/or *Vossia cuspidata* (hippo grass; *mojakubu*) as dominant species. Other less common species included *Cyperus papyrus*, *Ipomoea rubens*, *Leersia hexandra* (rice grass; *mokanja*) and *Persicaria senegalensis* (snake root; Table 5.4). This community had relatively

Table 5.5. Distribution of wetland community types within the Okavango Delta arranged from the Upper Panhandle to the upper permanent swamps (Guma Lediba) to the lower permanent swamps (Moremi Game Reserve) and to the interface between the permanent and seasonal swamps (Chief's Island). Communities have been arranged to give the table a diagonal two-way structure.

Community	Upper Panhandle	Guma Lebida	Moremi Wildlife Reserve	Chief's Island	TOTAL
3	9	0	0	0	**9**
4C	6	0	1	0	**7**
7	0	5	0	0	**5**
2	6	10	3	0	**19**
1	2	4	1	1	**8**
5	0	1	11	2	**14**
6	0	0	1	3	**4**
4B	4	2	10	19	**35**
4A	1	0	2	2	**5**
TOTAL	**28**	**22**	**29**	**27**	**106**

Table 5.6. Mean species richness and Shannon's diversity (H) of communities identified in the present study.

	Species richness	Shannon's diversity (H)
Community 1	4.63	0.99
Community 2	8.63	1.10
Community 3	9.67	1.03
Community 4A	10.60	1.57
Community 4B	8.69	1.69
Community 4C	5.71	1.22
Community 5	14.00	1.79
Community 6	10.20	1.14
Community 7	9.75	1.65
Community 8	9.60	1.54
Community 9A	23.80	2.28
Community 9B	25.11	2.57

high levels of diversity, with similar species richness and Shannon's diversity values similar to the *Cyperus papyrus* primary channel fringe community (Table 5.6). It was restricted to the Upper Panhandle of the system (Table 5.5) where it occurred close to the main river channel where deposition of clastic sediment is significant. The three dominant species that characterize this community are all stoloniferous plants that sprout from nodes along the underground stem, making it possible to colonize areas following large depositional events and/or the occurrence of fires.

Community 4: Shallow Open-water Community with Emergent, Floating-leaved and Submerged Plants

This community had submerged, floating-leaved and emergent macrophytes that dominated areas flooded to moderate depth throughout the year. The most widespread species was the floating-leaved macrophyte *Nymphaea nouchali* (blue water lily; *tswii*) that occurred in most of the samples in this community (75%). Other species that were common included submerged macrophytes *Lagarosiphon muscoides* (oxygen weed) and *Najas horridus* (saw weed), the floating leaved macrophyte *Potamogeton thunbergii* (broad-leaved pondweed), emergent sedges *Cyperus articulatus* (*moxodwa*), *Eliocharis dulcis* (*moxhitwana*) and *Schoenoplectus corymbosus* (mat sedge), and the emergent grass *Leersia hexandra* (rice grass; *mokanja*) (Table 5.2).

Community 4A: Shallow Open-water Community with Emergent, Floating-leaved and Submerged Macrophytes

The submerged species *Nesaea crassicaulis*, the floating-leaved species *Nymphoides indica* (floating heart) and the emergent grass *Cynodon dactylon* (couch grass; *motlhwa*) were frequent in samples in this community (Table 5.4). Of the 3 subcommunities this had the highest species richness and also relatively high values for Shannon's Diversity Index (Table 5.6). This community occurred mainly in the lower reaches of the permanent swamps such as along the Maunachira and Boro Rivers (Table 5.5).

Community 4B: Nymphaea nouchali Shallow Open-water Community with Emergent Sedges and Grasses

Nymphaea nouchali (blue water lily; *tswii*) was common in this community, as were species such as *Cyperus articulatus* (*moxodwa*), *Eliocharis dulcis* (*moxhitwana*), *Leersia hexandra* (rice grass; *mokanja*), and *Schoenoplectus corymbosus* (mat sedge) (Table 5.4). This community was widespread, although it was very common in the lower reaches of the permanent swamps such as along the Maunachira and Boro Rivers (Table 5.5). Of the 3 'sica' subcommunities this had intermediate species richness and high values for Shannon's Diversity Index (Table 5.6).

Community 4C: Shallow Open-water Community with Submerged Macrophytes

The submerged species *Ceratophylum demersum* (water hornwort), *Lagarosiphon muscoides* and *Najas horridus* (saw weed) were frequent associates in this community, with the floating-leaved water lilies *Nymphaea lotus* (white water lily; *tswii*) and *N. nouchali* (blue water lily; *tswii*) also relatively common (Table 5.4). This community was primarily restricted to the uppermost of the study areas, occurring in open water areas well removed from the major distributary channels (Table 5.5). Of the 3 'sica' subcommunities this had the lowest species richness and values for Shannon's diversity index (Table 5.6).

Community 5: Miscanthus junceus / Pycreus nitidus / Leersia hexandra Permanently Flooded Backswamp Community

The *Miscanthus junceus* (swamp savanna grass; *moxa*) / *Pycreus nitidus* / *Leersia hexandra* (rice grass; *mokanja*) permanently flooded backswamp community had the three species after which it was named as extremely common. Other common species of this community included *Cyperus pectinatis*, *C. articulatus* (*moxodwa*), *Fuirena pubescens*, *Nymphaea nouchali* (blue water lily; *tswii*), *Panicum repens* (couch panicum) and *Sacchiolepis typhura* (purple hood grass; Table 5.2). Of the wetland communities it had the highest species richness and values for Shannon's diversity index (Table 5.6). It occurred mainly in backswamp areas in the lower permanent swamps in the Moremi Game Reserve (Table 5.5).

Community 6: Imperata cylindrica Floodplain Grassland Community

The floodplain grass *Imperata cylindrica* (flame grass; *kwenyama*) was dominant and ubiquitous in this community, with *Cyperus articulatus* (*moxodwa*), *Panicum repens* (couch panicum), *Sesbania sesban* (Egyptian sesban, river bean) and *Setaria sphacelata* (golden bristle grass; *mabele*) as common elements (Table 5.4). It was relatively species rich but diversity was low due to the dominance of the indicator species (Table 5.6). This community was mainly restricted to the lower reaches of the Okavango system at Chief's Island on the Boro River system, samples were found in the Moremi Game Reserve and at Guma Lediba (Table 5.5).

Community 7: Eragrostis inamoena / Panicum repens Floodplain Grassland Community

Panicum repens (couch panicum) and *Eragrostis inamoena* were indicators of this community, while *Schoenoplectus corymbosus* (mat sedge) was common (Table 5.4). The species richness and diversity of this community were both moderate (Table 5.6). This community was restricted to the region of Guma Lediba (Table 5.5).

ISLAND PLANT COMMUNITY DESCRIPTIONS

Community 8: Island Interior Grassland and Pan Community

This community was mainly a grassland community with scattered herbs and shrubs, including a number of species that were present sufficiently frequently to warrant mention. They included *Cynodon dactylon* (couch grass; *motlhwa*), *Indigofera* sp. and *Sporobolus spicatus* (*tshunga*; Table 5.4). This community occurred in areas with saline soils, and there was often a saline pan associated with this community. The species richness of this community was high relative to the wetland communities, but was the lowest of the island communities (Table 5.6). The same applied to values for Shannon's Diversity Index.

Community 9: Island Fringe Community

The Island Fringe Community had *Acacia nigrescens* (knob-thorn; *koba*) and *Diospyros mespiliformis* (African ebony; *mokhutsomu*) as important constituents, although a variety of other species occurred relatively frequently, including *Abutylon angulatum* (*tsebe-yatlou*) *Achyranthes aspera* (rough chaff flower; *motshwarakgano*), *Cynodon dactylon* (couch grass; *motlhwa*), *Euclea divinorum* (magic guarri; *motlhakola*), *Garcinia livingstonei* (African mangosteen; *motsaodi*), *Maytenus heterophylla* (spikethorn; *motehono*), *Panicum maximum* (Guinea grass; *mhaha*) and *Setaria verticillata* (burr bristle grass; *bogoma*; Table 5.4). Of all of the communities sampled in this study, this community had the highest values of species richness and Shannon's Diversity Index (Table 5.6).

Community 9A: Jasminum fluminense / Phoenix reclinata / Rhus quartiniana / Syzygium cordatum Outer Island Fringe Community

This community was indicated by *Jasminum fluminense* (*motsweketsane*), *Phoenix reclinata* (wild date palm; *tsaro*), *Rhus quartiniana* (river rhus; *mabele-aditshwene*) and *Syzygium cordatum* (water berry; *kowa*), although many other species were frequent associates. Apart from those listed as part of the Island Fringe Community description, there were several others including *Aristida congesta* (tassel three-awn, *seloka*) *Ficus sycomorus* (sycomore fig, *motshaba*) *Protasparagus setaceus* and *Setaria sphacelata* (golden bristle grass; *mabele*) (Table 5.4). This community had exceptionally high levels of floristic diversity (Table 5.6).

Community 9B: Croton megalobotrys Inner Island Fringe Community

Croton megalobotrys (large fever berry; *motsebe*) *and Acanthaceae* sp. were indicators of this community, although once again there were many species that were associated with this community, including those listed as part of the island fringe community description above. Other species found included *Acacia erioloba* (camel thorn, *mogotlho*), *Combretum hereroense* (russet bushwillow; *mokabi*), *Hyphaene petersiana* (fan palm; *mokolwane*), *Kigelia africana* (sausage tree; *moporota*), *Lonchocarpus capassa* (rain tree, apple leaf; *mopororo*), *L. nelsii* (Kalahari apple leaf; *mohatla*), *Protasparagus setaceus*, *Securinega virosa* (white-berry bush; *mala-aditlhapi*) and *Sphaeranthus* sp. (Table 5.4). Once again this community had exceptionally high levels of floristic diversity (Table 5.6).

DISCUSSION

Community distribution in relation to environmental factors

The distribution of plant communities identified in this study is related primarily to the hydrological regime (such as the depth, duration, and timing of inundation), to processes associated with nutrient and sediment supply and sediment deposition, and to the nature of the substratum. This is reflected in the decision tree that hierarchically displays the environmental factors that determine community distribution (Figure 5.4) in a way that mimics the hierarchical vegetation classification (Figure 5.3) as far as possible.

Communities of wetlands and islands

The distinction between the plant communities of the islands and those of the wetlands is clearly related to the absence of surface water (in the case of the island communities) and to the presence of flooded soils (in the case of wetland communities). Flooding of soils leads to the creation of anaerobic conditions in the soil that is stressful to plants as they require oxygen in the root zone for respiration. It also leads to other physiochemical changes in the soil that are stressful to plants, particularly as the solubility of metals in the soils increases and may be toxic to plants. These changes thus create conditions that permit colonization by plants with specialized adaptations to tolerate anoxic conditions in the root zone only.

Wetland communities of proximal and non-proximal regions

Within the wetland habitats, samples have been divided into those that occur in "proximal" areas (i.e. those areas close to the top of the Panhandle or close to primary distributary channels) and those in "medial and distal" (non-proximal) reaches of the permanent swamps.

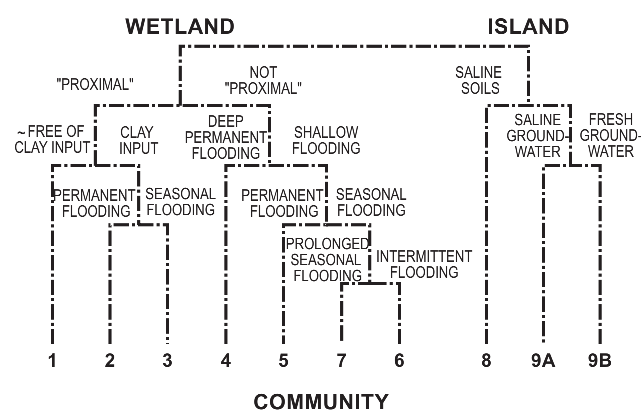

Figure 5.4. Dendrogram showing the environmental factors that are likely to contribute most to community distribution for the communities shown in Figure 5.3.

Proximal reaches are typically associated with a high seasonal water level fluctuation, higher clastic sediment (sand, silt and clay) concentrations, higher macronutrient concentrations and lower non-macronutrient concentrations than the non-proximal settings. Seasonal water level fluctuations increase upstream in the Panhandle as water entering the system from the catchment is confined between the shoulders of the Panhandle. The magnitude of these fluctuations decreases downstream of the Panhandle as water spreads out across the cone-shaped lobe of the permanent swamps. It increases again in the seasonal swamps to create large differences in water supply and demand over the seasonal cycle. Clastic sediments introduced into the system as bed-load are deposited entirely within the Panhandle while those introduced as suspended-load are deposited within very close proximity of the Okavango River in the Panhandle as well as the Nqoga River that extends onto the fan itself. Plant macronutrient concentration decreases rapidly away from proximal areas due to the uptake of these solutes by plants at the head of the system as water is lost from the distributary channels to the permanent swamps. The concentration of non-macronutrients increases gradually downstream within this system due to a combination of them not being taken up by plants at the head of the system and due to evaporative concentration that leads to a gradual increase in overall solute concentration downstream within the system. A combination of heterogeneity in seasonal water level fluctuations, clastic sediment concentrations, and macronutrient and non-macronutrient concentrations is likely to account for the division of samples in proximal and non-proximal areas of the system.

Proximal areas: Communities of backwaters, channel fringe and channel levee. Within the proximal areas, samples are divided into those that are in backwaters and therefore do not receive a high clastic sediment input, while those adjacent to the primary distributary channels are sites of suspended clastic sediment deposition. They are also exposed to higher plant macronutrient concentrations than those communities associated with backwaters. The community of the open backwaters where water depth is greater than 1.5 m is the **Lediba and Lediba Margin Community of the Upper Panhandle (Community 1)**, while the ***Cyperus papyrus*** **Primary Channel Fringe Community (Community 2)** and the **Seasonally Flooded Channel Fringe Community of the Upper Panhandle (Community 3)** occur in the channel fringe where they are exposed to high suspended clastic sediment and macronutrient concentrations. These two communities are differentiated on the basis of the depth and duration of flooding. The *Cyperus papyrus* community is situated in deeper water habitats where it exists as a semi-floating mat that is permanently flooded, while the *Echinochloa pyramidalis* (Limpopo grass)/ *Pennisetum glaucocladum* (riverbank pennisetum; *lebelebele*) / *Vossia cuspidata* (hippo grass; *mojakubu*) community is seasonally flooded due to its occurrence on elevated sites where clastic sediment deposition has created levees.

Distal areas: Communities of the non-proximal reaches of the system receive no sediment from source areas as deposition takes place entirely within the proximal reaches of the system. Similarly, plant macronutrients are taken up within the channel fringe in the proximal reaches of the system so that nutrient concentration within the non-proximal reaches of the system as a whole is remarkably low. In these areas the distribution of wetland communities is determined by the hydrological regime, as reflected in the zonation from deepwater habitats that are permanently flooded, to permanently flooded emergent communities that are rooted in peat deposits at a shallow depth, to seasonally flooded habitats that experience prolonged flooding, and finally to intermittently flooded habitats. The communities that occupy these habitats respectively are: the **Shallow Open-water Community with Emergent, Floating-leaved and Submerged Plants (Community 4)**; the ***Miscanthus junceus / Pycreus nitidus / Leersia hexandra*** **Permanently Flooded Backswamp Community (Community 5)**; the ***Eragrostis inamoena / Panicum repens*** **(couch panicum) Floodplain Grassland Community (Community 7)**; and the ***Imperata cylindrica*** **Floodplain Grassland Community (Community 6)**. These habitats extend logically into the island habitats.

Islands

Several vegetation communities occur on islands, with their distribution being determined by variation in soil and groundwater chemistry. The substratum of islands in the Okavango Delta is primarily Kalahari sand that is either a consequence of aeolian deposition or constitutes aeolian sand that has been reworked by fluvial processes. Locally in the proximal reaches of the system, clay deposits associated with the introduction of suspended load sediment from the catchment are present. There is therefore little difference in soil texture within the system that is a consequence of differences in parent geology or depositional characteristics.

Differences in soil and groundwater chemistry arise as a consequence of differential transpiration rates between different habitats in the system. In wetland systems most water is lost to the atmosphere as transpiration rather than evaporation, and solutes not taken up preferentially by plants accumulate in the root zone. Since transpiration is roughly proportional to the leaf area index (ratio of leaf area to ground area), most water from the Okavango Delta is lost to the atmosphere from the densely wooded island fringes. These plants are selective in their uptake of dissolved solutes, excluding most solutes as water passes through the semi-permeable membrane in the root. Thus, solutes are drawn into the soil in the island fringes by transpiration, but they are not taken up by plants. Thus there is a gradient of increasing solute concentration in the groundwater from the edge of the islands towards the center (Figure 5.5). As solute concentration increases there is a decrease in their solubility, but this does not happen uniformly. Calcium and then magnesium precipitate out of solution in the island fringe as calcium and magnesium carbonate. This leads to a volume

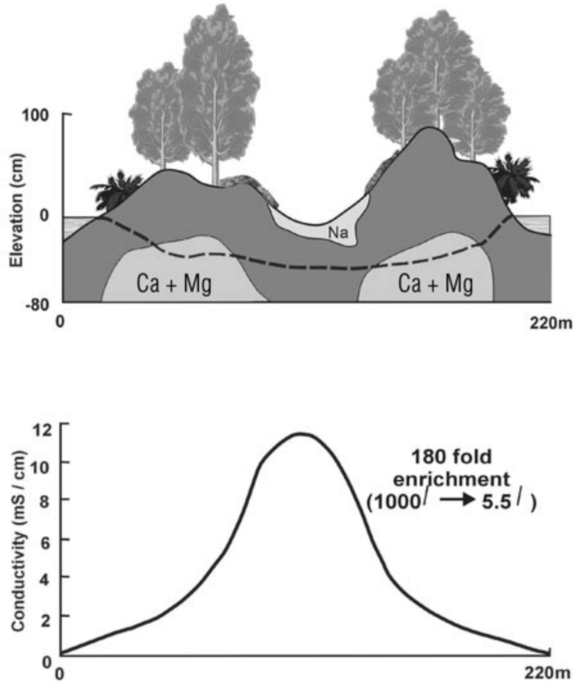

Figure 5.5. Schematic cross-section of a typical island in the Okavango Delta showing island topography, the zonation of vegetation, and the regions of high calcium, magnesium and sodium concentrations (top). The typical conductivity of groundwater is also illustrated (bottom).

expansion of the soil and to the creation of topographic relief such that the island fringes are situated at a higher elevation than the island centers. Sodium is soluble over a wide range of solute concentrations and it precipitates out of solution in the central regions of islands at the soil surface where it leads to salinization of surface soils. Sodium carbonate is toxic to most species of plant at the concentrations observed in the central regions of islands, and it is for this reason that islands typically have barren interiors.

Given these processes, there is a striking increase in groundwater solute concentration and soil salinity from the edge towards the center of islands that is matched by zonation of vegetation. Community distribution along this gradient is from the ***Jasminum fluminense* / *Phoenix reclinata* / *Rhus quartiniana* / *Syzygium cordatum* Outer Island Fringe Community (Community 9B)** in areas where groundwater is fresh, to the ***Croton megalobotrys* (large fever berry; *motsebe)* Inner Island Fringe Community (Community 9A)** where groundwater salinity is intermediate, to the **Island Interior Grassland and Pan Community (Community 8)** where groundwater and soils are extremely saline.

Floristic diversity and environmental heterogeneity

Local levels of diversity at the sample level (*alpha* diversity) are provided by the mean values within samples of species richness and Shannon's Diversity Index at each of the four focal areas (Table 5.3). There is an increase in mean species richness and in Shannon's Diversity Index from the Upper Panhandle to Guma Lediba (Lake) to Moremi Game Reserve and to Chief's Island. The influx of sediment and nutrients to the upper study sites seems to be associated with the presence of stands where one species dominates the flora and where other species are very subordinate. Depositional environments in the Upper Panhandle for example, are dominated by *Echinochloa pyramidalis* (Limpopo grass) or *Phragmites mauritianus*, and in areas that are not aerially exposed, by *Cyperus papyrus* (papyrus; *koma*). Species that form monospecific stands generally disappear downstream and vegetation communities generally become more species rich. Thus, as sediments and nutrients are removed from inflowing waters, species richness seems to increase. The link between nutrient status and species richness seems reasonably well established in other systems.

In contrast to the local scale levels of floristic diversity, it is interesting to consider the landscape level heterogeneity that characterizes the four study areas. The wetland samples in the Upper Panhandle cover a wide range of community types from those on elevated levees through papyrus swamp to those of lake fringes and even sica communities that are permanently flooded to considerable depth, giving rise to high landscape-level heterogeneity. The range of habitats sampled in the Upper Panhandle was relatively low (5 wetland community types were sampled), but the habitat diversity index was 4.20 (Table 5.7) due to the fact that communities were relatively evenly represented in this focal area (Table 5.5). This was the highest habitat diversity index sampled in the four focal areas, declining gradually from the Panhandle to the proximal permanent swamps at Guma Lediba (Lake) to the lower permanent swamps (Moremi Game Reserve) to the seasonal swamps.

This decrease in landscape level heterogeneity in wetland habitats arises from the fact that the Upper Panhandle provides the environmental conditions suitable for a wide range of habitats – from those that require sediment input to those that are free of sediment and flooded to greatest depth. The seasonal amplitude of the flood is much lower at Guma Lediba (Lake) than in the Panhandle, and it occurs in a region where sediment and nutrient inputs are also much

Table 5.7. Wetland habitat diversity within the four study areas showing the number of communities sampled and the evenness of representation of communities (calculated using Simpson's diversity index).

	Upper Panhandle	Guma Lebida	Moremi Game Reserve	Chief's Island
Number of communities	5	5	6	7
Community level diversity	4.20	4.08	3.00	2.01

lower than the Upper Panhandle. The seasonal variation in water level in Moremi Game Reserve is surprisingly low (less than 0.3 m) and waters here are starved of clastic sediment and nutrient supply. Although the amplitude of seasonal water level fluctuations are greater in the vicinity of Chief's Island than in the Moremi Game Reserve, creating a seasonally flooded landscape, nutrient supply is extremely low and the overall salinity of surface water higher than at any of the other focal areas. Thus, the range of habitats declines as the potential range of environmental conditions to which habitats are exposed is reduced downstream within the system, with increased levels of dissolved solids downstream also contributing to the observed decline in landscape level heterogeneity.

This pattern is likely to apply to island vegetation as well, as there is an overall increase in the solute concentration of surface water within the system. The island fringe in the upper reaches of the system is therefore likely to cover a wider range of solute concentrations than the islands in the lower part of the system. This is illustrated by the general absence in the lower parts of the system of species in the island fringe that are tolerant only of extremely low solute concentrations, such as *Phoenix reclinata* (wild date palm; *tsaro*) and *Syzygium cordatum* (water berry; *kowa*).

It is clearly of interest to attempt to understand how diversity within the Okavango system is partitioned between local scale and landscape level heterogeneity. This is not possible in this study, but requires a substantially larger data set than the one collected here. Ideally one should also use satellite imagery to determine landscape level heterogeneity, such that patterns of diversity within the system can be more fully understood.

Biota as Ecosystem Engineers

Typically, floristic heterogeneity at the landscape scale is viewed as being determined by underlying environmental heterogeneity. However, much of the environmental heterogeneity of the Okavango Delta is an endogenous product of biological activity, and an understanding of the underlying processes that contribute to heterogeneity, as well as the species and/or communities involved is important if the system is to be conserved and managed wisely.

Sedimentation, papyrus, and the hippopotamus as agents of channel change

The giant sedge *Cyperus papyrus* (papyrus; *koma*) is unusual in that it grows as a semi-floating mat adjacent to primary distributary channels. This floating mat confines the bulk of water flow to in-channel areas and these channels therefore act as conduits for the transfer of water to distal reaches of the permanent swamps. However, the banks are also porous due to the buoyant nature of the papyrus community, and since the water surface in these channels is elevated relative to the surrounding swamps, these channels lose water to the surrounding permanent swamps. As water leaks from these channels to the backswamp communities, papyrus takes up nutrients, contributing to a gradient of decreasing nutrient availability perpendicular to the channel axis.

As water is lost from these channels, the ability of water in the channels to transport bed-load sediment decreases. Thus sediment is deposited on the bed of these channels and they aggrade by as much as 8-10 cm per annum (Figure 5.6). Aggradation of the channel bed is accompanied by aggradation of the vegetated peat deposits adjacent to the channel, and over time the channel becomes increasingly elevated relative to the surrounding backswamp (Figure 5.7). As this happens, hydraulic gradients at right angles to the channel axis increase and water is increasingly lost from the channel. Water lost in this way carries little or no sediment, and in view of steep hydraulic gradients, erosion becomes a dominant process. This happens mainly along hippo trails leading away from primary distributary channels, and ultimately flow from the aggrading channel is diverted into a new region of swamp. This leads to channel failure of the primary aggrading distributary channel, and to radical changes in the distribution of water over the surface of the Delta over timescales of decades to centuries. The Thaoge River was abandoned in this way during the latter part of the last century, and the Nqogha River is currently in the process of failing as indicated by the blockage of its lower reaches at present.

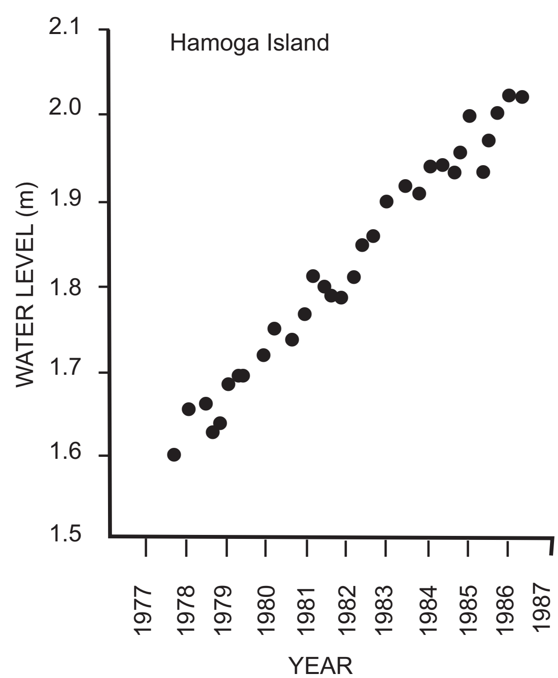

Figure 5.6. Change in water surface elevation as measured on a hydrological bench mark at Hamoga Island on the Nqoga River. Over the period of record, the water surface rose an average of 0.05m per annum, reflecting minimum sedimentation rates along this stretch of channel.

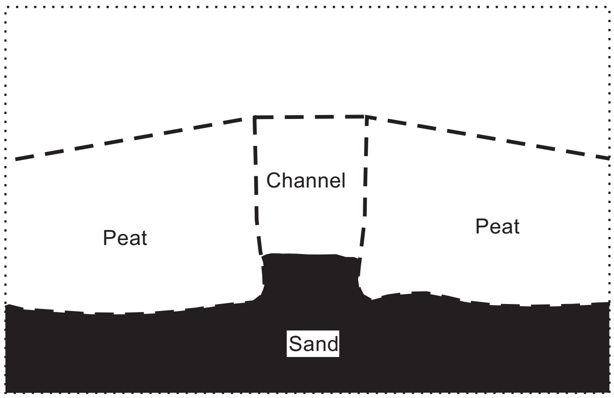

Figure 5.7. Schematic cross-section of a primary channel in the permanent swamps of the Okavango Delta, showing how sedimentation leads to aggradation of the channel bed, which is accompanied by aggradation of the channel bank, leading to a situation where the channel is elevated relative to the surrounding backswamp.

Such radical changes in water distribution lead to the creation of a variety of habitats in different stages of wetting and drying, and following abandonment the peat deposits flanking the former channel are burned in subsurface peat fires that burn for many decades as the regional water table is lowered. Combustion in this way contributes to the release of plant available nutrients into the ecosystem, and this similarly contributes to heterogeneity at the landscape scale. Channel switching also promotes renewal of salinized soils on islands as will be described later in the report. Therefore, changes in the distribution of water over the surface of the Okavango Delta over decades to centuries are important processes leading to heterogeneity as well as renewal.

Changes in the distribution of water over the surface of the Okavango Delta are therefore a consequence of three interrelated factors:

- bedload sediment input that leads to aggradation of the channel bed,
- growth of the giant sedge *Cyperus papyrus* in the channel margin, that enables aggradation of the vegetated levee, and
- the presence of the hippopotamus that creates trails that are hydraulically efficient and are oriented roughly parallel to the regional hydraulic slope and therefore promotes channel switching into flood basins at lower elevation than the aggrading source channel.

Channel switching is ecologically important, and management needs to ensure that these three factors are not disrupted in any way by human activities. Perhaps the most serious threat in this regard is the development of dams or weirs along the Okavango River in Namibia or Botswana. Such structures act as sediment traps, which would stabilize flow patterns in the Okavango Delta, in turn threatening the entire ecosystem.

Island fringe vegetation and surface water quality

An important omission in this study in general was the lack of attention to the flora and fauna of islands. Even though these are not strictly wetland habitats, they are central to the present structure and functioning of the ecosystem.

The evergreen trees in the island fringes of the Okavango are sites of considerable water loss by transpiration. These trees have their roots in the water table and they lower the groundwater table by as much as 8 cm per day as they transpire large quantities of water into the atmosphere. This results in the creation of an hydraulic slope from the swamp towards the island interior, causing swamp water to flow from the swamp towards the center of the islands as groundwater flow. However, trees selectively take up those solutes that they need for metabolism, and are able to actively exclude solutes that they do not require. As such, the solute load of groundwater increases towards the island center, and it becomes toxic to vegetation. These processes are associated with the precipitation of certain solutes in the soil such as calcium and magnesium as calcium and magnesium carbonate. Precipitation of solutes in this way leads to a volume increase in the soil and to the creation of topographic relief at the edge of the island that results in islands having a rim of high lying ground at the edge of the island, with the island center occupying a depression. This rim of high lying ground surrounding a central depression results in continual concentration of solutes in the center of the island by rainfall as well as by transpiration, and island centers are therefore important sites of solute disposal. This mechanism of solute disposal means that in a climate where evapotranspiration is greater than rainfall in every month of the year, surface water remains remarkably fresh. There is only a two-fold increase in solute concentration from the head to the toe of the Delta despite 98% of the water being lost to the atmosphere as evapotranspiration! Therefore, islands, particularly the riparian woodlands in the island fringes, function to focus detrimental solutes locally within the system, and islands function as kidneys within the landscape. In view of vegetation in the island fringe being essential to the functioning of this ecosystem as we observe it today, island fringe vegetation warrants special attention from a conservation perspective.

Overall Floristic Diversity in the Okavango Delta

One of the most significant accomplishments of the present study has been a compilation of a complete species list for the Okavango Delta (Appendix 7). This compilation is dedicated to the late Mr. P.A. Smith, whose contribution to our knowledge of the flora of the Okavango Delta was enormous.

There are differences between the list of plant species compiled as part of this study and the list compiled by Mr. P.A. Smith as part of the Okavango Ecozoning Report (SMEC 1989). One of the reasons for this is that different systems of nomenclature have been used, and in order to overcome this the South African system of Arnold and de Wet (1993) has been adopted. Other reasons are differences in the geographical extent of coverage between the two lists (Figure 5.8), as well as the fact that the combination of lists based on different collections and collectors is likely to be more comprehensive than is use of a single collection. The list of plants of the Okavango Delta published as Appendix 7 includes some notes on which list the material comes from, and where possible, the growth form, habitat and distribution of the species.

The flora of the Okavango Delta is diverse, with 134 families, 530 genera, 1256 species and 1299 taxa of species and lower rank having been collected and documented as part of this study (Table 5.8). The number of taxa of species and lower rank in the PRECIS list provided by the NBI in South Africa is 949, while the list provided in SMEC (1989) is 1040. While there was considerable overlap between these 2 lists (731 taxa of species and lower rank are common to both), 218 species and lower rank taxa were on the PRECIS list but not on the SMEC (1989) list, while 309 species and lower rank taxa were on the SMEC (1989) list but not in the PRECIS list.

The most diverse families are the Poaceae, Cyperaceae, Asteraceae and Papilionoideae, each of which have greater than 20 genera and 50 taxa of species and lower rank, while an additional 26 families have 10 or more species and lower rank taxa represented (Table 5.9). Most genera (73%) are represented by one or two species, while a small number (7%) are represented by 10 or more taxa (Table 5.10).

The life-form spectrum of the Okavango Delta is dominated by herbaceous plants, which comprise a total of at least 71.3% of the flora if graminoid plants are combined with aquatic and non-aquatic herbs (therophytes) (Table 5.11). Woody plants make up 18.1% of the flora, split approximately evenly between shrubs and trees. The contribution of 8.1% of aquatic plants (excluding aquatic grasses, sedges, trees and shrubs) is noteworthy.

Of the total number of taxa present in the Okavango Delta, a high proportion (60%) occur in dryland settings on islands or on sandveld tongues (Table 5.12). However, many of these taxa are not present in the surrounding savanna habitats as they require a high water table. Therefore, despite the high proportion of the taxa being terrestrial, many of these species and lower level taxa are intimately associated with the wetland environments of the Okavango Delta. A large number of species and lower rank taxa occur in the permanent and seasonal swamps (219 taxa), and many in flooded grasslands (86 taxa) or a combination of flooded grassland and dryland settings (80 taxa). Relatively few species and lower rank taxa are associated with other habitats or

Table 5.8. The number of plant taxa at family, genus, species, and subspecies level in the flora of the Okavango Delta.

Taxon level	Number
Family	134
Genus	530
Species	1256
Subspecies	1299

Table 5.9. Numbers of genera, species, and subspecific taxa in plant families with greater than 10 taxa at species or lower rank in the Okavango Delta.

Family	Genera	Species	Subspecies
Poaceae	69	217	220
Cyperaceae	22	116	118
Asteraceae	42	79	80
Papilionoideae	24	67	74
Acanthaceae	18	46	47
Euphorbiaceae	18	39	39
Liliaceae	15	33	33
Malvaceae	7	30	30
Convolvulaceae	6	26	27
Amaranthaceae	15	23	27
Mimosoideae	7	22	26
Scrophulariaceae	15	24	24
Rubiaceae	9	22	24
Caesalpinoideae	12	21	21
Asclepiadaceae	15	21	21
Lamiaceae	12	19	19
Cucurbitaceae	11	17	17
Molluginaceae	5	15	16
Commelinaceae	4	14	15
Capparaceae	5	14	15
Solanaceae	5	14	14
Combretaceae	2	14	14
Sterculiaceae	4	13	13
Orchidaceae	4	13	13
Tiliaceae	3	11	12
Polygonaceae	3	11	12
Lythraceae	3	10	12
Onagraceae	2	10	11
Lentibulariaceae	1	11	11
Boraginceae	3	10	10

habitat combinations. A small number of species and lower rank taxa are parasitic (18 taxa), or insectivorous (12 taxa).

Based on the current data it is possible to estimate the total species richness of the Okavango Delta. Based on the use of the mark-recapture method it is estimated that the total number of species and lower rank taxa in the Okavango Delta is 1405. It is also of interest to examine the relationship between the number of vouchers collected and the number of species and lower rank taxa represented by those vouchers in 49-quarter degree by quarter degree squares (Figure 5.9). The relationship presented in Figure 5.9 appears to saturate as more and more vouchers are collected. Presumably, when collection starts, there is little duplication of species, but as the number of vouchers increases, there is increasing duplication of species and there is little new information added per voucher collected. It is assumed that the asymptote to this curve represents the number of species present in the ecosystem. The number of species listed in SMEC (1989), by PRECIS in this study, and estimates for the total number of species present in the system by SMEC (1989) and this study are also illustrated in Figure 5.9.

Table 5.10. Frequency of species and lower level taxa by genus in the Okavango Delta.

Number of genera	Number of taxa
284	1
104	2
71	3
31	4
11	5
21	6-10
9	11-15
4	16-20
2	>20

Table 5.11. Percentage of genera of different life forms in the Okavango Delta.

Life form	Percentage of genera
Phanerophytes	18.1
Chamaephytes	6.3
Hemicryptophytes	55.6
Cryptophytes	4.4
Therophytes	7.6
Aquatic plants	8.1

Plant Species of Conservation Concern

A total of 23 species and lower rank taxa are listed in the red data list of southern African plants (Hilton-Taylor 1996), of which 16 are considered not threatened due to an increase in population sizes or the discovery of more individuals or populations. Insufficient information is available for a further 3 taxa (*Crinum euchrophyllum*, *Gossypium herbaceum* subsp. *africanum*, and *Hyparrhenia nyassae*) to determine whether they deserve to be placed in a special conservation category. *Leersia denudata* and *Zeuxine africana* are not recognized in Botswana as warranting placement in a special category for conservation, but are suspected of warranting placement in a special category elsewhere in the southern African region. *Harpagophytum procumbens* subsp. *procumbens* is considered vulnerable, which means that it is likely to become endangered if steps are not taken in the near future to limit its decline.

Species richness of the Okavango Delta Biome

It is of interest to compare the relationships between the numbers of specimens, taxa, and area sampled for the

Table 5.12. Habitat preferences of taxa of species and lower rank in the Okavango Delta (for those taxa with known preferences).

	Dryland habitats	Dryland riverine woodland	Flooded grassland	Rainwater pans	Seasonal swamps	Permanent swamps
Dryland habitats	696					
Dryland riverine woodland	2	43				
Flooded grassland	80		86			
Rainwater pans	1		24	36		
Seasonal swamps			25	1	8	
Permanent swamps			16		219	4

Okavango Delta, with other biomes in southern Africa (Table 5.13). The size of the area sampled for the Okavango Delta to compile the full species list in this study is similar to some of the areas sampled by Gibbs Russell (1987) for a similar floristic analysis of biomes in southern Africa, as is the number of specimens and taxa. The density of species in the Okavango Delta at between 0.029 and 0.039 taxa.km^{-2} is greater than for the savanna, nama-karoo and desert biomes, and is similar to the grassland and succulent karoo biomes. The number of specimens per taxon for the Okavango Delta on the PRECIS database is lower than for most biomes, suggesting that the area is in need of collection, and that with more intensive collection new taxa are likely to be discovered. However, based purely on this floristic analysis, the Okavango Delta is considered to deserve special attention from a conservation perspective in view of its exceptionally high species richness.

Reasons for the high species richness of the Okavango Delta are likely to be due to landscape scale environmental heterogeneity that results from the presence of a wetland system in the middle of the Kalahari environment. An examination of the environmental and floristic heterogeneity associated with key environmental gradients is the subject of the publication by Ellery et al. (2000). Examples that illustrate this heterogeneity include a consideration of the range of habitats from permanently flooded swamp to semi-arid savanna, as well as the gradient in soil and water chemistry from freshwater swamp to saline pan, both of which are associated with many species turnovers. This landscape-level heterogeneity is probably the main reason

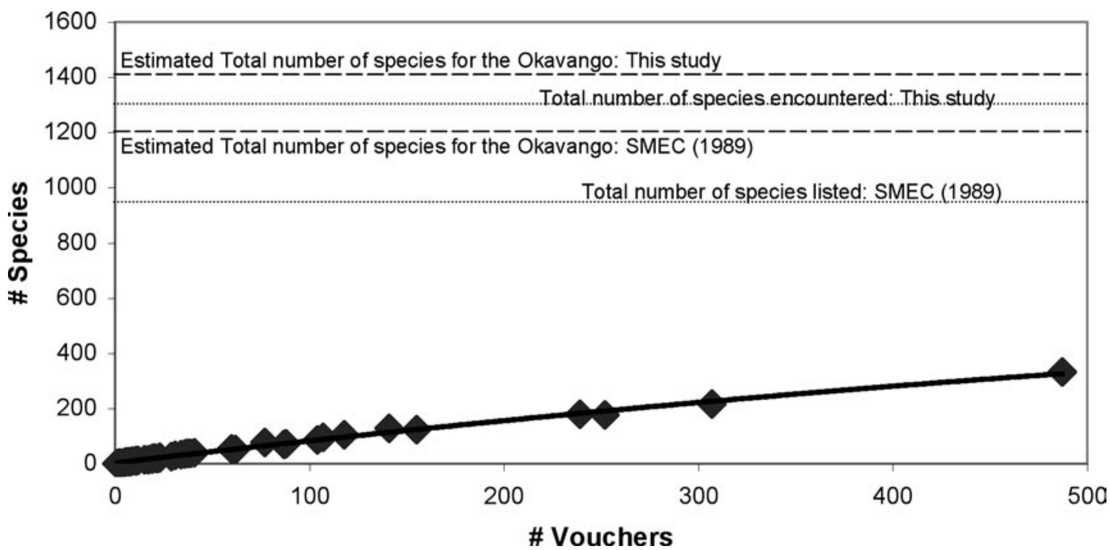

Figure 5.9: Relationship between the number of species and vouchers (specimens) in each quarter-degree grid square for which data were provided by the National Herbarium, Pretoria. Actual and predicted numbers of species are also shown for SMEC (1989) and the present study.

Table 5.13. Collecting intensity and species richness of southern African biomes (Gibbs-Russell 1987) and the Okavango Delta (this study) based on data from PRECIS. Area refers to the area searched for data based on the number of quarter degree grids searched (c.f. Gibbs Russell 1987).

Biome	No. specimens	No. taxa	Area (km^2)	Specimens/km^2	Taxa/km^2	Specimens/taxon
Desert	1334	497	41292	0.03	0.012	**2.7**
Fynbos	52650	7316	36628	1.36	0.200	**7.2**
Grassland	27685	3788	111888	0.25	0.034	**7.3**
Nama-karoo	7685	2147	198468	0.04	0.011	**3.6**
Succulent karoo	6484	2125	50516	0.13	0.042	**3.1**
Savanna	50460	5788	632034	0.08	0.009	**8.7**
Okavango 1*	2865	961	32634	0.09	0.029	**3.0**
Okavango 2**		1259			0.039	

*1 Refers to using only data obtained from PRECIS
**2 Refers to using data from this study

for the considerable floristic diversity that characterizes the Okavango Delta ecosystem.

A second factor that probably contributes to the exceptional species richness of the flora of the region is the fact that flow patterns are remarkably dynamic over time scales of decades to centuries. This is a consequence of localized aggradation along the primary channel system, leading to channel avulsion where one channel system dries up as flow is diverted elsewhere on the surface of the wetland. Following avulsion, the peat deposits flanking the abandoned channel burn, leading to the release of nutrients into the environment, contributing to dramatic differences in soil fertility in different parts of the system, and therefore floristic diversity.

CONSERVATION RECOMMENDATIONS

The Okavango Delta ecosystem is remarkable in many respects, particularly in that it has not been modified to any extent by human impacts. Its remoteness, the threat of disease and attack from wild animals, and longstanding conflict in the catchment in Angola and to a lesser extent Namibia, have all resulted in very low population densities in the region. However, the presence of large quantities of fresh surface water in a semi-arid region has stimulated interest in developing the water resources of the Okavango River and Delta to promote local and regional development. This is widely viewed as the greatest threat to the Okavango Delta ecosystem.

The Earth Summit of June 1992 in Rio de Janeiro highlighted the divergent standpoints of the developed and the developing nations regarding the use of resources provided by wetlands and other important ecosystems – many of which occur in the developing nations. The developed nations view these as a global heritage that must be conserved at all costs. In contrast, the developing nations see them as resources, which need to be harnessed from the spiral of poverty. These are relatively new developments that reflect the changed stance of the developed world in the post-colonial era. In the not too distant past, colonial governments spearheaded so-called 'development projects' in the colonies, with wetland 'reclamation' a highly favored practice. The history of development and utilization of the Okavango Delta in many ways epitomizes this evolution of attitudes to wetlands.

The importance of the Rio Declaration was one of sustainable development of resources. This is an attainable goal in the Okavango Delta in that there need not be conflict between legitimate development needs of the region and conservation of this unique ecosystem. However, the development needs must take cognizance of the functioning of this remarkable ecosystem such that its integrity is not disrupted. The important environmental criteria that need to be considered in formulating development proposals for the region have been highlighted by Ellery and McCarthy (1994), and will be briefly summarized here.

Ecosystem Dynamics

Changes in the distribution of water within the Okavango Delta over timespans of decades to centuries have been described previously in this report. They contribute to a mosaic of habitats in different stages of wetting and drying, and with differing nutrient availability and therefore productivity. Furthermore, and perhaps more importantly, they contribute to renewal by leaching of toxic salts from salinized islands into the deep groundwater, thus preventing extensive salinization of soils and surface water. Dramatic changes in the distribution of water over the surface of the Okavango Delta are thus essential to its long-term survival, and efforts to stabilize or alter flow patterns within the system directly threaten its integrity. Similarly, efforts to dredge the wetlands from the lower reaches are likely to be rendered ineffective due to the dynamic nature of flow. Channel change is reliant on the input of sediment into the system from the catchment, and any structures such as dams or weirs that impede sediment supply to the system, threaten the integrity of the system as a whole.

In view of their importance in promoting channel change and of ensuring rapid delivery of water to the lower reaches of the system, hippo warrant attention from a scientific and conservation perspective. Research into their behavior and role within the ecosystem should also be encouraged. Similarly, the papyrus community is important in promoting channel change and its integrity must be protected.

Islands as sites of toxic solute disposal

Due to exceptionally high rates of transpiration within the island fringes, islands are sites of solute accumulation. Transpiration by vegetation of floodplains, particularly in the seasonal swamps, similarly removes solutes such as silica from surface water. In the absence of this mechanism of toxin removal from surface waters of the Okavango Delta, it would be a shallow saline system typical of closed basins in semi-arid environments. Therefore, protection of adequate vegetation cover, particularly of the island fringe vegetation, is important as it ensures that the surface water of the Okavango Delta remains fresh.

The termite *Macrotermes michaelseni* is important in initiating island growth, and the use of persistent insecticides that threaten the activities of this species should be borne in mind.

The disposal of waste from camps in the Okavango, particularly of sewage effluent and other liquid waste, is difficult in an environment with a high water table. The risk of pollution of surface water is high in this setting. In general camps need to site French Drains in the central regions of islands well away from the island fringe, such that the hydraulic gradient from the drain never allows water to flow into the surface water of the system. Furthermore, water abstraction needs to take place well away from septic tank systems such that human health is not jeopardized. In many cases effluent should be pumped or transported away from the island fringe for the reasons mentioned above.

Additional Threats

The abstraction of surface water from the Okavango Delta and the river system supplying it with water is by far the greatest threat to the ecosystem. It is the view of several participants of the AquaRAP team (excluding ourselves) that water abstraction is not unacceptable, but that it needs to be carried out judiciously and using an appropriate approach. Abstraction of water is possible from the Okavango River and Delta, particularly as it is a large river and subject to highly variable flows from year to year (McCarthy et al. 2000). However, offtake should be small at less than 1% of mean inflow, and should be regulated. It should be carried out in ways that do not jeopardize ecological functioning of the system, such as by dredging or in a manner that requires the construction of weirs or dams.

Additional threats include the prospect of agricultural development in the catchment and in areas fringing the Okavango River that will require the use of agrochemicals that may pollute waters of the Okavango. The flora of the Okavango Delta is sensitive to high solute concentrations, and increased solute concentrations may potentially reduce the occurrence of certain plant species. In particular, the elimination of the giant sedge *Cyperus papyrus* (papyrus, *koma*) may jeopardize the functioning of the system as it is important in water dispersal within the system as well as being able to tolerate aggradation that is extremely important in promoting channel switching.

Alien weeds, such as *Salvinia molesta*, pose a threat to the floristic diversity of aquatic habitats, and steps in place to control their introduction and spread should continue to be enforced.

The siting of conservation areas

In view of the importance of sedimentary processes in the Panhandle and the upper region of the fan in promoting channel switching, and of the importance of this process for renewal within the system, the Panhandle should ideally be set aside for activities that have a low environmental impact. Similarly, in view of the fact that water may be dispersed in a wide arc around the fan itself, conservation efforts should ideally ensure the protection of areas within this arc at the head of the fan. This would ensure the conservation of a wide range of habitats, including some that are in different stages of wetting and drying, thus ensuring conservation of a wide range of species.

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Chapter 6

Fish Diversity and Fisheries in the Okavango Delta, Botswana

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CHAPTER SUMMARY

During the June 2000 AquaRAP survey of the Okavango Delta, the fish team was responsible for establishing fish biodiversity and abundance in the system, and also for addressing the perceived conflicts between users of the fish resources.

A total of 64-66 species out of the 71 species previously recorded from the system were taken in 74 collections in this brief survey, indicating that sampling methods and selected sites effectively covered the diversity of Delta habitats. There were differences between the four focal areas (Upper Panhandle, Lower Panhandle, Moremi Game Reserve, and Chief's Island) and these indicate real differences in community diversity, although as the focal areas were at different phases in the flood cycle, this may have affected our collection efficiency.

The highest diversity was at Shakawe (Upper Panhandle), where the 54+ fish species recorded included predominantly rheophilic species in the main river. The apparent absence of tigerfish, *H. vittatus*, from the other three sampling areas is a striking example of the difference between the main river fauna and the smaller stream habitats downstream. Other species common at Shakawe and absent from catches in the other areas in the AquaRAP survey were *Barbus radiatus* Peters, *Labeo cylindricus* Peters, *Nannocharax macropterus* and *Chiloglanis fasciatus*.

Guma Lagoon had the lowest diversity, due in large part to the absence of riverine habitats with well-defined banks that could be effectively sampled. The low oxygen levels in the area because of floodwater flushing under the extensive papyrus mats probably also have an impact.

At Xakanaxa (Moremi Game Reserve), a broad range of habitats was available for sampling, resulting in high diversity. One undescribed species of *Aplocheilichthys* was collected at several sites at Xakanaxa.

The variety of habitats available for sampling was lower in the Chief's Island area, resulting in a lower total species count, but the diversity in the individual samples from the well-vegetated riverine and flow-through lagoon habitat was very high. Noteworthy was the presence of five of the six *Serranochromis* species occurring in the Delta in a single gillnet catch.

The addition of several new distribution records for the Delta in the present survey shows that scientific knowledge of finer scale distribution patterns within the Panhandle and Delta is still incomplete.

No exotic fish species were found in the system. If there are serious attempts to introduce fish farming into the region, the species used should be indigenous. Exotics such as *Oreochromis niloticus* (L.) should not be permitted under any circumstances.

There are conflicts of interest between commercial fishermen and the recreational/tourist fishery. Tourist lodges and commercial fishing sites are adjacent to one another and the two groups share the same fishing grounds and compete for the same fish resource, particularly the large cichlid species. Options for management include setting and enforcement of regulations to protect stocks and/or segregation of fishing areas to separate commercial fishing and angling tourism.

Regulations to be considered for implementation include licensing with strict sets of conditions, prohibition of use of nets blocking lagoon entrances, limitation of effort, closed seasons, limitation of net mesh sizes, limitation on night-time fishing activities, and segregation of fishing areas.

The current conflicts between commercial fishermen and angling tourist lodge operators in the Panhandle area in particular are not a result of overfishing. The issues at stake are economic, social, and environmental, and the impacts of commercial fishing and angling tourism need to be considered. Before management decisions can be taken, a thorough review of all issues is needed, including not just fisheries aspects but other users of the Panhandle resources. Recommendations for further research include the economic viability of the commercial fisheries, the economic status of the angling tourism industry, the scale of the subsistence fisheries sector and its role in the nutritional status of villages in the area, the extent of the fishable area in relation to the overall area in the Panhandle, continuation of the Fisheries Unit's stock assessment research, collection of data on angling catches, further ecological research, environmental impacts of tourism and commercial fisheries operation, commercial fisheries impacts, tourism impacts, fish biodiversity and distribution, impact of fish kills on the fish populations, and fish farming.

INTRODUCTION

The fish diversity of the Okavango Delta was extensively studied during the 1980s by the J.L.B. Smith Institute of Ichthyology (JLBSI, now called the South African Institute for Aquatic Biodiversity (SAIAB) (Merron and Bruton 1988, Merron 1991), and the fishes of the area are covered by a Southern African Field Guide (Skelton 1993). Seventy-one fish species were recorded in the previous surveys in the area covered by the AquaRAP.

The findings of the previous JLBSI surveys formed the foundation for the AquaRAP sampling programme, which was based at four of the previously explored sampling areas. The fish team (four scientists from South African institutions, four members of the Botswana Fisheries Unit staff from Maun, and a stock assessment adviser from Norway) were responsible for establishing fish biodiversity and abundance in the system, and also for addressing the perceived conflicts between users of the fish resources at these four sites.

Fisheries management

Until the 1980s, the fishery of the Okavango Panhandle, Botswana, was exploited only by anglers based at several fishing camps in the area and by traditional subsistence fishermen using fences and traps, hook and line, and small lengths of gillnet. The development since the 1980s of a commercial gillnet fishery in the Panhandle equipped with aluminium boats, outboard engines, and freezers to hold the fish before marketing in major towns led to numerous complaints from angling tourism operators. They claimed that the commercial fishermen were wiping out the stocks of large cichlid species (locally known as bream) that, along with tigerfish, are the main target of tourist anglers.

Studies conducted to assess the effects of commercial fishing (Bills 1996, Kolding 1996, Ramberg and Van der Waal 1997) are in full agreement that there is no evidence of overfishing in the broadest sense of the word in the Delta. The Delta system shows high diversity, relatively unchanged from earlier studies (Merron and Bruton 1988, Merron 1991, Bills 1996). These reports centre on the question of whether or not overfishing is taking place. The issues of management and possible zonation of the various fisheries have been covered, and Merron (1993b) reviewed the findings of an earlier workshop on the fisheries issues. Earlier reports have not, however, addressed the broader environmental and economic issues, and in this report we draw attention to all aspects of the problem and discuss a range of options for further research and management.

Angling Tourism Requirements

Important issues need to be considered that were not fully addressed in previous reports. The tourist angler has specific expectations when he fishes. The abundance of large bream species and tigerfish in the Panhandle is the main attraction in the Delta. Virgin (i.e. unfished) fish stocks yield the best angling, with abundant fishes and, in particular, large adult specimens available. The high quality of angling in the Okavango Delta has been the subject of several articles in the angling press worldwide (e.g. Meintjies 1995) and angling safaris are actively promoted. The contribution that tourism angling can make to the economy of the Panhandle area and to Botswana as a whole has not yet been fully addressed.

There are two sources of conflict between angling tour lodge operators and commercial fishermen. One of the problems that the tour and lodge operators face is that the commercial fishermen target a particular lagoon and fish intensively for the large bream in that lagoon for several days until catches decline (see discussion of fishing operations). If a lodge operator then takes an angler to that lagoon a few days later expecting to catch fish, the angler will be disappointed. News of poor fishing quickly spreads in the angling press such that angling tourism to Botswana thus suffers. Tourists may head instead for areas such as the Upper Zambezi where angling tourism is being actively promoted.

The second issue causing concern to tourism operators is the impact that fishing and associated activities have on the environment. This is dealt with at length later in this report.

Commercial Fishing

When commercial exploitation takes place, fish stocks are inevitably reduced as fish are removed from the system. The aim of any commercial fishery is to take the largest yield possible without adversely affecting recruitment to the fishery through breeding and growth of the next generation of juveniles. The fishery target may be to obtain the maximum sustainable yield by weight (if the supply of food is the most important criterion) or in revenue (if economics are the main consideration). In the latter case, the yield by weight will be lower than in the former because of diminishing returns, i.e. as the fishing effort increases to increase the total catch, competition between fishermen for the same resources causes reduced individual catches. The size of the fish stock in a fishery regulated economically will be greater than in one regulated for food production. Where a fishery has open access, i.e. no restrictions on fishermen or their gears, there is no reason to exploit the fishery conservatively. Fishermen have the attitude that if they don't catch the fish someone else will.

In the Okavango, the commercial fishermen target only the large bream species that have a high economic value. Most of the fish populations in the Delta are not fished commercially. In particular, the waters of the Delta hold large, unexploited concentrations of silver catfish (*S. intermedius*), striped robber (*B. lateralis*) and numerous other small species. Efforts to develop fisheries for these species (Merron and Bruton 1988) have not succeeded because of their low market value and local consumer resistance.

The commercial fishery operates mainly in the Panhandle area, with fish populations in the rest of the Delta being relatively unexploited because of (a) lack of access to electrical power and thus freezing facilities, (b) trade-off in cost/benefits between fuel and maintenance costs and fish catches, (c) inaccessibility of some areas, (d) wildlife regulations, and (e) dangers to fishing gear posed by large aquatic animals such as crocodiles and hippos. The fish fauna of the Delta differs from that of the more riverine Panhandle (Merron and Bruton 1988), and evidence collected during the AquaRAP field work on water quality, vegetation, and fish distribution suggests that the low oxygen levels in the extensive papyrus swamps at the base of the Panhandle may inhibit fish movements and thus contribute to maintaining faunal separation. If there is effective separation, whether due to the papyrus swamps or to different life history styles of fishes in riverine and swamp environments, the Panhandle fisheries may be considered as a discrete unit with important consequences for the long-term management of the Panhandle fisheries. Further studies are needed in the role of the papyrus as a barrier under varying water regimes.

Training aspects

Throughout the AquaRAP sampling programme, attention was given to training needs of Botswana researchers and staff from the Botswana National Government's Fisheries Unit. Newly graduated biology students from the University of Botswana accompanied the fish team on some sampling trips and the use of the various fishing gears was demonstrated. The students were also given introductory lessons in the identification of fish, using the keys in Skelton (1993).

Fisheries Unit staff accompanied the team at Shakawe, Guma, and Xakanaxa and assisted in the sampling programme, particularly with the gillnets. They also assisted in interviewing fishermen. The staff were also given training in the use of keys for fish identification, but more formal training is considered necessary in future, as under field conditions with an intensive sampling programme it was not always possible to spend the required amount of time in sorting fish. Some of the small fish in particular require microscopic examination to use the keys properly.

METHODS

Sampling in the Okavango Delta system by the fish team began on June 4, 2000 and continued to June 24, 2002. At geo-referenced sampling sites (Appendix 11) several discrete habitats or slightly separated areas were often sampled, while sometimes the same place was sampled using more than one method (e.g. gill and seine nets). These different fish collections were given distinct field numbers by the fish team, thus at each geo-reference site fish collection sites are numbered as OK1.1, OK1.2, etc.

Sampling included: gillnets (two graded fleets of the following mesh sizes in mm: [net 1: 21, 27, 36, 56, 73, 96, 118, 130]; [net 2: 50, 75, 100, 115, 125]); 30 m and 3 m long seine nets (with anchovy mesh bunts); a cast net (3 m diameter); a D-frame dipnet; angling; electric fishing; and examining local fishermen's catches and buying relevant specimens from them. Details of sampling at each site are shown in Appendix 11.

Whole fish samples

Collections using seines, the D- frame and throw nets, and angling were usually fixed in 10% formalin. Larger specimens (>15 cm TL) were injected with formalin to ensure good penetration of the fixative. All samples were returned to JLBSI where they were sorted, identified, and measured. Gillnet catches were identified and measured (TL, cm below (e.g. 9 cm = 9.0-9.9 cm)) in the field and were sub-sampled for specimens of interest. All specimens were transferred to 60% propanol preservative at the JLBSI.

Muscle tissues for molecular DNA analysis

DNA tissues (preserved in 95% ethanol) and their voucher specimens (fixed and preserved as above) were collected for a wide variety of species. Some of these are for on-going taxonomic projects while others are routine collections for future studies. Approximately 200 DNA tissue samples were collected. Some have already been posted to researchers for analysis: riverine cichlids have been sent to Dr. Ole Seehausen in UK and anabantid samples to Ms. Heidi Roos at Pretoria University, RSA. Other samples will be used to examine taxonomic differences between isolated populations of species in the upper and lower areas of the Zambezi system, e.g. the anabantids *Ctenopoma multispine* Peters and *Microctenopoma intermedium* (Pellegrin) and the small sicklefin barb *Barbus haasianus* David.

Cyprinid blood samples

The cyprinid family, which occurs throughout Europe, Asia and Africa, exhibits its widest range of ploidy levels (chromosome numbers) in southern Africa. Southern African species are therefore of considerable scientific interest for phyogenetic and biogeographic studies. Over 80 samples of blood from 13 species of cyprinids were taken for genomic and karyological analyses. These have been sent to Dr. M. Collares-Pereira of Lisbon University, Portugal, for flow cytometry, which relates nuclear volumes and diameters to ploidy levels and chromosomes.

Skeletons

Twenty larger fish specimens were defleshed and dried in the field for preparation as skeletons. On arrival back at the JLBSI in Grahamstown these were placed in a dermestid beetle colony to remove the remaining flesh. These samples will be used for comparative osteological studies. Species prepared are mostly cichlids (*Serranochromis* and *Sargochromis*) for a current project exploring their phylogenetic relationships. Other species included the African pike *Hepsetus odoe* (Bloch), the mormyrids *Mormyrus lacerda* Castenau and *Marcusenius macrolepidotus* (Peters), and heads of the two clariid catfishes *Clarias gariepinus* (Burchell) and *C. ngamensis* Castelnau.

RESULTS

Appendix 12 lists the number of specimens of each fish species caught and the size range for each species at each geo-reference sampling site. Appendix 13 provides a summary of the number of fish species and specimens caught in each of the four sampling areas.

Biodiversity

Upper Panhandle

The region is dominated by the main Okavango River channel. Only habitats close to the main channel were sampled. The peripheral floodplains, which are more extensive on the eastern bank in the Shakawe area were not visited due to lack of time. Of the seven geo-reference sites in this focal area, one (site OK1-07) was not sampled by the fish team. Fish collections were made at 19 sites, some of which were not geo-reference sites (see Appendices 1 and 11).

The sites were at different stages in the annual flood cycle and it appears this was a dominating factor in the fish communities found. A small side channel at Mohembo was draining (estimated drop from peak flood of about 40 cm) and the catch was dominated by juvenile cichlids (*Oreochromis*, *Tilapia* and *Serranochromis* spp.). Over-topping banks nearer the campsite yielded typical rheophilic species such as the suckermouth catlet *Chiloglanis fasciatus* Pellegrin, several barbs and characins. Many of the fish in flooded grass were half grown juveniles. On sand bars in the main channel the sand-burrowing catlet *Leptoglanis* and juvenile barred minnows *Opsaridium zambezense* (Peters) (15.4-33.7 mm SL) were relatively widespread and common.

Interesting records included high numbers of the distichodontid *Nannocharax macropterus* Pellegrin (50+ at one site, 57% of the catch) and juvenile *C. fasciatus*. The only Zambezi Grunter *Parauchenoglanis ngamensis* (Boulenger) collected was gillnetted above Drotsky's camp in a marginal lagoon although live specimens were also observed at night in torchlight in the shallows at Sepopa (not a geo-reference site). The only *Barbus barotseensis* Pellegrin (two specimens) found during the trip were collected at Shakawe fishing camp (site OK6.4).

The catches from a few children who were hook and line fishing were examined. Their catches were dominated by *Sargochromis* spp. The subsistence fishery has never been assessed and this would be an important subject for future study. The Samochima fishing project was visited on the last morning. Good catches, dominated by *Serranochromis* spp., *C. gariepinus* and tigerfish *Hydrocynus vittatus* Castelnau, were observed although this is not the best season for fishing. Fishermen at the Samochima fishing project were interviewed and voucher samples (formalin, tissues and photos) of the fishermen's catches were collected.

The fish community around Shakawe is diverse with 54+ species (+ includes *Sargochromis giardi* (Pellegrin) bought from fishermen and 3-4 *Synodontis* species presently grouped as spp.) being collected from a known total of 71 prior to this expedition (see Appendices 11 and 12).

Lower Panhandle

Guma Lagoon is in a region of the Delta which experiences annual fish kills. The kills are caused by seasonal flood waters flushing detritus-laden water with a very high BOD from under papyrus mats into open waters. Guma was visited after the annual flood peak and fish kill. The waters in the main lagoon were peat stained, low in oxygen concentrations and fish numbers appeared low. Sampling in Guma Lagoon was by gill and seine nets and angling. The margins and flooded grassland areas and isolated pools were sampled with a D-frame net, throw net and 3 m seine. A total of 14 discrete fish collection sites included the seven geo-reference sites around Guma Lagoon.

From a fish perspective, four broad habitat types were represented in our sampling:

1. papyrus mat edges in lagoons and along channels;
2. main lagoon - large open water bodies;
3. shallow peripheral (but connected to main water bodies) pools or flooded grasslands; and
4. small pools which appear to be isolated for most of the year

The fish communities living inside the papyrus and other dense weed mats could not easily be sampled because the only effective means of collecting fish in thickly vegetated habitats is an ichthyocide such as rotenone, and the use of this was impractical in the short sampling time available during the AquaRAP programme.

Fishes under and along the edges of the papyrus mats included juvenile catfish *Clarias theodorae* Weber, several mormyrids, of which *Pollimyrus castelnaui* (Boulenger) was the most common, the two anabantids, *M. intermedium* and *C. multispine*, several topminnows, *Aplocheilichthys* species, and the spottail barb *Barbus afrovernayi* Nichols & Boulton. Most of these species are either air breathers or known to tolerate low oxygen conditions.

Few fish were collected in deeper waters along the northern edge of the lagoon. Oxygen levels were particularly low at site OK10 where water was flowing into the lagoon from under the papyrus mat. It appears that fish were avoiding the low oxygen levels around inflows during this period. On the south side of the lagoon (at site OK11) fish numbers and species diversity were considerably higher. It is uncertain whether this was due to movement away from areas with low oxygen levels or was simply due to more diverse habitat at the sampled section of shoreline. A second lagoon nearer to the main channel was also sampled but only along its margins and not with gillnets set overnight.

Several sites were flooded grasslands or shallow peripheral lagoons of varying depth and vegetation type. During low water periods many of these would be dry grasslands which were found to be the most ecologically diverse areas and harboured highest numbers of fishes. This may be partly due to greater sampling efficiency. Catches in flooded grasslands were dominated by *Barbus* species, three *Aplocheilichthys* topminnows and several juvenile cichlids (most numerous were *Pseudocrenilabrus philander* (Weber) and *Tilapia sparrmanii* A. Smith).

Two small, muddy pools isolated from the main lagoon were sampled. One was found to contain large adult straightfin barbs *Barbus paludinosus* Peters while at another the catfish *C. gariepinus* was seen but not caught. Both are typical pioneer species.

With the exception of papyrus sudd, our ability to sample most sites visited was good and the total number of fish species collected at Guma was 36. Gillnet catches were lowest here and it is assumed that the seasonal effect of low oxygen levels during flooding is the major factor for this finding.

Moremi Game Reserve/Xakanaxa

A wide variety of habitats was sampled around Xakanaxa, ranging from Gadikwe Lagoon, which was a non-flow-through lagoon, Xakanaxa Lagoon, a flow-through lagoon, the connecting Maunachira channel where we were effectively able to sample in the channel over shallow sand banks and in dense weed beds (both in and out of current), to shallow flooded peripheral grasslands and isolated pools. Of the 13 geo-reference sites, two (OK 24 & 25 - both backwaters) were not visited by the fish team while 19 discrete fish collection sites were sampled. The annual flood waters had not yet reached the area. Nevertheless, there were extensive floodedgrasslands/ backwaters due to heavy rains during the previous season. Consequently this habitat type was more extensively sampled at Xakanaxa than in the three other regions.

Species or points of special interest

- The only two specimens of the banded jewelfish, *Hemichromis elongatus* (Guichenot), collected during the survey were caught at Gadikwe Lagoon, one from dense vegetation at the lagoon edge and one in the Maunachira channel nearby.

- An undescribed species of *Aplocheilichthys* was collected at four sites between Gadikwe Lagoon and the seasonal "Paradise Pools" south of Xakanaxa camp site. Approximately 30 specimens were collected and preserved in formalin (20) and ethanol (10) for comparative anatomy and DNA analysis.

- The catch of *Opsaridium zambezense* from Gadikwe Lagoon and the Maunachira channel was dominated by large adults (25.6-92.6 mm SL) in contrast to juveniles in the Shakawe area (Upper Panhandle). The habitats where they were collected were shallow, sandy substratum river channels which were extensive in the region. Tissue samples and blood for karyological work were taken.

- The first record during this trip of the brownspot bream *Serranochromis thumbergi* (Castelnau) was collected by angling in Xakanaxa Lagoon.

- Gillnet catches were dominated by the silver catfish *Schilbe intermedius* Rüppell and the striped robber *Brycinus lateralis* (Boulenger).

- Surprisingly, no squeakers, *Synodontis* catfishes, were collected.

Sampling of channel and peripheral habitats was very effective while the lagoons were only effectively sampled by gillnets. Gillnet catches can be quite variable and it is always preferable to set nets for more nights than were possible during the short period of the AquaRAP survey to ensure comprehensive collections. The number of species collected in the Moremi Game Reserve/Xakanaxa region was 49.

Chief's Island

The main channel of the Boro River and its flooded grassy margins were the main habitats sampled. Of the ten geo-reference sites, two sites (OK29 & 33) were not sampled by the fish team. Sixteen fish collections were made mainly by gillnetting and angling in deeper waters or by D-netting vegetated margins. Extensive vegetation, deep water and operating from mokoros all contributed to ineffective setting of large or small seine nets. What would be the channel margins/banks during the low water period were not sampled satisfactorily as they were under 2-3 m of water.

The flooded grass habitats had very similar species compositions. Catches were dominated by *Aplocheilichthys* spp., several of the small barbs (e.g. *B. haasianus* and *Coptostomabarbus wittei* David & Poll) and several cichlids (all three *Tilapia* species and *P. philander*).

Interestingly, very few juvenile cichlids were collected - those present were dominated by *Tilapia* spp. and *P. philander*. Almost no *Oreochromis*, *Serranochromis* or *Sargochromis* juveniles were collected despite the dominance of *Serranochromis* adults in the gill net catches in the main channel and lagoons. This may indicate that breeding had not yet occurred or that juveniles and/or brooding females were in areas not sampled.

Gillnet catches were the largest of the four regions sampled. The most common largemouth bream was *S. thumbergi*, of which only a single specimen had previously been collected at Xakanaxa. This confirms the observations of Merron and Bruton (1988) that *S. thumbergi* is a lower Delta specialist despite occasional records from the Panhandle area.

Although *Serranochromis* spp. were abundant, their size was smaller than those observed at Shakawe (Upper Panhandle). Clearly this is not due to fishing pressure as exploitation of fish stocks is very low at Delta camp. It may be due to relatively small water bodies supporting smaller fishes compared to the Upper Panhandle as food supply is lower and thus fish grow more slowly and reach smaller adult sizes. Another possibility is that as fish mature they migrate out of the area (upstream) into more productive waters. This needs further research as proposed later in this report.

Additional Sites Sampled In The Okavango System

The Nata River upstream from the main road bridge at Nata town contained typical pioneer species e.g. *B. paludinosus*, *Barbus unitaeniatus* Günther, *C. gariepinus* and *Oreochromis andersonii* (Castelnau) juveniles. The Thamalakane River at the new bridge in Maun, just downstream from the Fisheries Unit station, was sampled before and after the AquaRAP expedition on the June 4 and 24, 2000. The Okavango River margins at "du Plessis" camp at Sepopa were sampled three times on the June 5, 10, and 23, 2000. The Boro River at the "Ostrich Farm" just north of Maun was sampled on the June 24, 2000. It had a very diverse fauna despite having only recently starting flowing, with 19 fish species recorded.

The two sites where repeat collections were made were particularly valuable as the catches emphasised the changeability of fish compositions with time and varying conditions. The early sampling at Maun when the flood waters were just pushing into the town yielded males of several species of barb (*Barbus thamalakanensis* Fowler, *Barbus bifrenatus* Fowler and *Barbus barnardi* Jubb) in typical golden-yellow breeding colouration.

At Sepopa, the sample was dominated by juvenile *Barbus multilineatus* Worthington and *Barbus fasciolatus* Günther, and topminnows (*Aplocheilichthys* spp.) of 10-20 mm SL. On the last visit to Sepopa, the grassy margins were no longer inundated and the species composition had changed considerably from the first sampling. Several cichlid species caught in the first two samples were not found in the last sample and *B. multilineatus* and *H. odoe* juveniles were also absent.

Fisheries Issues

Tourist lodge owners and guides interviewed

Mr. J. and Mrs. E. Drotsky, Mr. D. Drotsky, Mr. B. Pryce, Mr. G. and Mrs. N. Randall, Mr. G. Lobjoit.

Complaints raised by the tourist lodge owners against commercial fishermen:

- Commercial fishermen move into a lagoon, fish out all large bream specimens over a few days and then move out to another area.
- Commercial fishermen set nets completely blocking lagoon entrances. These are often not visible on the surface and become entangled in boat propellers, which can be dangerous as well as extremely inconvenient. The nets have to be cut away from the propeller, which leads to the fishermen complaining that the lodge owners deliberately cut their nets. It is illegal under Water Affairs legislation to block waterways.
- The nets catch and drown many otters and crocodiles.
- Commercial fishermen destroy the island habitats by burning off the vegetation at low water periods and setting up unsightly camps there, chopping down palm trees to smoke fish and by leaving a great deal of litter including discarded netting and outboard engine oil containers. (The AquaRAP team picked up a large tangle of discarded gillnet on an island near Guma).
- Commercial fishermen are active throughout the night driving their motor boats up and down the river, disturbing the peace for tourists.
- Commercial fishermen have been observed destroying the eggs of African Skimmers, *Rynchops flavirostris* (Vieillot), which are laid on bare sand on sandbanks, so that they could lay out their nets for drying and repair. African Skimmers are considered to be under threat and in need of protection. Fishermen have also been seen taking Skimmer eggs to eat.
- Fishing camps are too close to tourist facilities. Commercial fishermen clean their fish at the riverbank, leaving the offal, which is unsightly and attracts scavengers, at the water's edge. They also dump unwanted fish. Heaps of catfish remains were observed at the Guma fishing camp site by Prof. Skelton during the AquaRAP.
- Commercial fishermen take advantage of lodge owners clearing access channels to lagoons, setting nets there

before the tour operator has a chance to take angling clients there.

- Commercial fishermen target the *O. andersonii* nesting arenas by surrounding the nesting fish population with nets and driving the fish into them.

Commercial fishermen interviewed
Mr. K. Makhanga, Mr. X. Kachara

Complaints and comments made by the commercial fishermen:

- Fishermen denied destroying Skimmer eggs. They know when the Skimmers nest and go there afterwards. When they were accused of destroying nests, only old shell fragments were present. Fishermen are not prepared to designate sandbanks used by Skimmers as no-go areas. They claim that tourists also use the islands for camping.

- They are not in favour of a scheme for zoning of fishing grounds whereby anglers and commercial fishermen fish different lagoons, even if lagoons are alternated, e.g. annually. They insist on access to all lagoons.

- They do not want the number of commercial fishermen to increase. They state that there are enough commercial fishermen now.

- They want the crocodile population to be reduced because of damage caused to their nets.

- When asked what their main problems were, they considered lodge owners to be their enemies. They stated that the lodge operators regularly cut their nets.

- They want a forum to develop coordination and pointed out that the 1997 meeting (Ramberg and Van der Waal 1997) was supposed to form a committee, but this did not materialise. They are willing to meet with the lodge owners and would like to negotiate with them, but they are not welcomed when they approach them.

- Catfish and tigerfish are kept for the family and friends and for barter in the village. They are not normally discarded.

DISCUSSION

General comments

A total of 74 collections were made by the fish team. Most were centred around the 37 geo-reference sites and 64-66 fish species out of the previously recorded 71 were collected. The collection of such a high percentage of species known to be present in the area in such a brief survey indicates that sampling methods and selected sites effectively covered the diversity of Delta habitats.

There were differences between the four focal areas and these indicate real differences in community diversity, although as the sites were at different phases in the flood cycle, this may have affected our collection efficiency.

The highest diversity was at Shakawe (Upper Panhandle), where more than 54 species were recorded, largely due to the presence of predominantly rheophilic species in the main river. The apparent absence of tigerfish, *H. vittatus*, from the other three sampling areas is a particularly striking example of the difference between the main river fauna and the smaller stream habitats downstream. The absence of this species is also noteworthy because Merron (1993a) recorded it as common in Moremi, particularly in the Xakanaxa/Maunachira area where it comprised 29% of the sample catch by weight. It may be speculated that the recent series of drought years resulted in the loss (or at least severe reduction in numbers) of this species from the lower delta. Other species common at Shakawe and absent from catches in the other areas in the AquaRAP survey were *Barbus radiatus* Peters, *Labeo cylindricus* Peters, *Nannocharax macropterus* and *Chiloglanis fasciatus*.

Guma Lagoon (Lower Panhandle) had the lowest diversity, due in large part to the absence of riverine habitats with well-defined banks that could be effectively sampled. The low oxygen levels in the area because of flood water flushing under the extensive papyrus mats probably also have an impact.

At Xakanaxa, a broad range of habitats was available for sampling, resulting in high diversity. One undescribed species of *Aplocheilichthys* was collected at several sites at Xakanaxa.

The variety of habitats available for sampling was lower at Oddball's/Delta Camp on Chief's Island, resulting in a lower total species count, but the diversity in the individual samples from the well-vegetated riverine and flow-through lagoon habitat was very high. Noteworthy was the presence of five of the six *Serranochromis* species occurring in the Delta in a single gillnet catch.

The addition of several new distribution records for the Delta in the present survey shows that scientific knowledge of finer scale distribution patterns within the Panhandle and Delta are incomplete. This may possibly be improved with the assistance of local fishermen. The submission to the Fisheries Unit of accurate fishing records may help to provide good distribution maps and possibly indicate migration patterns within the system.

No exotics were found in the system. If there are serious attempts to introduce fish farming into the region the species used should be indigenous, e.g. *O. andersonii*, *Oreochromis macrochir* (Boulenger) and *Tilapia rendalli* Boulenger), and not exotics such as *Oreochromis niloticus* (L.), *Oreochromis mossambicus* (Peters), *Oreochromis aureus* (Steindachner) or *Cyprinus carpio* L.

CONSERVATION CONCERNS AND RECOMMENDATIONS

Biodiversity

Upper Panhandle

With the exception of Maun, which is situated downstream of the main Delta system, Shakawe is the most heavily populated/developed area of the Delta and Panhandle. Consequently, sewage and agricultural pollution around settlements, and refuse from settlements being dumped on the floodplain are major concerns. Although numerous allegations of overfishing have been made (Bills 1996) this is considered to have little impact on biodiversity as the fishery is targeted towards a relatively small proportion of the fish community. The fisheries issues are discussed later in this report.

Lower Panhandle

The region is relatively remote with development consisting of two tourist camps (one under development and one being redeveloped), a commercial fish and vegetable farm, the Water Affairs camp and associated residents. Impacts were perceived as minimal and very localised. As recognised for all of the lodges and dwellings close to the water, however, the disposal of wastes was a concern at Guma Lagoon. The development of a fibreglass boat building operation was also considered by some of the AquaRAP members to be inappropriately sited on the shores of the lagoon. It is recommended that the mode of operation of the factory, especially waste disposal, should be reviewed to assist the owner in ensuring that there are no hazards or threats to biodiversity posed by this operation.

Moremi Game Reserve

One impact observed was physical damage to submerged and emergent weed beds within the Xakanaxa Lagoon and the Maunachira channel by motorised boats. Their propellers cut up beds resulting in large mats of flotsam at bends in the channel. It is difficult to prevent this completely but boat operators should be requested to avoid driving unnecessarily through weed beds.

The recent ban on angling by the Wildlife Department was questioned by several lodge managers. They expressed a wish for angling to be allowed in the reserve and/or for the reasoning behind the regulations to be explained to them. The issues and options are discussed in the fisheries section of this report.

Chief's Island

The disposal of sewage waste from lodges, although very localised, is of concern. The lodge owner, Mr. P. Sandenberg, expressed his own concerns on this point which indicates that there is variation between lodge facilities around the Delta, from properly constructed septic tanks to French drains right at the water's edge. Facilities throughout the Delta need to be checked so that they meet recognised national health standards. The likely effects of present levels of sewage waste on fish biodiversity are negligible.

Staff at the tourist camps engage in subsistence fishing at levels likely to have negligible impact on the stocks. If these fishermen were trained in basic data recording and to regularly record their catches and the general level of catches in the area it would be a useful source of information. Angling data should also be recorded and submitted to the Fisheries Unit.

Management Options

The issues surrounding the fisheries conflicts are complex and not easy to resolve. It is emphasized that the role of AquaRAP is to draw attention to these issues and suggest possible avenues for resolving the conflicts. The issues involve people and their livelihoods on all sides, and thus the only way to develop workable management regimes is to develop a consensus of opinion. This can only be achieved through dialogue and a series of meetings involving all those exploiting the resources is thus essential. In this report we present a series of options, not to be imposed unilaterally, but to be the focus of discussion in order to develop workable management scenarios to share the resources equitably.

Four focal areas were examined during the AquaRAP surveys: Upper Panhandle, Lower Panhandle, Moremi Game Reserve, and Chief's Island. They each had separate characteristics with different management scenarios possible in each area. Options to be considered by the various authorities and organisations involved in management of the Okavango Delta resources are presented below with brief observations on expected results and effects as seen by the AquaRAP team.

Upper Panhandle

The Okavango River itself here is a major component of the system, with small lagoons and floodplains adjacent to, and connected with, the main river. In addition there are large lagoons away from the main river that were not visited during the AquaRAP survey. The river and lagoons of the Panhandle are the main fishing grounds for both commercial fishermen and anglers. Fishing lodges and commercial fishing sites are adjacent to one another and the two groups share the same fishing grounds. Options for management include the setting and enforcement of regulations to protect stocks, and/or the segregation of fishing areas to separate commercial fishing and angling tourism. Other important factors for consideration are the economic and environmental impacts of commercial fishing and angling tourism.

Regulations for the commercial fisheries and enforcement thereof

The fishery is at present unregulated. Regulations, which were not available for the AquaRAP team to review, have been proposed but are not at present implemented. The Fisheries Unit is small and would require strengthening if regulations were to be enforced. Involvement of communities in self-regulation is under consideration. Continued delays in implementing fisheries regulations will have damaging consequences for the fisheries in future. Failures in regulation may lead to uncontrolled increases in fishing effort, more conflicts over resource availability, and localised excessive harvesting with detrimental effects on all sections of the fishery. Regulations that might be considered include:

- *Licensing*. The possession of a licence should be a pre-requisite for all fishing activities in the Delta. Angling licences should be made available at all access points to the Delta's waters, particularly through tourist facilities. Subsistence fishing licences should be available free or for nominal fees through local authorities.

  All licences should be based on a set of conditions. The licences for commercial fishermen should be conditional on observing any regulations imposed concerning permissible net lengths, mesh sizes, prohibited fishing times or seasons, etc. and should be controlled by the Fisheries Unit. All licences, whether commercial or angling, should be conditional on providing standardized data on fish catches to the Fisheries Unit.

- *Banning blocking lagoon entrances with gillnets.* Existing Water Affairs legislation prohibiting the blockage of waterways is not observed, despite fishermen being encouraged to observe regulations by the Fisheries Unit. Fishermen block the entrances to lagoons (observed on four occasions in this area by the AquaRAP team) with gillnets. This leads to conflicts when nets become entangled in boat propellers and have to be cut free, resulting in accusations by fishermen of deliberate net destruction by lodge owners.

- *Limitation of effort.* This is favoured by commercial fishermen themselves. They state that there are already enough commercial fishermen and there is no room for expansion. At present there are no limitations on the number of fishermen or on the number of nets that can be used by a fisherman. At Sepopa landing site, where many commercial fishermen used to operate, only one is now operating. There are insufficient data from stock assessment studies currently underway by the Fisheries Unit assisted by the University of Bergen to set limits based on analysis of catch data, but it seems prudent in any case to set conservative limits to prevent present conflicts from worsening. In addition, fishing effort needs to be spread out by relocation of some existing fishermen to assist in preventing localised stock depletion.

- *Closed seasons.* Closed periods for commercial gillnetting during peak breeding seasons for the main bream species is a conservation measure worthy of consideration. Commercial fishermen are accused of surrounding breeding arenas with their nets and driving the fish into the nets.

- *Limitations on mesh sizes.* Depending on the aims of fishery management in the Delta in future, strategies with regard to mesh size regulation may be considered. In a fishery operated to obtain high but sustainable yields, with the emphasis on fishing for food and no consideration of recreational angling, no mesh size regulation is necessary. Effort should ideally exploit all species and fish sizes in the fishery to maintain the ecosystem structure, albeit with lower stock densities than in a virgin population. Merron and Bruton (1988) suggested developing a small-meshed net fishery for small, currently unexploited species in the Oakavango Delta, but viable markets are not presently available for these species. The development of marketing in nearby countries where dried fish are in high demand is worthy of consideration. The Okavango commercial fishery presently targets only large specimens of the large cichlid species, thus causing changes in the ecosystem structure. If areas are established where tourist angling has management priority, and if commercial fishermen in such areas continue to target only pan-sized cichlids for urban markets, limiting permissible mesh sizes in the fishery may assist in protecting the angling resource. At present we do not know how vulnerable the juveniles of the cichlid species are to capture if targeted by fishermen in their nursery areas. If further research or study of actual fishing activities shows excessive harvest of juveniles, mesh size limitation might be considered to allow fish to grow to maturity and breed before becoming vulnerable to capture. Limiting maximum mesh size also would allow those fish that escape capture while growing through the vulnerable size range of permitted mesh sizes to grow large, become valued angling specimens, continue to contribute to the breeding stock, and reduce the risk of genetic selection for small individuals. Limiting permissible nets to a narrow mesh size range with a maximum of 102 mm stretched mesh size to target mature fish but not angling trophy-sized fish would be an option for the commercial fishery, but only if fishing pressure on the species targeted by anglers is shown to be excessive.

  There are thus two alternative scenarios to management by mesh sizes, either (a) encourage the use of all mesh sizes to fully exploit the food fishery, or (b) provide some protection to the large fishes most sought-after by anglers by limiting mesh sizes. Future research should investigate the present fishery activities throughout the delta to decide on the appropriate management measures.

- *Limitations on night-time fishing activities.* Many commercial fishermen operate throughout the night. This causes considerable disturbance not only to the fauna of the Delta (otters, crocodiles, hippos, sitatunga, etc.) but also to tourists in riverbank-side lodges. There are allegations of poaching and other activities being conducted at night. Restricting night-time fishing activity would remove these concerns, while not seriously affecting the livelihood of the fishermen.

Segregation of fisheries

There are two options for segregation of the fisheries, one of which is more radical than the other. The first is local segregation of the fishing grounds, while the second is complete separation of the two fisheries.

Local segregation. Local segregation is favoured by lodge owners and accepted in principle by commercial fishermen, but the latter are very dubious about the way in which this could be implemented. The fishermen want access to all lagoons as they suspect recreational angling interests would be allocated the "best" fishing areas. The tour operators suggest operating the lagoons on a rotation system arranged by dialogue between the different parties. A possible option is to divide up fishing areas between the two groups to include good fishing areas in the river, lagoons, backwaters, etc. for each group. Each group will be in charge of responsible fishing in their areas and for following regulations. Another option is to divide up fishing areas between the two groups for an agreed period of months or years, then rotate the areas for another period of time.

Regional segregation. Local segregation would not resolve the issue of tourist lodges and commercial fishing camps being sited adjacent to one another. Relocating fishing camps or lodges would reduce the effects to tourism of adverse environmental impacts of the fishing camps, which include noise, smells and litter. Agreement to divide the Panhandle into large zones for different activities may be difficult to achieve. The close proximity of lodges and fishing camps is a result of both activities requiring labour, and thus being situated close to villages. The limited availability of high ground at the river bank is another key factor in the parallel developments. The existing lodges represent major financial investments and relocating them would be impractical given the high cost and lack of suitable high ground. The fishing camps are more recent developments than the lodges, but the fishermen are mainly local whereas the lodges represent outside investment.

Without some form of agreed segregation, conflicts are likely to continue to the detriment of all users of the fish resources.

Reviewing the economic and environmental effects of commercial fishing and angling tourism

Both commercial fishing and tourism have economic impacts on the villages in the area and on the economy of Botswana as a whole. Both also have environmental effects. Research to look into these issues is recommended below.

Lower Panhandle

Guma Lagoon and other lagoons in the area are effectively open water areas in extensive papyrus swamps. At the time of the AquaRAP fieldwork, the oxygen levels in Guma Lagoon were very low and few fish could be observed in the vicinity of water inflows to the lagoon through the papyrus. The fieldwork took place shortly after the annual floods had entered the lagoon. Almost every year, as discussed earlier, fish kills are observed in the lagoon at the time of the annual floods. This is because of low oxygen levels due to the flushing effect of the floods bringing decaying detritus, with a high BOD, into the lagoon from under the papyrus. Such a kill was documented by Bills (1996). *Oreochromis andersonii* was the main species observed in the kill in the lagoon itself, with *Hydrocynus vittatus* found in numbers in the Thoage channel. It is the opinion of the AquaRAP team that Guma Lagoon was effectively isolated from the main river system at the time of sampling and for most, if not all, of the year by a "chemical wall" under the papyrus. Water quality sampling at other times is needed to confirm this observation. Fish kills may also occur when cold weather causes surface chilling and an overturn of water in the lagoon, bringing deoxygenated bottom water to the surface.

Guma Lagoon is an area of conflict between lodge operators and commercial fishermen. A small commercial fishing site has been opened near two tourist camps. The commercial fishermen do not normally fish the lagoon because catches are generally lower than elsewhere in the system, but they use their site on the shore as a base to reach other lagoons near the main river. Angling success in the lagoon varies considerably from year to year (G. Randall, pers. comm.). While stock depletion by commercial fishing may contribute to poor angling catches in the lagoon, the fish kills, and also the low water levels in recent years, have an adverse and probably major impact. The isolation of the lagoon, if confirmed by studies at other times of the year, suggests that the lagoon should be treated for management purposes as a closed system. As many fish die annually in the fish kills, protection of those that remain may be necessary to allow the stocks to recover. An alternative argument has been suggested that as the fish will die anyway in fish kills they might as well be harvested first.

The continued presence of the commercial landing site at Guma Lagoon adjacent to tourist camps is likely to remain a source of conflict. As the commercial fishermen do not normally fish the lagoon, the option of closing the lagoon completely to commercial fishing while allowing catch and release angling is a possible management scenario. It may be possible to avoid resentment and conflict over such a course of action provided the reasons are fully explained and discussed in a consultative forum. The possibility of granting angling concession areas is discussed later in this report.

Moremi Game Reserve

Xakanaxa Lagoon falls within Moremi Game Reserve and thus comes under the regulations and authority of the Department of Wildlife and National Parks. Since April 2000, angling has not been permitted in the reserve, although lodge owners are permitted to take anglers outside the reserve area to fish. Before April, anglers were permitted to take 10 fish per day under licence. The Fisheries Unit was not consulted about the change in regulations. Lodge owners previously offered angling as part of their facilities and reported to the AquaRAP team that fishing for the large bream species was excellent in the area. The AquaRAP fieldwork showed that lagoons in the area have high fish populations.

Policies on exploitation of fauna and flora in national parks and game reserves vary from country to country. In many countries, all fauna and flora are strictly protected. This is a justifiable policy and has been adopted in the Moremi Game Reserve. Protection of fish in reserves can have beneficial effects on fishing outside the reserves by protecting breeding populations and thus enhancing recruitment. Data from marine line fisheries show that angling can have major effects upon the size and age structure of reef communities (Cowley et al. 2002). In other countries, all terrestrial fauna and flora are protected but fishing is allowed and sometimes angling is actively promoted to attract visitors, e.g. the trout fishery of the Nyika National Park in Malawi.

While managing fish populations in the same way as the other fauna in the Moremi reserve, i.e. by giving full protection, is a sound principle, arguments can also be made for non-exploitative use of the resource. Even where terrestrial animals are protected from hunting, game viewing by visitors causes some disturbance to the animals' normal activities, particularly at peak tourism periods. A management option for the fish populations that the Department of Wildlife and National Parks might consider is to permit catch and release angling under licence (thereby increasing revenue from the reserve), using barbless hooks that cause a minimum of damage to the fish. A code of conduct for handling and releasing fish unharmed is under development by tour guides elsewhere in the Delta (G. Lobjoit, pers. comm.). Allowing the taking of fish by anglers for consumption would be unwise and lead to possible flouting of the regulations by other fishermen. If the Department of Wildlife and National Parks was to adopt such a policy, a condition of licences issued to anglers and/or tour guides must be that all fish caught are recorded using forms designed by the Fisheries Unit, to whom completed forms should be sent for data analysis. Over time a valuable database would develop showing long-term fluctuations in stocks in a natural environment.

Chief's Island

The Boro River flowing past Oddball's Camp borders the Moremi Game Reserve. At the time of sampling the river was flowing strongly, with well-established floodplain and lagoons up to 2 m deep bordering the river channel. Fish were abundant with high diversity. Angling and gillnetting yielded numerous specimens of the large bream species sought after by anglers and commercial fishermen, but the specimens caught were small, maximum weight approximately 400 g. It is reported (P. Sandenberg, pers. comm.) that before the recent series of low flood years, large bream were abundant. During the low flow period, the river will be small, confined largely to within its banks, and will have a large hippo and crocodile population. A small amount of subsistence fishing by tourist camp staff for their own consumption was observed. Such fishing will have a negligible effect on stocks. The small size of the fish observed is doubtless due to the small size of the river system in recent low flow years. If there is now a series of good flow years, large bream should once again provide excellent tourist angling.

Conclusions on fisheries issues

It is stressed that the current conflicts between commercial fishermen and angling tourist lodge operators in the Panhandle area are not a result of overfishing. The issues at stake are social, economic and environmental, and any decisions on management of the fishing activities must take all aspects of the problem into consideration. Before management decisions can be taken, a thorough review of all issues is needed. This review should include not just the fisheries aspects but also other users of the Panhandle. It is recommended that this review should be integrated in the development of the management plan for the entire area, under the programme "Management Plan for the Okavango River Panhandle" which has been recently put out to tender. For effective conservation of biodiversity and management of the fish stocks, further research is needed on many issues, and these are noted below.

RECOMMENDATIONS FOR FUTURE RESEARCH

The economic viability of the commercial fisheries

The fishery has been established with the aid of grants from the Financial Assistance Policy (FAP) programme and the local government grant scheme (LG109) for boats, engines, nets, buildings, generators and deep freezers. FAP small-scale grants of up to P 65000 are available, but grants to fishermen are reported to average roughly P 25000. The two fishermen interviewed at Samochima during the AquaRAP had 18 nets between them.

The fishermen target the large bream species but also catch many clariid catfishes and tigerfish. The large bream are frozen and transported to Maun for sale. The fishermen earn P 9 per kg and the fish are sold for approximately P 14 per kg in Maun. All other fishes caught are sold or bartered locally, or if no outlet is available, they are disposed of by dumping.

Circumstantial evidence gathered during the AquaRAP and reported by Bills (1996) raises questions about the economic efficiency of the commercial fishery. While the boats, engines, nets, freezers and generators are relatively new and in good condition, commercial fishing is profitable. However, provisions for replacement of worn out equipment may not be sufficient. In particular, outboard motors, generators and freezers are expensive items. Bills (1996) pointed out that the 'Minus 40' freezers used for freezing and storage of fish are not designed to be used in the way they are by the fishermen. It was reported to the team that only three fishermen were operating at Ngarange at the time of AquaRAP survey because of a generator breakdown. There is reportedly a high turnover of fishermen taking part in the scheme. Only one fisherman is now operating from Sepopa. All evidence points to fishermen travelling very long distances to fishing grounds at considerable expense in fuel and engine maintenance. Guma fishermen travel for over an hour to the main channel to fish, while Samochima fishermen report their present fishing grounds to be at Ngarange, 30 minutes downstream. Some fishermen, though, manage fuel more efficiently by travelling to a fishing area by motor boat then fishing the area by mokoro. They make camps and store fish in ice until they have enough to take back to market.

A thorough economic assessment of the long-term viability of the commercial fishery is therefore required. This assessment should include the financial status of the fishermen and their employees, the marketing arrangements for the catches, the capital costs in terms of both initial investment and long term maintenance and replacement, and the role of the fishery in the economy in the immediate vicinity of the Delta.

The economic status of the angling tourism industry, including the feasibility of introducing angling concession areas

Considerable private investment has been made in tourism lodges and camping facilities in the Panhandle area. The lodges currently in operation were all established primarily as fishing camps but they offer a variety of other activities such as bird-watching. Because of the decline in fishing quality in recent years, Shakawe Fishing Camp, operated by Mr. B. Pryce, has changed its name to Shakawe Camp. The angling does still attract top international anglers. Several American fly-fishing groups were scheduled to fish under the guidance of Mr. G. Lobjoit later in 2000, while annual international angling competitions take place.

The study on the economics of the angling tourism sector should include the contribution that employment in the fishing lodges makes to the economy of villages in the vicinity of the lodges, and to the overall economy of Botswana, taking into consideration the relative proportions of angling and non-angling visitors to the lodges.

Much of the Okavango Delta is managed by the granting of concession areas on leases, for various activities such as Wildlife Reserve, hunting concessions or photographic concessions. In investigating the economic status of tourism in the Panhandle, the feasibility of extending the principle of concession areas to the Panhandle should be explored. Granting concessions to lodge owners for management of certain areas for angling tourism may be financially viable and acceptable to the local communities if derived revenue is utilised for the benefit of the communities.

The scale of the subsistence fisheries sector and its role in the nutritional status of villages in the area

The subsistence sector has been neglected in all discussions of the fisheries in the area. Small-scale fishing for local consumption has always been important locally. Fishermen use hook and line, short lengths of gillnet, and traps to feed their families. Fishing is not a full-time occupation and such fishermen will carry out different activities such as farming or other occupations at different times of the year. It is reported that these subsistence fishermen resent the commercial fishermen, but this has yet to be confirmed. Some of the commercial fishermen started out as subsistence fishermen and have increased the scale of their activities to operate at a business level.

The extent of the subsistence fishery and its role in the economy and village nutritional status needs to be explored by means of a detailed questionnaire in the villages in the Panhandle area. Subsistence fishing contributes significantly to protein intake in the local community in the Kavango section of the river in Namibia (Van der Waal 1991). The potential adverse impact on the fish stocks of the catching of large numbers of juvenile bream species by hook and line fishermen on the floodplain also needs quantifying. It is recommended that future meetings to discuss fisheries problems should include representatives of subsistence fishermen and that such meetings should be held in the Panhandle area, e.g. Shakawe, to enable the local fishermen to attend. Until now, all meetings have been held in Maun.

The extent of the fishable area in relation to the overall area in the Panhandle

The AquaRAP fieldwork, showing marked differences in fish faunal composition in different areas, suggests that the Panhandle is effectively separated from the main Delta, either by the papyrus swamp, the different life history styles of the fishes, or both. If so, it should be managed as a separate unit for fisheries. Estimates of potential fish yield based on total water area in the Delta and yields per unit area derived from other floodplain fisheries in Africa where fisheries are based on the rapidly reproducing pioneering species such as the clariids (Merron and Bruton 1988), are unrealistic for the Delta fisheries. This is because of the very different habitats in the Delta as a whole, limitations in access, extensive areas closed to fishing, and, particularly, the limited ranges of species present which are actually exploited by the fisheries. A study is needed to quantify the extent of water actually occupied by the bream species targeted by both commercial fishermen and anglers and to what extent this area is being exploited. This information is essential if an agreement is reached on partitioning of the resource by segregation of the different fishing activities, to ensure equitable sharing of resources. The information can be obtained by a combination of study of existing aerial photography of the area and surveys in the field to assess the habitat suitability and presence or absence of target species.

Continuation of the Fisheries Unit's stock assessment research

The Okavango is a complex system governed to a large degree by the extent and duration of the annual floods. Without good quality, consistent, long-term data collection on fishermen's catches together with studies on growth and mortality, estimates of potential yields from the Delta can only be guesswork. Because of the absence of historical catch data, there is no evidence to support the perception held by tourist lodge operators that overfishing has caused a decline in angling catches. Catch rates in African floodplain fisheries are known to be strongly influenced by the flood regime and the recent series of low flow years in the Okavango would cause poorer catches than before because of poor recruitment in low flow conditions (Merron and Bruton 1988). Without data on catch rates over a range of flood levels, the additional impact of fishing pressure on the stocks cannot be estimated. Low water levels facilitate fishing because fish are confined in smaller, more easily exploited areas, thus low water levels can increase fishing mortality even with constant effort. The data collection system developed by the Fisheries Unit, if continued over a long period, will allow more accurate assessments to be made of the fisheries potential of the Panhandle.

Collection of data on angling catches

In addition to commercial fishery catch statistics, the catches of anglers need to be recorded. A major constraint in all studies to date has been the complete absence of angling records. There seems little doubt that angling catches have declined considerably in recent years but all information is anecdotal. The maintenance of full catch records and submission to the Fisheries Unit for analysis should be a condition in granting leases for tourism operations.

Further ecological research

Knowledge of the fish populations in the reserve is largely based on the studies of Merron and Bruton (1988) and Merron (1991). This extensive work forms a sound baseline for further studies. Particular attention needs to be paid to the large bream species that are the target of both the commercial and angling fisheries.

Different fish species can respond very differently to fishing pressure depending on their behaviour and ecology. The largemouth breams, *Serranochromis* species, in particular may prove to be vulnerable to even modest exploitation rates because of their territoriality. Many cichlid species are known to be territorial (Ribbink 1991). If a dominant male holding a territory is removed, it is replaced by a less dominant male. This has been noted for *Serranochromis robustus* in Lake Malawi (D. Tweddle, personal observations), where large territorial males removed by angling are invariably replaced by smaller males. Continued removal of males leads to an absence of fish in the area very rapidly. A greater extent of habitat and thus potential territories is available for *Serranochromis* species in the Okavango River, but the danger of overexploitation is nevertheless much greater than for non-territorial species. *Oreochromis andersonii* is a shoaling species that may range more widely in the system than the serranochromines and thus be less vulnerable to localised fishing pressure. It is, however, reported to be targeted by fishermen while males congregate in breeding arenas and thus further study of this species is also warranted.

The catches in the gillnets during the AquaRAP survey were dominated by piscivorous species. Studies should be developed on general ecology, including feeding studies, population dynamics, and the possibility of using modelling programmes such as Ecopath to develop ecological models for the Delta.

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Chapter 7

Suggestions for an Aquatic Monitoring Program for the Okavango Delta

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CHAPTER SUMMARY

This chapter presents a summary of suggestions from the AquaRAP scientists for developing a long-term aquatic monitoring program aimed at local schools, communities, and tourist camps. It has been written as simply as possible so that non-scientists can follow it. Methodologies are presented to monitor water quality parameters such as channel depth, water flow, visibility, pH, temperature and colour, selected invertebrates, aquatic weeds and plants, cranes, skimmers and bird breeding sites, climate and channel dynamics, and fishes. These methodologies need to be field tested and revised in order to formulate a standard aquatic monitoring plan for the Okavango Delta.

INTRODUCTION

Because the Okavango Delta ecosystem is a critical resource for the people and wildlife of Botswana providing freshwater, food, transportation, and habitat for local and regional communities as well as for wildlife, it is very important that those people who depend on it also make the effort to look after it.

One of the objectives of Okavango AquaRAP 2000, Botswana was to start the development of a program to monitor the quality of the aquatic resources (water and biodiversity) of the Delta to help the local communities, schools and tourist camps to obtain baseline data and then to monitor any changes over time or between seasons. By looking at all sets of environmental data, the aim is for those participating in the monitoring program to notice any negative changes in the system that suggest that the resource that they depend on is in danger of changing or disappearing.

This chapter presents scientific methodologies developed from discussions during the 2000 AquaRAP survey. Simple methodologies are presented to monitor water quality parameters such as channel depth, water flow, visibility, pH, temperature and colour, invertebrates, aquatic weeds and plants, cranes, skimmers and bird breeding sites, climate and channel dynamics, and fishes.

It is important to note that the suggested methodologies are purely scientific and do not take into account community views, interest levels, budgetary requirements/constraints, capacity, possible logistical constraints etc. These methods need to be discussed with representatives from local communities, schools, and tourist camps, then field tested through projects before a standard aquatic monitoring plan can be developed for the Okavango Delta. The monitoring methodologies do not cover all environments, nor do they include all factors that could be monitored. There is thus room for a huge amount of growth as this project develops. The methodologies suggested may not be suitable for a certain area/community and may need to be adapted as required, within a set of given parameters.

The main aim of the program is to create awareness of the importance of the aquatic resources of the Okavango Delta by getting local people involved in monitoring its status.

While the data collected will hopefully contribute to the management of the Delta, the greater purpose is that of educating people about how their everyday activities have an impact on the water quality, plants, and animals of the Delta.

Existing monitoring programs

Certain concession owners, communities and governmental institutions in Botswana have attempted, currently carry out, or are in the process of setting up environmental monitoring programs. Many of these have failed or have not been very successful due to the lack of one or more of the following: expertise, funding, training, capacity, proper consultation, proper interpretation of data, follow-up, or interest.

Objectives of monitoring program

The objectives of this environmental monitoring program are therefore to:

- Provide suggestions for monitoring methods that are simple, replicable, and scientifically sound;
- Involve communities, lodge operators, Government and other interested parties in a joint conservation program in the Okavango Delta;
- Create conservation awareness through education.

Guidelines to follow when using these monitoring methodologies:

- All data should be recorded on standard worksheets such as the one provided in Appendix 14.
- Specific monitoring sites should be selected. All future monitoring should be carried out at these same specific sites to ensure that any changes in environmental status are recorded.
- All monitoring should be done within a 25 m radius of each selected site.
- Unless stipulated, monitoring should be done once a month.
- Monitoring must be consistent. This means that the same methods must be used and all sampling must be done at the same time of day each time.
- Data should be shared with community members, government, and other interested parties.

SUGGESTED METHODOLOGIES

I. Water Quality Parameters

A. Water Depth

Why do we measure Water Depth?

Water Depth is important to monitor as it gives an indication of how much water is coming into the Delta. This is important because more water usually means more fish, a wider floodplain, and more water eventually reaching the communities/lodges downstream.

Monitoring depth also gives information about the movement of sediment on the bottom of the channels, i.e. whether sand is being brought in or removed from an area. Too much sand entering a channel could block it, whereas too much sand leaving a channel could make it very wide and deep. This is of particular interest to a community that relies on a particular river crossing for access.

Equipment required

- 1 depth stick (long stick marked in 5 cm intervals) for each location measured
- 1 permanent marker,
- 1 mokoro

Methodology

1. Make a depth stick by marking it in 5 cm intervals with a permanent marker.
2. Secure the depth stick in the water, preferably in a seasonally flooded grassland (a grassland that only floods when the annual floods come in) or a shallow channel.
3. Measure the distance from the top of the stick to the water level. You could also do this using a tape measure (Figure 7.1).

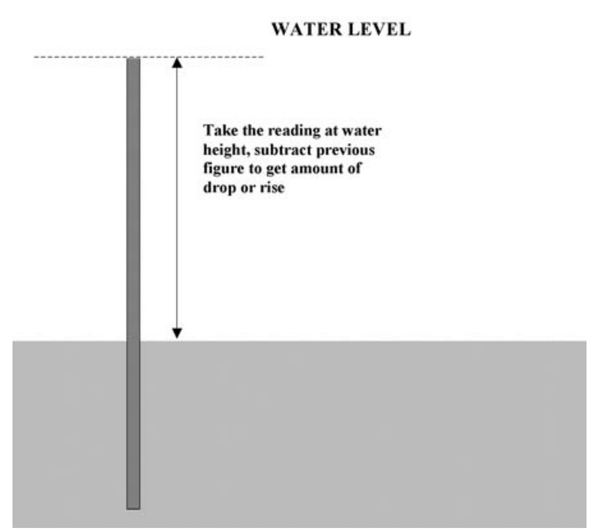

Figure 7.1. Measuring water depth.

4. Readings should be taken once a week throughout the year. While the flood is coming in, readings should be taken every 1-2 days to provide more accurate data.

Interpretation of Results

If the water is rising, subtract the new reading from the last one to find out how much it has risen i.e. if the last reading was 10 cm and the new reading is 8cm, it means that the water has risen 2 cm (10-8 = 2). If the new reading is higher than the last one, it means that the water has dropped. If the water is dropping, subtract the last reading from the new reading to see how much it has dropped.

Has this changed since your last reading? If so, can you think of what changes in the Okavango may have caused this?

Notes

- Make sure that the stick is buried deep in the ground so that the current cannot carry it away.
- It will be easier to bury the stick properly if it is put in when the floodwaters are low.
- Make sure that you will be able to get to the stick with a mokoro to take the readings once the floodwaters have arrived.
- Get an idea of how much the floodwaters usually rise from people that have been in the area for a few years.
- Make sure that the stick is at least half a meter higher than what they predict to avoid it becoming submerged.

B. Water Flow

Why do we measure Water Flow?

Water flow tells us how fast the water is moving. It is good to be aware of very fast flowing waters as they could result in an increase in the erosion of banks etc. Different species of fish are found in waters with different flow rates. Thus monitoring the flow rate could be used to explain why a certain fish is no longer being caught i.e. if it prefers slow waters and the flow rate has increased, it may have migrated to another area. Flow also gives us a good idea of how long it is going to take for the water to get to the areas below us and to Maun.

Equipment required

- 2 wooden sticks (2 meters long)
- measuring tape (at least 10 m long)
- 1 stopwatch
- 1 cork

Methodology

This measurement is best done using 3 people.

1. Put the 2 sticks along the banks of the channel exactly 5 m apart, using the measuring tape to measure the distance between sticks.
2. Have one person stand behind each of the sticks.
3. When they are ready, the third person must drop the cork a few metres upstream of the first stick
4. The other two people call out when the cork has passed their stick.
5. The third person should then use the stopwatch to measure how many seconds it takes for the cork to float from the first stick to the second stick.

Interpretation of Results

To calculate the flow rate, divide the number of seconds by 5 (due to the 5 meters between sticks). This gives a flow rate in metres per second (m/sec). If you place the sticks at another distance apart (such as 10 m) then use that number as the divider. Has the result changed since your last reading? If so, can you think of what changes in the Okavango may have caused this?

Notes

- Select the straightest open channel that you can - avoid bends and barriers (fences, vegetation mats, logs) near the stick, which could change the flow of the water past your stick.
- Call out and put your hand up in the air when the cork floats past your stick so that the timekeeper knows when to start and when to stop keeping the time.

C. Water Visibility

Why do we measure Water Visibility?

Visibility is the ability to see through the water. If water becomes more and more turbid (full of floating material) and the visibility decreases in the same area over a long time it could mean that water is getting polluted. If the water gets too dirty, the plants underneath can no longer photosynthesize and may die, making the water even dirtier as they decay. Very dirty water should be avoided but remember: clear water is not always clean water and should not be seen as indication of good drinking water!

Equipment required

- 1 Secchi disc made up of a white enamel plate, weight, string, drill, marker, tape measure to calibrate (see Figure 7.2)

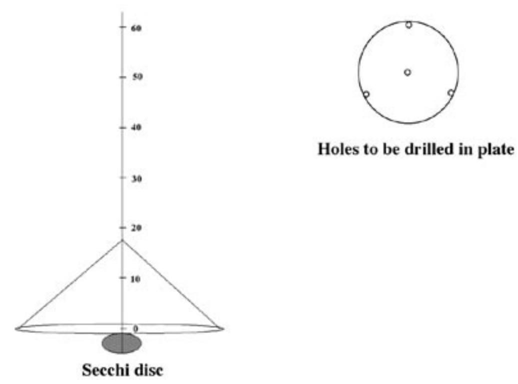

Figure 7.2. Secchi Disc.

Construction of Secchi disc (see Figure 7.2)

- Turn the plate upside down. Drill 3 holes around the outside (equal distance apart) and one through the center.
- Thread a piece of string through each of the holes, tying a large knot on the underside of each to stop the string from pulling through the hole again. The string threaded through the center hole should be at least 4m long.
- Suspend a weight underneath the plate. This should be large enough to pull the plate underwater and overcome the effects of a strong current. A large rock/brick should be suitable.
- Join the string from the 3 outside holes at the same place on the center string.
- Calibrate the center string by making a mark every 5 cm along the whole length of the center string starting from the top of the plate.

Methodology

1. Lower the plate into the water.
2. At the exact moment that it is no longer visible, grab the string at the point where it enters the water.
3. Measure the string from the plate to the place where you grabbed the string. You can do this by counting off the number of marks on the string (5 cm intervals) or by using a measuring tape.

Interpretation of Results

The length of the string from the plate to the surface of the water indicates the water's visibility – how deep you are able to see into the water. Has this changed since your last reading? If so, can you think of what changes in the Okavango may have caused this?

Notes

- Lower the secchi disc into the water slowly.
- Go past the point where the disc becomes invisible and bring it up slowly until you can just see it, then grab the string just at the surface.
- Keep your grab on the string at the measured spot until you measure it or else you'll lose your spot.

Figure 7.3. Invertebrate sieve.

D. Water Temperature

Why do we record Water Temperature?

The temperature of the water will determine which species of organisms (fishes, insects, plants, etc.) live in that water. Higher temperatures cause less oxygen in the water. Different aquatic organisms require different oxygen and temperature levels and thus different species occur as the temperature and oxygen levels change. Water temperature will also affect the rate of ecosystem processes such as the decomposition of plants, photosynthesis, and nutrient cycling.

Equipment required

- Thermometer for use in the water (°Celsius)
- String
- Watch
- Ruler or short measuring tape that is water-proof (e.g., plastic)

Methodology

1. Shake the thermometer.
2. Submerse the thermometer just below the surface of the water.
3. Take a reading after 1 minute.
4. Record the depth at which you took the reading.
5. Shake the thermometer again.
6. Submerse the thermometer as close to the bottom as possible and take another reading.
7. Record the depth at which you took the reading.

Interpretation of Results

The reading (number) on the thermometer tells you the temperature of the water in degrees Celsius (°C). The difference between the temperature of the water at the surface and that at the bottom may be due to many variables including water depth, flow rate, visibility, and the amount of chemical processes occurring such as decomposition and photosynthesis.

Notes

- Take the readings at the same depths each time so that you can monitor changes over time.
- Pull the thermometer out of the water as quickly as possible and take the readings as soon as you can.
- If the water is deeper than 3m, take readings at the halfway mark.
- Make sure that you record the depth for every single reading.
- If you have more than one thermometer available, you must cross-calibrate them. This is done by taking a reading with each in the same place and then checking to ensure that they give the same reading.

E. pH of the Water

Why do we measure pH of the Water?

A pH reading indicates whether the water is neutral (pH of 7), acid (pH from 1 to 6) or alkaline (pH from 8 to 14). The pH should be between 6 and 8. If it is lower than 5 or higher than 8, it can cause the death of fish, plants (and crops). Very acidic water (lower than 4) also causes boats to rust and cement to dissolve. Also, if the pH changes drastically over a period of time, it could also suggest that the water is being polluted.

Equipment required

- pH pen and batteries OR litmus sticks/papers
- Glass jar

Methodology

1. Take a jar full of water from your site.
2. Dip the litmus stick or pH pen into the jar for 1 minute. If using the stick, flick off the excess water.
3. Read the value displayed on the pH pen, or record the color of the litmus stick.
4. Repeat two times.

Interpretation of Results

The value displayed on the pH pen is the pH value of the water. A pH of 7 is neutral, pH from 1 to 6 is acidic, and pH from 8 to 14 is alkaline or basic. Normal pH should be between 6 and 8. Sometimes pH values are a bit lower/acidic (4.5 to 5.5), which may be due to higher concentrations of dissolved humic compounds that stain the water a pale yellowish-brown colour. If your pH value is lower than 4.5 or higher than 8, please contact the Department of Water Affairs & Forestry (DWAF) as it could indicate a problem with heavy metals, too many salts or other form of water contamination. Since three readings are taken at the same site, your final value should be an average of all 3 readings (add them all together and divide by 3). If using a litmus stick or paper, the stick/paper will turn color when placed in the water. Pink indicates that the pH is acidic and blue indicates that the pH is alkaline.

Notes

- Readings must be taken immediately.
- A minimum of 3 samples should be taken at each sampling point.

F. Water Colour

Why do we measure Water Colour?

If the water near a village or camp suddenly turns green, it could mean that the toilets or the fertilizer from the fields are polluting the water. Thick clumps of slime are also usually visible when this happens. The green colour is caused by an increase in plant and algal growth in the water as a result of the excess nutrients (mostly nitrogen and phosphorous) that are being released into the water. The decaying of dead plants, animals, household rubbish and/or rusty metal in the water could cause it to turn very brown.

Methodology

1. Observe and record the colour of the water.

Interpretation of Results

The water colour should be clear, light brown (with sediments), a slightly darker brown (with a lot of humus or decaying material). Green colour may indicate pollutants or an over-abundance of algae caused by increased phosphates in the water. See above for other possible contaminants. If the water turns any other colour, it is likely to be very serious and should be reported to DWAF.

G. Nitrates, phosphates & bacteria

Other tests that could be considered include phosphates, nitrates and bacteria. There are special school test kits readily available for these. These can be purchased from Umgeni Waters in Pietermaritzburg, South Africa or found off various sites on the internet.

II. Invertebrates

Why do we look at invertebrates?

The presence or absence of certain invertebrates can give an indication of how clean the water is. If the presence of invertebrates declines suddenly, it is a definite indication that something has changed in the water. Some invertebrate species carry the organisms that cause diseases in animals and humans. It is a good idea to be aware of these, particularly in the water in which you drink and swim. We recommend monitoring the three invertebrates listed below. See the photo section of this report for photographs of each.

Biomphalaria pfeifferi

Medium-sized snail belonging to the family Planorbidae; shell disc-shaped measuring up to about 14mm diameter and 5mm high; colour generally pale brown, soft parts usually darker brown/grey. Slow-moving, completely aquatic and commonly found crawling on submerged vegetation. Serves as the intermediate host of *Schistosoma mansoni*, the parasite causing intestinal bilharzia (schistosomiasis).

Appasus spp.

Waterbugs belonging to the family Belostomatidae; medium-sized, brown/green in colour, adults with wings clearly visible dorsally but juveniles lack wings. Suctorial feeders. Active swimmers and voracious predators – some of the larger specimens can deliver a painful bite with their raptorial forelegs! They breathe air and so must come to the surface to replenish their air supply. Several species of *Appasus* occur in the Okavango Delta.

Caridina nilotica

A common shrimp belong to the family Atyidae; grows up to about 40mm long, nearly transparent (colourless) when alive though its body does have darker reddish/brown flecks. Antennae are long and distinct, eyes dark and mounted on short stalks. Females may carry large numbers of eggs attached to the pleopods of their anterior abdominal segments. These are active crustaceans that are often abundant in marginal, submerged and floating vegetation in many kinds of habitat; larger specimens are capable of flicking their abdomens to 'jump' out of the net when caught!

Equipment required

- Invertebrate sieve (Figure 7.3) or scoop net

Methodology

1. Push the sieve/net in under or into the vegetation, move it up and down a few times to dislodge any animals present so that they fall into the net.
2. Bring to the surface.
3. Empty the contents into a plastic bowl (preferably light coloured) about half full of water and count how many of *Caridina nilotica, Appasus* spp., and *Biomphalaria pfeifferi* that you have caught. (See the photo section of this book for photos of each species).
4. Scoop again 9 times at each site and count the number of each species.

During any sampling session, do not net repeatedly in the same precise patch of vegetation. This is because most animals that were dislodged by your first attempt and were not caught will have fallen to the bottom and your subsequent samples will no longer be representative.

Interpretation of Results

You need to consider the biology of the three types of invertebrates that you are monitoring. Of these, *B. pfeifferi* and *C. nilotica* are totally aquatic and get their oxygen requirements from the water via gills (*C. nilotica*) or via both a 'lung' and the skin (*B. pfeifferi*). In this respect they represent other freshwater molluscs (Gastropoda and Bivalvia), many insect larvae (e.g. Ephemeroptera and Odonata) and lower invertebrates such as leeches. The waterbugs (*Appasus* spp.) are air-breathers and need to replenish the air in their tracheal system by coming to the surface to get access to atmospheric air. They are therefore representative of the Heteroptera generally as well as some insect larvae (e.g. mosquitoes) and crabs. One might therefore expect that the 'dissolved oxygen breathers' would be affected more quickly than the air-breathers by deterioration in water quality. Presumably, therefore, the continued presence of 'dissolved oxygen breathers' is desirable and indicative of good water quality – a dominance of air-breathers would probably not be a healthy sign.

Biomphalaria pfeifferi and *C. nilotica* are both grazers feeding on periphyton (especially decaying organic matter) while *Appasus* is a predator, capturing its prey by chasing it. Its prey includes whatever it can catch, including snails and other insects. Water quality affects the availability of arthropod prey and decaying matter for these organisms.

In addition, while many insects have aerial adults, all arthropods and snails lay their eggs beneath the water so water quality will determine the success of either the development of larvae inside the eggs or the survival of hatchlings.

If you find *Biomphalaria pfeifferi* in your samples, this does not necessarily mean that you will have an outbreak of schistosomiasis. To prevent infection and illness, everyone who is in contact with the water should: (i) practice good hygiene. Never defaecate near the water's edge. Use pit latrines whenever possible. The eggs of *Schistosoma mansoni*, the parasite causing intestinal bilharzia (schistosomiasis), are transferred in faeces and can be washed into the water by rain. These eggs have a delayed hatching mechanism to improve the chances of this happening. (ii) go to the nearest health centre for treatment if you suspect that you have become infected. The most common sign is blood in the faeces. There are routine annual treatments with praziquantel regardless of infection status. Praziquantel *should* be available at all health facilities.

Notes

- 10 samples should be taken at each selected sampling site.
- Try to get the sieve as far underneath the vegetation as possible.
- Make sure that you bring the sieve up gently so that you do not lose your sample.

III. Aquatic weeds

Why do we look at aquatic weeds?

Certain water plants are referred to as aquatic weeds because they grow quickly and eventually dominate and out-compete many naturally occurring plants. Once introduced, they spread quickly through movement of water (flow) and by attaching to hippos, lechwe, elephants, and boats. They grow where they are not wanted and interfere with the intended uses of water (i.e. livestock or human consumption, irrigation, preservation or wildlife resources).

Three types of weeds have been recorded in Botswana and thus are very important to monitor and control. They include:

- Motshimbama, Kariba weed (*Salvinia molesta*)
- Water hyacinth (*Eichhornia crassipes*)
- Water lettuce (*Pistia stratiotes*).

Refer to the brochure produced from the Botswana Department of Water Affairs for identification pictures and more relevant information.

Equipment

- Aquatic weeds ID book (available from the Botswana Department of Water Affairs)
- Mokoro or other boat

Methodology
1. Check all waterways regularly for signs of these weeds.
2. Record the location, species, and number of plants you find.
3. Contact DWAF with your information.

Interpretation of Results
Finding aquatic weeds in your area is very serious and should be immediately reported to DWAF. These weeds can displace native plants and have large impacts on many aspects of water quality.

Notes
- Stop all types of movements through the infected waters (including mokoros, motor boats, animals and swimming) until DWAF has responded and has removed the weedy plants.

IV. Aquatic plant monitoring
Why do we look at aquatic plants?
Changes in the plant communities of the waterways of the Delta give us clues about the health of the aquatic ecosystem and what sort of changes are occurring, i.e. if the water is moving faster or if there is less oxygen in the water, the plant communities could change.

Equipment
- Grid: 4 x poles, string, tape measure
- Aquatic plants ID book (such as *Plants of the Okavango Delta* by Karen and William Ellery, 1997).

Methodology
1. Make a 3 m x 3 m square by cutting 4 x 3.2 m pieces of string and tying them exactly 3 m apart on the four poles (Figure 7.4).
2. Choose areas with different types of vegetation such as:
   - Deep, open water
   - Narrow channel
   - Grassland
   - Riverine forest etc.
3. Bury a grid in each of the areas that you have identified.
4. Identify all the plant species within your grid (the final monitoring manual should provide picture sheets of what plants you should expect to find in each environment).
5. Count how many there are of each species.
6. Note the size of the plants.

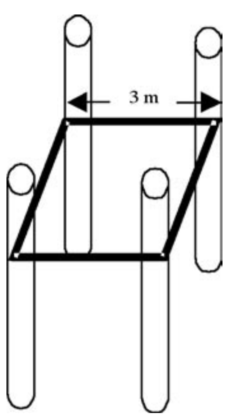

Figure 7.4. Square for monitoring aquatic plants.

Interpretation of Results
Compare the species and numbers of plants recorded each time. Are there any major changes? Have any weedy plant species entered the plot? Can you think of any changes in water levels, climate or human activities that may have caused these changes?

Notes
- The grid can be made smaller if required. Make sure that you note down the new size.
- Make sure that the plant counts are done in the same areas every month.
- Ideally the grids should remain in the ground. Sketch a plan of where they are in case they are removed.

V. Cranes
Why do we monitor Cranes?
The Endangered Wildlife Trust (EWT) National Crane Conservation Project in South Africa is in need of information on cranes (particularly with respect to the Wattled Crane) in other southern African countries. Eleven of the 15 crane species in the world are threatened, including the 3 species found in Botswana: Wattled Crane (*Bugeranus carunculatus*) and Blue Crane (*Anthropoides paradiseus*) - critically endangered - and the Crowned Crane (*Balearica regulorum*) - endangered.

The decline of these species is largely due to the loss/degradation of crane habitat as a result of agriculture, dam construction, industrialisation, deforestation, increased fires, poisoning, and increased human settlement.

Equipment
- Guidebook to the birds of Botswana (such as *Roberts' Birds of Southern Africa* by G.L. Maclean, 1993)
- Mokoro or other boat

Methodology
1. Survey your area for the presence of cranes.
2. Record information about the cranes in your area on the worksheet.
3. Record this information on an ongoing basis, i.e. once a month on a set date.

Interpretation of Results
This information will be very useful in developing plans to protect and save these crane species from extinction. Be sure

to give your information to local conservation groups or directly to the Endangered Wildlife Trust (EWT) National Crane Conservation Project in South Africa.

VI. Skimmers

Why monitor Skimmers?

The Botswana Bird Club is currently setting up programs to monitor skimmers in northern Botswana. They will require input from the communities once the project is up and running. Contact the Botswana Bird Club directly to see how you can be involved.

VII. Bird breeding Sites

Why do we monitor breeding sites?

If birds stop breeding in an area where they have bred before, there is a good chance that the water could be polluted or there has been some type of disturbance to their nesting sites.

Equipment

- Guidebook to the birds of Botswana (such as *Roberts' Birds of Southern Africa* by G.L. Maclean, 1993).
- Mokoro or other boat.

Methodology

1. If you have a breeding site in your area, visit it at least once a month.
2. Record the species of breeding birds, the number of birds, and the number of nests.
3. Re-visit the site once a month.

Interpretation of Results

If birds stop breeding, it means that the environment in which they are in is no longer suitable. This could mean that there are negative changes occurring in that environment. If you see a decline in the number of birds or the number of species, contact DWAF with your information.

Notes

- Be careful not to disturb the birds or their nests during your survey
- Motorized boats should not be used

VII. Channel dynamics

Why do we monitor the channels?

There is great interest in how the channels of the Okavango Delta are formed. Your information could contribute towards finding the right answers.

Methodology

1. Record any changes that you note in the way the channels flow in your area.

Interpretation of Results

Changes in the channels may be caused by a variety of factors, including rainfall, flood levels, vegetation growth, and movements of animals such as hippos. Draw a sketch of the channels of your area and the changes you observe over time. If you see any major changes, report it to DWAF.

VIII. Climate

Why do we measure climate?

The weather may affect some of the data that you are monitoring. It is therefore important to record what the weather patterns were like on the day that you were monitoring in case these data are ever required. Rainfall data is very important as they give us a clue of how much of the water in the Delta is from rain and how much has come down from Angola. It also helps us to calculate how big the next flood could be.

Equipment

- Rain gauge marked in mm or a cup
- 127 mm funnel (if using a cup)
- Thermometer

Methodology

1. Rainfall should be measured daily.
2. Place the rain gauge or cup in a location where rain will directly fall into it.
3. Measure rainfall by recording the number of mm of water in the rain gauge.
4. If you use a cup, pour the water from the cup into the funnel and then record how much water is in the funnel.
5. Secure the thermometer permanently to a tree or post where it is in the direct sun for most of the day.
6. Temperature readings can be read straight off a thermometer.

Notes

- Ensure that the rain gauge is placed on a pole in an open area.
- Try to keep it away from all animal paths.
- Make sure that the thermometer is placed in the sun.
- Take the rainfall and temperature readings at the same time of day each time.

IX. Fishes

Why monitor fish stocks?

Monitoring fish stocks over a long time series allows us to observe changes in fish community structure and life histories due to external factors such as fishing pressure, environmental perturbations etc. Fish can be used as bio-indicators and monitoring their dynamics over time can illustrate what is happening in the ecosystem.

Equipment

- Fish species identification book reference (such as *A Complete Guide to the Freshwater Fishes of Southern Africa* by Paul Skelton, 1993)
- Fish nets: Multi-panel, multi-mesh research nets, seine nets; scoop nets

- Outboard boat
- Measuring boards
- Electronic weighing scales

Methodology

Tropical fish population dynamics consist of a set of methods that can be used quantitatively to interpret data on:

1. Stock sizes,
2. Recruitment,
3. Growth, and
4. Natural rates of mortality.

What to monitor

1. Describe the species caught.
2. Record the number of individual fishes for each species and for each type of collecting gear used in each location.
3. Take length measurements of each individual specimen (for each species) caught (standard, total and fork lengths).
4. Measure weight of each individual specimen (for each species) caught.

When to monitor

Fish stocks should be monitored every month by collecting fish species samples from different locations. A standardized net setting procedure should be followed so that trends in catchability and availability can be easily observed.

Interpretation of Results

Describe changes in species abundance, size and species composition by month to follow seasonal change. Major changes in the species, size, or number of fishes may indicate that the fish communities are disturbed or over-fished. Report any major changes to DWAF.

REFERENCES

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Maclean, G.L. 1993. Roberts' Birds of Southern Africa, Sixth Edition. John Voelcker Bird Book Fund. Cape Town, South Africa. 871 pp.

Skelton, P.H. 1993. A complete guide to the freshwater fishes of southern Africa. Southern Book Publishers, Halfway House, RSA, 388 pp.

Gazetteer

See Appendix 1 for locations of each georeference sampling point.

1. UPPER PANHANDLE (CENTRED AROUND SHAKAWE/ MOHEMBO): 6-9 JUNE, 2000; BASE CAMP AT S 18º24'40.8", E 21º52'48.2"

Sampling of water quality parameters, aquatic and terrestrial plants, fishes, and invertebrates was conducted around seven georeference points along the Okavango River from the town of Mohembo at the Botswana-Namibia border, south to the town of Shakawe, and then on to approximately three kilometres south of Drotsky's Cabins.

2. LOWER PANHANDLE (CENTRED AROUND GUMA LAGOON): 10-12 JUNE, 2000; BASE CAMP AT S 18º57'13.2", E 22º22'24.4"

Seven georeference sampling points were sampled, particularly in and around Guma Lagoon (Ngquma Lebida) and in the small channel (Thaoge Channel) connecting Guma Lagoon to the Okavango River. Water quality characteristics, aquatic and terrestrial vegetation, fishes and invertebrates were studied at each of these sampling points.

3. NORTH-WESTERN MOREMI GAME RESERVE (AROUND XAKANAXA LAGOON): 13-16 JUNE, 2000; BASE CAMP AT S 19º11'25.7", E 23º23' 46.7"

Thirteen georeference points were sampled in order to assess the great variety of aquatic habitats at this site, which included several important lagoons as well as land-locked pools within the reserve. The team investigated water quality, vegetation, fishes, invertebrates and aquatic birds in small and medium sized channels, lagoons, permanently and seasonally flooded pools, and saline pools.

4. SOUTH-EAST OF CHIEF'S ISLAND ALONG THE BORO RIVER: 17-20 JUNE, 2000; BASE CAMP AT S 19º32' 08.5'', E 23º05' 56.8''

Ten georeference points were sampled. Since motor boats are prohibited at this site, all sampling was conducted from mokoros (dug-out canoes) or from land, which was much more challenging and did not always allow for complete access to all habitat types. Small channels, lagoons, seasonal pans and pools, and a borrow pit were sampled at this site.

Appendix 1

Georeference points sampled during the AquaRAP Expedition to the Okavango Delta, Botswana, June 5-20, 2000

Georeference Point	Country	Site	Region	Focal Area	Latitude	Longitude	Date
OK1-01	Botswana	Okavango Delta	Ngamiland	Upper Panhandle	S 18º24’ 26.8”	E 21º53’ 08.4”	7-Jun-00
OK1-02	Botswana	Okavango Delta	Ngamiland	Upper Panhandle	S 18º24’40.8”	E 21º52’48.2”	7-Jun-00
OK1-03	Botswana	Okavango Delta	Ngamiland	Upper Panhandle	S 18º16’27.3”	E 21º47’14.0”	8-Jun-00
OK1-04	Botswana	Okavango Delta	Ngamiland	Upper Panhandle	S 18º16’19.8”	E 21º48’35.3”	8-Jun-00
OK1-05	Botswana	Okavango Delta	Ngamiland	Upper Panhandle	S 18º20’28.8”	E 21º50’09.2”	8-Jun-00
OK1-06	Botswana	Okavango Delta	Ngamiland	Upper Panhandle	S 18º26’22.9”	E 21º54’41.8”	9-Jun-00
OK1-07	Botswana	Okavango Delta	Ngamiland	Upper Panhandle	S 18º24’18.5”	E 21º58’19.0”	9-Jun-00
OK1-08	Botswana	Okavango Delta	Ngamiland	Guma Lagoon/ Upper Delta	S 18º57’13.2”	E 22º22’24.4”	11-Jun-00
OK1-09	Botswana	Okavango Delta	Ngamiland	Guma Lagoon/ Upper Delta	S 18º57’41.5”	E 22º23’8.4”	11-Jun-00
OK1-10	Botswana	Okavango Delta	Ngamiland	Guma Lagoon/ Upper Delta	S 18º57’21.4”	22º22’39.1”	11-Jun-00
OK1-11	Botswana	Okavango Delta	Ngamiland	Guma Lagoon/ Upper Delta	S 18º57’21.4”	E 22º22’39.1”	12-Jun-00
OK1-12	Botswana	Okavango Delta	Ngamiland	Guma Lagoon/ Upper Delta	S 18º57’30.4”	E 22º24’02.3”	12-Jun-00
OK1-13	Botswana	Okavango Delta	Ngamiland	Guma Lagoon/ Upper Delta	S 18º51’34.6”	E 22º24’21.7”	12-Jun-00
OK1-14	Botswana	Okavango Delta	Ngamiland	Guma Lagoon/ Upper Delta	S 18º57’04.8”	E 22º22’23.0”	12-Jun-00
OK1-15	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º09’44.5”	E 23º14’29.4”	14-Jun-00
OK1-16	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º09’54.8”	E 23º14’40.7”	14-Jun-00
OK1-17	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º09’20.1”	E 23º15’33.3”	14-Jun-00
OK1-18	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º09’22.1”	E 23º16’12.8”	14-Jun-00
OK1-19	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º08’58.3”	E 23º16’44.0”	14-Jun-00
OK1-20	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º08’17.0”	E 23º22’33.0”	15-Jun-00
OK1-21	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º08’ 17.0”	E 23º23’44.0”	14-Jun-00
OK1-22	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º11’25.7”	E 23º23’46.7”	15-Jun-00
OK1-23	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º12’15.2”	E 23º27’36.8”	15-Jun-00
OK1-24	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º12’ 12.7	E 23º27’ 39.3	15-Jun-00
OK1-25	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º11’36.4”	E 23º24’55.8”	16-Jun-00
OK1-26	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º13’19.1”	E 23º24’54.8”	16-Jun-00
OK1-27	Botswana	Okavango Delta	Ngamiland	Xakanaxa, Moremi	S 19º12’30.6”	E 23º24’11.1”	16-Jun-00
OK1-28	Botswana	Okavango Delta	Ngamiland	Chief’s Island	E 19º32’38.9”	S 24º03’50.2”	18-Jun-00
OK1-29	Botswana	Okavango Delta	Ngamiland	Chief’s Island	E 19º32’01.6	S 23º04’48.6”	18-Jun-00
OK1-30	Botswana	Okavango Delta	Ngamiland	Chief’s Island	S 19º32’01.6”	E 23º04’48.3”	18-Jun-00

continued

Georeference Point	Country	Site	Region	Focal Area	Latitude	Longitude	Date
OK1-31	Botswana	Okavango Delta	Ngamiland	Chief's Island	S 19º31'36.5"	E 23º05'46.4"	19-Jun-00
OK1-32	Botswana	Okavango Delta	Ngamiland	Chief's Island	S 19º32'36.4"	E 23º06'22.3"	19-Jun-00
OK1-33	Botswana	Okavango Delta	Ngamiland	Chief's Island	S 19º32'46.6"	E 23º06'03.3	19-Jun-00
OK1-34	Botswana	Okavango Delta	Ngamiland	Chief's Island	S 19º32'10.8"	E 23º05'14.5	19-Jun-00
OK1-35	Botswana	Okavango Delta	Ngamiland	Chief's Island	S 19º31'17.5"	E 23º06'15.6"	20-Jun-00
OK1-36	Botswana	Okavango Delta	Ngamiland	Chief's Island	S 19º32'08.5"	E 23º05'56.8"	20-Jun-00
OK1-37	Botswana	Okavango Delta	Ngamiland	Chief's Island	S 19º32'13.5"	E 23º05'54.1"	20-Jun-00

Appendix 2

Macro-invertebrate collections by geo-reference point

Chris C. Appleton, Barbara A. Curtis, and Jens Kipping

UPPER PANHANDLE (UPH), 6-9 JUNE, 2000

OK1-01-INV01: 1 km upstream of Drotsky's Cabins. *Echinochloa pyramidalis*-dominated backswamp (S 18° 24' 26.8", E 21° 53' 08.4") 7th June 2000. DO = 6.92, EC = 35.0, pH = 6.97.
The invertebrate fauna in this swamp, through which water flowed slowly at about 0.1 m/sec., was dominated by two groups, the Heteroptera which are predators and/or scavengers and the Anisoptera which are predators. Amongst the Heteroptera, the surface dwelling *Limnogonus capensis* (Gerridae) and *Rhagovelia* sp. (Veliidae), were patchily abundant in small areas of shaded, open water while the small *Micronecta scutellaris* (Corixidae) and *Anisops apicalis* (Notonectidae) were common amongst submerged vegetation. A second notonectid, *Nychia marshalli*, was less common. The predaceous **Appasus nepoides* (Belostomatidae) was also common. The most abundant predators were undoubtedly the adults of the dragonfly *Aethiothemis discrepans* which were recorded flying over the grass (*E. pyramidalis*) at densities of up to 50/m^2. Two other anisopterans, *Trithemis sticta* and *T. hecate*, were much less common as was the zygopteran *Pseudagrion deningi*. The shrimp *Caridina africana* (Crustacea) was also present. Two gastropods, *Ceratophallus natalensis* and *Bulinus depressus*, were recorded here and large mayfly larvae (*Elassoneuria ?grandis*) were found in the fine sandy sediments of a 2 m-wide, fast-flowing channel through the swamp into the river. Larvae of two other mayfly species were also collected, *Cloeon* nr. *virgiliae* and *Povilla adusta*.

(*Note: waterbugs previously included in the genus *Diplonychus* are now placed in *Appasus* following Polhemus 1995).

A brief collection was also made in a stand of *Cyperus papyrus* on the opposite bank of the Okavango River (OK1-01-INV02; S 18° 24' 25.6", E 21° 53' 04.6") but this proved difficult to do effectively from a boat (see also Guma Lagoon). The crevices formed by the rhizomes and culms of *C. papyrus* were colonized by the snail *Bulinus* sp., the small bivalve *Eupera ferruginea*, *Appasus* sp., and the crab *Potamonautes bayoniansis* (juvenile). *Potamonautes bayonianus* is endemic to the Okavango/upper Zambezi/Kunene river systems.

OK1-02-INV05: Human and cattle contact site ±0.5 km upstream of Drotsky's Cabins (S 18° 24' 40.8", E 21° 52' 48.2") 7th June 2000. DO = 2.22, EC = 33.2, pH = 6.43.
A feature of this sheltered site was disturbance and pollution by local people who use it for washing, collecting water and watering their cattle and donkeys. The invertebrate fauna was poor and the only species found were the shrimp *C. africana*, the mayfly *Elassoneuria ?grandis* and the veliid *Rhagovelia* sp. All three were common. Red chironomid larvae (*Chironomus formosipennis*) were common in the bottom (organic detritus on fine sand) indicating low oxygen concentrations as reported above. The water was ±1.5 m deep.

Other collection sites within a 1km radius of OK1-02-INV05 (i.e. INV03, 04 & 06) yielded five mollusc species, *Bellamya capillata*, *Cleopatra elata, Lymnaea natalensis* and *Bulinus depressus* (Gastropoda) and juvenile *Eupera ferruginea* (Bivalvia), the shrimp *C. africana,* the crab *Potamonautes bayonianus*, many *Rhagovelia* sp. and the adults of three species of Odonata: *Aethiothemis discrepans* and *Crocothemis erythraea* (Anisoptera) and *Pseudagrion deningi* (Zygoptera). The semi-aquatic snail *Oxyloma patentissima* was fairly common on emergent vegetation.

OK1-03-INV07 & 08: Ferry landing site at Mohembo; 8th June 2000. EC = 33.9-34, pH = 7.2-7.4.
The main invertebrate collecting sites here were a shallow (±30cm deep), *Nitella*-dominated pool close to the river bank at the Eastern Pontoon Landing (S 18° 16' 19.9", E 21° 47' 36.8") and an extensive backswamp dominated by the hippo grass *Vossia cuspidata* about 500 m west of the Western Pontoon Landing (S 18° 16' 27.3", E 21° 47' 14.0").

The oxygen content of the pool was close to saturation. It harboured several heteropterans (*Limnogonus* sp., *Stenocorixa protrusa* and *Appasus nepoides*), unidentified mosquito larvae and six gastropod species: the prosobranchs *Gabiella kisalensis* and *Cleopatra elata* and the pulmonates *Lymnaea natalensis, Ceratophallus natalensis, Biomphalaria pfeifferi* and *Bulinus depressus*. The sediments contained many red chironomid larvae, several unidentified baetid mayfly larvae and the bivalve *Eupera ferruginea*.

The *V. cuspidata* backswamp supported a similar invertebrate fauna to the pool, but in greater numbers. The corixid *M. scutellaris* was dominant with another corixid, *S. protrusa* and at least two species of *Appasus*, *A. nepoides* and *A.?ampliatus*, present as well. Odonata were particularly well represented, with 10 species (four Zygoptera and six Anisoptera) being collected (see Appendix A). The most abundant was the zygopteran *P. deningi*; this species was also the most common in a small, deep backwater lagoon nearby [18º 24' 50.1" S, 21º 53' 07.6" E]. Mayfly larvae (*Cloeon* cf. *virgiliae*) were common here and a new genus and species of Caenidae were present. The shrimp *Caridina africana* was common and the fish-eating spider (*Thalassius* sp.) was also recorded.

The snail fauna of the backswamp was similar to that from the pool with the addition of numerous large, fresh shells of *Lanistes ovum* and a single *Pila occidentalis* shell lying on recently exposed grass. These did not seem to have been preyed upon but lacked opercula (see under predation on *L. ovum* in CHI section). The *P. occidentalis* (45.7 x 43.6 mm) was alive and emerged later in a bowl of water. The pulmonate *Bulinus globosus* was also present and two terrestrial species, the semi-aquatic *Oxyloma patentissima* (Succineidae) and a slug, *Elisolimax* sp. (Urocyclidae), were common and present respectively on emergent grasses, especially where these were shaded.

OK1-04-INV09: Island (sandbar) in Okavango River main channel ±3km downstream of Mohembo (S 18° 16' 19.8", E 21° 48' 35.3") 8th June 2000. DO = 7.2-7.5, EC = 33.9-34.1, pH = 7.23

This small but permanent island was situated in mid-channel and surrounded by a fringe of *V. cuspidata*. It included small pools about 70 cm deep and lined with the grass *Pennisetum glaucocladum*. These were connected to the river by a slowly-flowing channel. Several dragonfly larvae (*Macromia* sp., *Paragomphus genei* and *Gomphus* sp.) and juvenile bivalves (*Corbicula fluminalis*) were collected in the sediments (clean sand with very little organic debris) in the connecting channel. *Corbicula fluminalis* was present at a mean density ±SD of 6.7 ±5.3/m^2 (n=4 x 1 m^2 quadrats). This is somewhat higher than at other areas of the delta (see MGR and CHI). Collecting in the pools themselves produced more *Caridina africana*, a large crab (*Potamonautes bayonianus*), mayfly larvae (*Pseudocloeon piscis*) and only one heteropteran, *Appasus nepoides* (Belostomatidae). Small numbers of adult *Crocothemis erythraea* (Anisoptera) and *Pseudagrion sjoestedti jacksoni* (Zygoptera) were also collected. Only one gastropod species was found, *Cleopatra elata*.

River bank near Drotsky's Cabins (18° 24' 50.1" S, 21° 53' 07.7" E) 8th June 2000.

Not a geo-reference site. The damselfly *P. sjoestedti jacksoni* (Zygoptera) was common around a small stand of fringing reeds.

OK1-05-INV10: Sandbar (point or scrollbar) on main channel of Okavango River, west of Shakawe (S 18° 20' 28.7", E 21° 50' 09.1") 8th June 2000. DO = 7.11, EC = 34.0, pH = 6.64.

Quadrat sampling (n=7) on the sandbar at 0.5-0.8 m water depth revealed gomphid larvae (Anisoptera) at 0.4 ±0.5/m^2 and bivalves (*Coelatura kunenensis*) at a density of 0.7 ±1.1/m^2. Single specimens of three heteropteran species, *Limnogonus capensis* (Gerridae), *Microvelia ?major* (Veliidae) and *Anisops gracilis* (Notonectidae) were collected amongst the *P. glaucocladum* in the backswamp behind the sandbar (INV11).

OK1-06-INV14: Irrigation Farm Pump Station downstream of Drotsky's Cabins (S 18° 26' 22.9", E 21° 54' 41.9") 9th June 2000. DO = 3.22-7.0, EC = 34, pH = 6.19-6.39.

Although this site was contaminated by pesticides and fertilizer, the invertebrate fauna associated with the marginal vegetation (e.g. *Vossia cuspidata* and *Polygonum salicifolium*) was more diverse than some unpolluted habitats. The shrimp *Caridina africana* and six species of Heteroptera were recorded including the gerrids *Limnogonus capensis* and *Tenagometra* sp., the notonectids *Anisops apicalis* and *Enithares chinai*, the Giant Waterbug, *Limnogeton fieberi* and the smaller *Appasus nepoides* (Belostomatidae), but none was common. Mayfly larvae included *Pseudocloeon piscis* and the new genus and species of Caenidae collected at Mohembo (OK1-03). The prosobranch snail *Cleopatra elata* and the pulmonates *Lymnaea natalensis, Biomphalaria pfeifferi* and *Bulinus depressus* were found on vegetation close to the pump as was the leech *Batracobdelloides tricarinata*. A rich odonatan fauna was also present. This comprised one zygopteran and nine anisopteran species of which the zygopteran, *Pseudagrion deningi*, was very much more abundant than the others. *Biomphalaria pfeifferi* is the snail intermediate host for *Schistosoma mansoni,* the parasite causing intestinal bilharzia (schistosomiasis) in people, and since human contact occurs at this site, it must be considered a potential focus of transmission. The bottom is of sand covered with large quantities of organic material which harboured red (bloodworms),larvae of the chironomid genus *Chironomus*. The red colour is due to haemaglobin in the haemolymph and the presence of these larvae is often indicative of low dissolved oxygen and high nutrient levels in the water (see data above).

Xaro Lodge, Okavango River channel (S 18° 25' 24.7", E 21° 56' 21.7") 9th June 2000.

This was not a geo-reference site. Adults of seven species of Odonata were collected within the grounds of the lodge. The genus *Pseudagrion* (Zygoptera) was particularly well represented: *P. sjoestedti jacksoni* was abundant while *P. deningi*, *P. sudanicum ruboviride* and *P. sublacteum* were all present. The anisopterans *Trithemis aconita, Aethiothemis discrepans* and *Lestinogomphus angustus* were also present.

OK1-07-INV17 & 18: Lagoons near Kgaolatlhogo Channel (S 18° 24′ 18.9", W 21° 58′ 17.6") 9th June 2000. DO = 2.8-4.3, EC = 37.1, pH = 6.45-6.66.

These well-vegetated sites supported a rich diversity of invertebrates. Nine species of Heteroptera were present with the Notonectidae (*Anisops apicalis* and *Enithares chinai*) the most common but neither was dominant. The others included *Naucoris obscuratus* (Naucoridae), the only naucorid bug found at any of the UPH localities. Three species of Odonata were collected of which two, *Pseudagrion deningi* (Zygoptera) and *Ischnura senegalensis* (Anisoptera), were common and *Anax imperator* present. *Lymnaea natalensis, Biomphalaria pfeifferi* and the semi-aquatic *Oxyloma patentissima* were the only molluscs sampled amongst the marginal vegetation. *Caridina africana* was also present.

Other Habitats

Two additional rather specialized habitats which were sampled in and around UPH geo-reference sites deserve separate consideration since they generally supported a restricted fauna.

Floating vegetation (predominantly *Trapa natans, Nymphaea nochuli* and *N. lotus*) (OK1-06 [extra]-INV15, OK1-07-INV18) 9th June 2000.

The undersides of *Nymphaea nouchali* and *N. lotus* leaves supported small numbers of predaceous heteropterans (*Appasus nepoides*), pulmonate snails (mostly juveniles), *Lymnaea natalensis, Biomphalaria pfeifferi* and *Bulinus* sp. and an unidentified glossiphoniid leech. No invertebrates were found beneath the leaves of *T. natans.*

Submerged weed beds (mostly *Ceratophyllum demersum* and *Utricularia* sp.) (OK1-02-INV04) 7th June 2000.

These were dominated by the shrimp *Caridina africana* but included the heteropterans *Micronecta scutellaris*, *Limnogonus capensis* and *Appasus nepoides*, and four species of pulmonate snails, *L. natalensis, B. pfeifferi, Bulinus globosus* and *B. depressus,* in low numbers.

Sediments beneath *Cyperus papyrus* and *Vossia cuspidata* mats were sampled at the same times as the mats themselves (OK1-06-INV15). 6th June 2000.

They always contained a large quantity of decaying organic matter or peat overlying sand but yielded virtually no burrowing or benthic invertebrates. The only forms recovered were the conspicuous red larvae of chironomid midges, probably *Chironomus* sp. As noted above (OK1-06-INV14), the pigment haemoglobin enables these larvae to survive in habitats with a low dissolved oxygen concentration as was confirmed here by measurements of ±25 % saturation. It is likely that the substrata beneath *C. papyrus* and *V. cuspidata* mats are similar wherever they occur. Because they are extensive, this means that the huge areas of swamps in the delta and associated panhandle are likely to be devoid of invertebrate life, or nearly so.

Sandbanks associated with the river channel (OK1-04-INV09, OK1-05-INV10 & 11) 8th June 2000.

Where these comprised clean sand with only a small quantity of organic debris, gomphid dragonfly larvae (Anisoptera) and bivalves (*Coelatura kunenensis* and *Corbicula fluminalis*) were found. The mean densities of these two bivalve species were estimated at <1 and 7/m^2 respectively but distributions were probably aggregated. These are very low when compared with data from lagoons and slow-flowing channels in the delta proper and other wetlands in southern Africa. These sediments are characteristically unstable and subject to considerable movement which may restrict colonization.

GUMA LAGOON (LPH) 11-14 JUNE, 2000

OK1-08-INV19: Seasonally flooded grassland behind campsite (S: 18° 57′ 13.2":E 22° 22′ 24.4") 11th June 2000. DO = 4.46-5.80 (8.12 in afternoon), EC = 37.6-36.7, pH = 5.80-6.41.

This extensive habitat measuring ±90 x 40 m and up to 40 cm deep was dominated by the grass *Panicum repens* and had filled from Guma lagoon 13 days previously. It harboured a rich fauna of mobile insects as well as the prosobranch snail *Pila occidentalis.* The latter species was present at a mean density of 0.2/m^2 (n=10 x 1m^2 quadrats). A further 67 *P. occidentalis* were collected in order to examine the size structure of the population which must have successfully aestivated since the previous inundation in January-April 2000. The mean shell height ±SD was 24.8 ±7.3 mm indicating that virtually the whole population was below 32 mm shell height and was therefore largely juvenile. The species grows to 60 mm. Empty shells of *Lanistes ovum* and *Bulinus globosus* were also found. A heteropteran fauna of eight species was dominated by *Micronecta scutellaris* (Corixidae) with the notonectids *Anisops apicalis*, *Anisops* sp. and the gerrid *Limnogonus nigriventris* being common. This latter species was not collected at any of the UPH sites. Two anisopterans *Ischnura senegalensis* and *Brachythemis leucosticta* were present. Larvae of the mayfly *Cloeon* nr *virgiliae* were common with a second species belonging to a new genus less so. The sediments contained much organic matter and the only invertebrates found here were chironomid larvae.

OK1-14: (S 18° 57′ 04.8′, E 22° 22′ 23.0). A second shallow, seasonally flooded depression 12th June 2000. DO = 8.01-8.36, EC = 54.9-55.4, pH = 6.75 –7.04.

Broken valves of the mussel *Mutela zambesiensis* were collected but no live specimens were found. Unlike other large bivalves, this species probably cannot aestivate for long because its valves gape posteriorly when closed and so will allow uncontrolled water loss. For species like this and the prosobranchs *P. occidentalis* and *L. ovum* to survive, these grassland areas must remain filled for long periods. In this case, the annual period of inundation is usually 8 – 10 months.

OK1-09-INV20 & 22: Guma Lagoon – fringing *Cyperus papyrus* swamps in northern section. (S 18° 57′ 41.5″, E 22° 23′ 08.3″) 11th June 2000. DO = 0.96-3.41 (* dropping to 0.2-0.5 mg/l at night), EC = 33.3-35.1, pH = 4.57-5.12.

This habitat type was almost certainly under-sampled because, as noted under UPH, access was difficult, especially from boats. However by clambering several metres into the stands and collecting from the water overlying the matted rhizomes, a rich heteropteran fauna was found. This was dominated by notonectids (*Anisops apicalis, Anisops* sp. and *Enithares* sp. nymphs). Other species sampled were the corixid *Sigara* sp., the veliid *Microvelia ?major*, the hydrometrid *Hydrometra albolineolata*, the gerrids *Limnogonus* sp. and *Naboandelus* sp. and the belostomatids *Appasus nepoides* and *A. ?ampliatus*. Anisopteran larvae were present as well. The small cryptic bivalve *Sphaerium capense* was fairly common in the deposits of fine silt that accumulate between the rhizomes ± 40 cm below the surface. This is somewhat surprising since these bivalves are filter feeders and also get their oxygen from the water flowing through these beds but it is low in oxygen, only ±25 % saturated . It is also slightly acidic. The snails *Lymnaea natalensis*, *Biomphalaria pfeifferi* and *Bulinus depressus* were found as well but in small numbers.

The small discoid snail *Afrogyrus coretus* was fairly common on drowned *C. papyrus* inflorescences. There was a thick layer of periphyton (*aufwuchs*) on these senescing *C. papyrus* culms and which may be an important food resource for other grazers. Case-dwelling chironomid larvae were common on these submerged culms.

The sedge fringe (*Pycreus mundtii*) bordering the swamps of papyrus and the savanna swamp grass *Miscanthus junceus* which line the channels here both supported a more diverse invertebrate fauna than the *C. papyrus* stands themselves. This fauna comprised corixids (*Stenocorixa protrusa*), notonectids (*Anisops apicalis*, *Anisops* sp., *Enithares* sp.) and belostomatid waterbugs (*Appasus nepoides*) in low numbers. Mayfly larvae (*Elassoneuria ?grandis*) and large haematophagous leeches (*Asiaticobdella fenestrata*) were also present as were the anisopterans *Brachythemis leucosticta* and *Urothemis edwardsi* and the pulmonate snails *Lymnaea natalensis, Biomphalaria pfeifferii, Afrogyrus coretus* and *Bulinus depressus*. As in the *C. papyrus* and *V. cuspidata* swamps, the only invertebrates in the sediments here were red chironomid larvae.

OK1-11-INV24: Department of Water Affairs landing site on western shore of Guma Lagoon (S 18° 57′ 21.4″, E 22° 22′ 39.7″) 12th June 2000. DO = 1.58-3.43, EC = 34.5-35.4, pH = 4.95-5.30.

No samples of invertebrates were taken amongst the marginal vegetation but the snail *Bulinus depressus* and the bivalves *Sphaerium capense* and *S. incomitatum* were found in samples of sediment from the exposed sandy shoreline. The largest *S. capense* measured 7.85 x 6.25 mm which is a size record for the species. These two species are often found together. The water was oxygen depleted, at 25-27 % saturation.

OK1-12-INV25: Burnt papyrus stand in Thaoge Channel. (S 18° 57′ 30.4″, E 22° 24′ 02.3″) 12th June 2000. DO = 1.31, EC = 34.5, pH = 5.40.

Burning of papyrus stands is carried out deliberately by local people. One such stand was sampled in the Thaoge Channel and yielded a similar fauna to unburnt stands in Guma Lagoon but lacked anisopteran larvae or adults.

OK1-13-INV26: Permanent lagoon between Nqoga Channel and Guma Lagoon (S 18° 51′ 34.6″, E 22° 24′ 21.7″) 12th June 2000. DO = 3.5-7.4, EC = 54.8-55.4, pH = 6.23-7.17.

Situated 13km north-east of Guma Lagoon, this lagoon is 2.5m deep and fringed by *C. papyrus* with *T. natans* and *N. lotus* in the open water. Seven species of Heteroptera were recorded here but none was common. Of particular interest however were two species not previously collected, the predaceous *Macrocoris flavicollis* (Naucoridae) and *Sigara ?pectoralis* (Corixidae). The leech *A. fenestrata* and the gastropods *Lanistes ovum, Lymnaea natalensis, Biomphalaria pfeifferi, Bulinus globosus* and *B. depressus* were also present. Both *Sphaerium capense* and *S. incomitatum* (Bivalvia) occurred between the *C. papyrus* rhizomes.

As was noted for several UPH sites, submerged weed beds supported a lower invertebrate diversity than emergent stands of *C. papyrus* or grasses. The fauna associated with submerged *Ceratophyllum demersum* and *Najas horridus* included occasional belostomatid bugs and notonectids. The snails *Biomphalaria pfeifferi* and *Bulinus depressus* were also present. No invertebrates were found beneath floating *N. lotus*, *T. natans* or *Ludwigia leptocarpa* leaves.

MOREMI GAME RESERVE (XAKANAXA LAGOON) (MGR) 14-16 JUNE, 2000

Limited data on Odonata are available for this focal area but a list of species *likely* to occur in the MGR and CHI focal areas has been drawn up by JK from field collections made in the vicinity between April and June 2000 (see Appendix 5).

OK1-15-INV30: Herony in Gadikwe Lagoon (S 19° 09′ 44.5″, E 23° 14′ 29.4″) 14th June 2000. DO = 6.85-7.34, EC = 55.4, pH = 7.17.

Sampling was carried in the *Pycreus mundtii* swamp adjacent to the well-known herony in the lagoon. This floating grass mat harboured a fairly rich invertebrate fauna dominated by shrimps (*Caridina africana*) which were abundant. Odonata nymphs (Anisoptera and Zygoptera) common, *Appasus capensis* (Belostomatidae) was also common but *A. nepoides* less so; *Ranatra* sp. (Nepidae), mayfly larvae and the gastropods *Cleopatra elata, Lymnaea natalensis,* and *Afrogyrus coretus* were all present. *Oxyloma patentissima* occurred on the aerial parts of grass stems.

Four samples of the sediment beneath the *P. mundtii* mat using the small grab revealed a fine windblown black mud with a large quantity of organic debris and containing the bivalve *Sphaerium incomitatum* as well as anisopteran and chironomid larvae. The density of *S. incomitatum* (mean ±SD) in this mud was estimated at ±41.6 ±31.9/m^2. This is the first such density estimate for this species in any habitat. A seine net pulled from a boat (to sample fish) produced a valuable collection of benthic molluscs as well, viz. the prosobranch snails *Melanoides victoriae* and *Cleopatra elata*, the bivalves *Coelatura kunenensis* (both adults and juveniles), *Mutela zambesiensis, Sphaerium incomitatum* and anisopteran nymphs (Gomphidae). Most of the *M. zambesiensis* measured over 100mm length, close to the maximum recorded size. Two juveniles were included in the sample. A quantity of the submerged plant *Ceratophyllum demersum* brought up by this seine contained the snails *C. elata, L. natalensis, B. pfeifferi* and *Bulinus depressus. Biomphalaria pfeifferi* was particularly common in this sample suggesting that, as was the case in Lake Sibaya, South Africa (Appleton, 1977), these submerged weed beds support a rich mollusc fauna.

Several of the *M. victoriae* were very large, >40mm, which is a size record for the species. It is also the first population of *M. victoriae* found in the delta (see next georeference site) although it is common in the Okavango River in Namibia (Curtis & Appleton, 1987; Brown et al., 1992).

Some of these shells and those of *M. zambesiensis* were very severely eroded such that the nacreous layer was exposed over most of the surface.

The water immediately above the bottom mud was virtually anoxic and no flow could be detected. Assuming that it is not continually anoxic and that currents do flow over the sediments at times, survival of benthic molluscs here (i.e. the snails *M. victoriae* and *C. elata*, and the bivalves C. *kunenensis*, *M. zambesiensis* and *S. incomitatum*) may depend, as it does for many of their intertidal counterparts, on a store of glycogen in their tissues. This glycogen can be used as a source of energy when conditions are unfavourable; not only can it be mobilized quickly for metabolic purposes but it can provide energy under low oxygen levels and even anoxia.

OK1-16-INV31: Shore of Gadikwe Lagoon (S 19° 09′ 54.8″, E 23° 14′ 40.7″) 14th June 2000. DO = 6.78, EC = 54.9, pH = 8.36.

Marginal vegetation was dominated by grasses and the fern *Thelypteris interrupta*. Samples produced *Caridina africana*, seven gastropod species (*L. ovum, M. victoriae*, *C. elata*, *L. natalensis*, *B. pfeifferi*, *Bulinus globosus* and *B. depressus)* and three bivalve species, *Coelatura kunenensis*, *Sphaerium capense* and *S. incomitatum. Bulinus globosus* is the intermediate host for both human urinary bilharzia (caused by *Schistosoma haematobium*) and cattle bilharzia (caused by *S. mattheei*). These were the first live specimens of *B. globosus* found, confirming the opinion of Brown et al. (1992) that it is uncommon in the delta. The larvae of two mayfly species were also found, *Pseudocloeon piscis* and the same new species recorded at OK1-08-INV19.

OK1-17-INV32: Submerged stands of *Nesaea crassicaulis* in Maunachira Channel (S 19° 09′ 20.1″, E 23° 15′ 33.3″) 14th June 2000. DO = 7.73, EC = 55.0, pH = 6.36.

Water flow varied from 0.07m/sec immediately above the sandy substratum to 0.26m/sec near the surface. The stands of *Nesaea crassicaulis* sheltered many tiny ephemeropteran nymphs (not identified), the shrimp *Caridina africana* and the snail *Biomphalaria pfeifferi*.

OK1-18-INV33: Channel shaded by *Syzygium cordatum* (waterberry tree) (S 19° 09′ 22.1″, E 23° 16′ 12.8″) 14th June 2000. DO = 7.60, EC = 54.5, pH = 6.45.

Since the habitats were similar, data for OK1-19-INV34 are included here. Mid-channel measurements showed water flowing at 0.1m/sec close to the substratum and 0.5m/sec at the surface. The channel was flanked by *S. cordatum* trees and with submerged *N. crassicaulis* stands on the bottom. Two 1m^2 quadrats in the clean coarse sand-in-the-current produced no invertebrates but two further quadrats in finer sediments with organic debris at the side of the channel (see Table 4.2, Chapter 4 this volume) produced four small bivalve species (*Corbicula fluminalis*, *Eupera parasitica, Pisidium reticulatum* and *Pisidium* sp.) as well as ephemeropteran larvae (*Pseudocloeon piscis*), an unidentified trichopteran larva and chironomid larvae. The average density of *C. fluminalis* in the channel was estimated at 0.5/m^2 (see comments on sandbanks in *UPH other habitats*), *E. parasitica* at 0.25/m^2 and *Pisidium* sp. 6.25/m^2 (n=4 quadrats). A single specimen of *Pisidium reticulatum* was found. These are the first records for the genus *Pisidium* in the Okavango River system but they may have been overlooked in previous surveys due to their small size of 2-3mm. *Pisidium reticulatum* was previously known only from Zimbabwe and Madagascar (Kuiper, 1966) and seems to be a variable species. Mesh analyses of sediment samples from the two habitats are given in Table 2.

OK1-20-INV35: *Miscanthus junceus* backswamp (S 19° 08′ 17.0″, E 23° 22′ 33.0″) 15th June 2000. DO = 6.50-7.16, EC = 66.0-79.6, pH = 6.45-6.84.

Several similar backswamp sites in this area were dominated by *M. junceus* and characterized by large numbers of blue-green algal "balls" (?*Gleotrichia*) on the bottom. These sites, generally 50-70cm deep, and supported a similar invertebrate fauna which was dominated by the shrimp *Caridina africana*. A range of insect taxa was also collected, including 11 heteropteran species, viz. *Centipocoris africana, Laccocoris limicola, Laccocoris* sp. (Naucoridae), *Poissonia longifemorata, Appasus grassei* and *A. ?ampliatus* (Belostomatidae), *Anisops apicalis, Plea pullula* (Notonectidae), Corixidae, *Ranatra* sp. (Nepidae), ephemeropteran and odonatan larvae (Zygoptera and Anisoptera), and mayfly larvae (*Cloeon* nr *virgiliae*). Pulmonate snails, *Lymnaea natalensis, Biomphalaria pfeifferi*, *Bulinus depressus* and the bivalve *Sphaerium incomitatum* were also found as was the blood-sucking leech *Asiaticobdella fenestrata*. Site OK1-22-37 (S 19° 11′ 25.7", E 23° 23′ 46.7") was similar with *A. fenestratata* also present.

Several isolated pools were sampled in the MGR focal area: OK1-23-INV38: Pool with *Salvinia molesta* (S 19° 12′ 15.2″, E 23° 27′ 36.8″) 15th June 2000. DO = 2.0-2.3, EC = 143.5-165.8, pH = 5.73-5.77.

This is one of the few places in the delta where the invasive floating fern *Salvinia molesta* is found. These plants and their roots were examined for an associated fauna. This comprised mostly small individuals of the following groups: nematodes, Ephemeroptera larvae (*Cloeon* nr *virgiliae*), Anisoptera larvae, Zygoptera larvae and mosquito larvae (Culicidae). The biocontrol weevil, *Cyrtobagous salviniae,* imported from Brazil, was also collected. This weevil was introduced in the 1985 and has clearly become established.

The invertebrate fauna was dominated by the hemipteran family Corixidae, viz. *Sigara wahlbergi, S. meridionalis* and *Micronecta scutellaris.* Also present were *Appasus nepoides* (Belostomatidae) and *Anisops sardea* (Notonectidae). Adults of four species of Odonata were collected here but none was common: *Agriocnemis exilis, Pseudagrion* sp. and *Ischnura senegalensis* (Zygoptera) and *Crocothemis erythraea* (Anisoptera).

OK1-24-INV39: Large saline Pool (S 19° 12′ 12.7″, E 23° 27′ 39.3″) 15th June 2000. DO = 4.5, EC = 560, pH = 5.7.

This shallow, sparsely vegetated pool was situated a few hundred metres from OK1-23-INV38 and was ecologically very different. It had a higher salinity and the only vegetation here consisted of clumps of the grass *Sporobolus spicatus.* The fauna collected was exclusively arthropod. The surface-dwelling *Rhagovelia* sp. (Vellidae) was common while the notonectid *Anisops sardea*, the predaceous waterbug *Centipocoris africana* (Naucoridae) and a rat-tail larva (Diptera: Syrphidae) were also collected. No molluscs were found, presumably because they cannot tolerate salinities above about 30-40 mS/m (Jennings, 1972).

OK1-25-INV40: Seasonally flooded pool near Xakanaxa camp (S 19° 11′ 36.4″, E 23° 24′ 55.8″) 16th June 2000. DO = 4.8, EC = 345, pH = 6.58.

Depth ±10cm and lined by grass *Imperata cylindrica.* The fauna was characterized by three notonectids (*Anisops sardea, A. apicalis, Enithares* sp.), *Appasus nepoides* (Belostomatidae), *Ranatra parvipes, Ranatra* sp. (Nepidae), and the pulmonate snail *Bulinus scalaris.* This was the only mollusc found and is characteristic of temporary pools. *Bulinus scalaris* is known from the Okavango River in Namibia (Brown *et al.* 1992) but had not been confirmed from Botswana because the male genitalia, on which identification depends, were immature in all specimens previously collected in the delta. Other faunal elements were nematodes, mayfly larvae (*Cloeon* nr *virgiliae*), tabanid and mosquito larvae (Diptera).

OK1-26-INV41: Newly flooded pool (19° 13′ 19.1″, E 23° 24′ 54.8″) 16th June 2000. DO = 7.7, EC = 342-3478, pH = 7.21.

Large recently flooded pool (within past six months), inundated trees, shrubs and terrestrial grass, *Cynodon* sp. Characterised by mosquito larvae and pupae, unidentified Gerridae, *Micronecta scutellaris* (Corixidae), Ephemeroptera nymphs (*Cloeon* nr *virgiliae* and gen. sp. nov.) and Chironomidae larvae. Anisopteran nymphs were present along with *Anisops sardea* (Notonectidae) and *Ranatra* sp. (Nepidae). Adult *Agriocnemis exilis* (Zygoptera) and *Brachythemis leucosticta* (Anisoptera) were also collected. Two snail species, *Bulinus scalaris* and *B. depressus*, were present.

OK1-27-INV42: Elephant Pool (S 19° 12′ 30.6″, E 23° 24′ 11.1″) 16th June 2000. DO = 6.05-6.61, EC = 142-147, pH = 6.01.

This was a permanent pool. Samples were taken in the flooded grass, *Cynodon dactylon*, around the pool's margins. Despite its physical similarity to the previous site, the fauna was very different. Snails present were *Lanistes ovum*, *Lymnaea natalensis, Bulinus globosus* and *B. depressus.* The insect fauna was dominated by *Micronecta scutellaris* (Corixidae), *Aquarius stappersi* (Gerridae), unidentified Veliidae and *Ranatra* sp. (Nepidae).

CHIEF'S ISLAND (CHI), 18-20 JUNE, 2000

OK1-28-INV43: Flooded grass on edge of island near Xaxaba lagoon 18th June 2000. DO = 1.28-1.82, EC = 66-76, pH = 6.97.

Water 20-50cm deep, shaded by large trees. Fauna characterized by *Appasus ?ampliatus* (Belostomatidae), Anisoptera larvae and *Bulinus depressus.* Other snails included *Biomphalaria pfeifferi, Bulinus globosus* and *Ceratophallus natalensis.* Occasional specimens of *Appasus grassei, Anisops apicalis* (Notonectidae), *Sigara* sp. (Corixidae) and *Ranatra parvipes* (Nepidae) were found. Mayfly larvae (*Cloeon* nr *virgiliae* and gen. sp. nov.) also found.

Floating vegetation: Nymphaea Leaves

Five sheltered lagoon sites were sampled and were characterized by large numbers of floating *Nymphaea* leaves (mostly *N. nouchali*) which occupied a significant proportion (estimated at 40-60%) of the water's surface area. They must therefore constitute an important habitat, especially their undersurfaces, and the associated fauna was therefore examined in detail.

OK1-30-INV44: (S 19° 32′ 01.6″, E 23° 04′ 48.3) 18th June 2000. DO = 4.12-4.78, EC = 65.8-71.1, pH = 6.56-6.87.

Small lagoon with *N. nouchali* and bordered by the grass *Leersia hexandra.* The large prosobranch *L. ovum* was found on the upper surfaces of the *N. nouchali* leaves and the ancylid limpet *Ferrissia* cf. *victoriensis* occurred underneath. The fauna associated with the undersurfaces of these leaves was however dominated by Anisoptera nymphs. The belostomatid *Appasus capensis* was present while mayfly larvae (*Psudocloeon piscis*), unidentified weevils were fairly common under the lily pads – usually feeding on the edges of the leaves which showed signs of damage.

OK1-31-INV45: (S 19° 31′ 36.5", E 23° 05′ 46.4") 19th June 2000. DO = 1.99-3.42, EC = 68.3-80.5, pH = 6.54-6.93.

Three different habitats were sampled: (1) beneath *N. nouchali* leaves in water about 1.3 m deep. Weevils, leeches (*Helobdella conifera*), *Appasus capensis* (Belostomatidae) and Zygopteran nymphs were all present under the lily leaves. The bottom sediments were rich in organic debris and harboured five taxa, including the snails, *Lanistes ovum* and *Biomphalaria pfeifferi*, (2) amongst dense vegetation comprising sedges, *Ludwigia* sp.and *Potomageton* sp. Twelve taxa were present here, including the heteropterans *A. capensis, Anisops apicalis*, *Ranatra parvipes*, and the snails, *Biomphalaria pfeifferi* , *Lymnaea natalensis* and *Bulinus globosus*. Habitat (3) was amongst a dense stand of *Miscanthus junceus* in water about 50-60 cm deep. The dominant group was ephemeropteran nymphs (*Cloeon* nr *virgiliae* and *Pseudocloeon piscis*) with *Biomphalaria pfeifferi* being the only snail found. The blood-sucking leech *A. fenestrata* was present.

OK1-34-INV48: (S 19° 32′ 19.1", E 23° 05′ 17.6") 19th June 2000. DO = 3.44-5.59, EC = 67.6-68.3, pH = 6.2-6.39.

Lagoon with *Nymphaea nouchali* in water about 1.8m deep. The fauna recorded under lily leaves consisted of several taxa, of which small glossiphoniid leeches (*H. conifera*), mayfly larvae (*Pseudocloeon piscis*), unidentified lepidopteran larvae and insect pupae were the most abundant. Several snails, (*Lanistes ovum, Lymnaea natalensis, Ferrissia* cf. *victoriensis*, *Biomphalaria pfeifferi, Afrogyrus coretus* and *Bulinus depressus*) were also found. Glossiphoniid leeches, probably *Batractobdelloides. tricarinata*, were seen moving over the headfoot and under the lip of the shell of almost every *L. ovum* taken from the leaves. As noted by Appleton (1979), *B. tricarinata* has been reported from the mantle cavities of large bivalves such as *Spathopsis wahlbergi* from this area. They are probably commensals rather than parasites.

This limited invertebrate fauna associated with *Nymphaea* leaves is noteworthy in view of the many African Jacana (*Actophilornis africanus*) seen foraging on them. These birds are recorded as feeding extensively on snails and insects (Maclean, 1984). Sediment samples were collected with a long-handled net and revealed *Lanistes ovum* and zygopteran nymphs.

OK1-32-INV46 (S 19° 31′ 36.5", E 23° 06′ 22.3") 19th June 2000. DO = 1.73-2.42, EC = 91.1-116.3, pH = 6.26-6.41.

Marginal vegetation (*Leersia* sp, *Ludwigia* sp. and *Miscanthus* sp.) was sampled in water up to 80cm deep. *Lymnaea natalensis,* Anisoptera and Zygoptera nymphs and two species of glossiphoniid leech (*Batracobdelloides tricarinata* and *Helobdella conifera*) were all present. Adults of the damselfly *Agriocnemis exilis* were also collected. In addition to *L. natalensis*, five other snail species were present; these included *Ferrissia* cf. *victoriensis*, *Ceratophallus* sp. and *Bulinus depressus*. The heteropterans *Anisops apicalis* (Notonectidae) and *Limnogonus* sp. (Gerridae) were also collected.

Three Isolated Pools near Oddballs' Camp (Each of the three pools sampled was saline):

OK1-35-INV49 (S 19° 31′ 17.2", E 23° 06′ 15.5") 20th June 2000. DO = 4.38, EC = 580, pH = 8.04.

Drying rainwater pan with muddy water up to 20 cm deep and sedges in the middle. Several small (±4m^2) stands of the rooted fern *Marsilea* sp. were noted, the rest was devoid of vegetation in the water. This pan was sampled by one person for 30 mins and produced 17 taxa. The dominant groups were *Anisops sardea* (Notonectidae), larval Culicidae, *Micronecta scutellaris* (Corixidae), *Appasus nepoides* (Belostomatidae). Three species of water scorpions (Nepidae) were collected, *Ranatra parvipes*, *Laccotrephes fabricii* and *Laccotrephes* sp. This site was the only one at which the latter two were found. The snail *Bulinus scalaris* was common and the mayfly *Cloeon* nr. *virgiliae* present.

OK1-36-INV50 (S 19° 32′ 09.2", E 23° 05′ 56.7") 20th June 2000. DO = 10.7, EC = 91.0, pH = 6.52.

Seasonal pool with much flooded terrestrial grass. Half an hour's sampling by one person with help from four school pupils using a scoop and net produced many larval mosquitoes (Culicidae), with the gerrid *Limnogonus nigrescens,* Ephemeropteran larvae (new genus and species), *Lestes pinheyi* (Anisoptera) and a zygopteran larva were present as well. This was the only locality at which *L. nigrescens* was collected.

OK1-37-INV51 (S 19° 32′ 13.7", E 23° 05′ 54.3") 20th June 2000. DO = 15.0, EC = 7380, pH = 6.91.

Borrow pit at end of airstrip - filled with rainwater but with a very high conductivity. Lacking vegetation except for some sparse grass, but with a layer of algae on the substratum. Seven taxa were found, with unidentified Culicidae larvae and *Anisops sardea* (Notonectidae) abundant. Two unidentified species of *Anisops* were also collected but in small numbers as were *Micronecta scutellaris, Ranatra* sp. and zygopteran nymphs.

OK1-38-INV52 (S 19° 31′ 38.0", E 23° 05′ 25.7") 21st June 2000.

Grassy marginal fringe at the *mokoro* (dugout canoe) landing site at Oddball's Camp. Water shaded by overhanging trees (*Croton megalobotrys*) and with much plant debris on the bottom. Five pulmonate snails were found, *Lymnaea natalensis, Segmentorbis angustus, Ceratophallus natalensis*, *Bulinus depressus* and *B. globosus*. *Segmentorbis angustus* was only found on fallen *C. megalobotrys* leaves which is interesting because this tree is thought to produce molluscicdal secondary compounds (P.E. Reavell, pers. comm.). No water quality data available.

Appendix 3

Freshwater invertebrate species from the Okavango Delta

Chris C. Appleton, Barbara A. Curtis, and Jens Kipping

Abundance Category	Estimated number of individuals collected per 30 minutes
P = Present	1 – 10
FC = Fairly Common	10 – 20
C = Common	20 – 50
VC = Very Common	50 – 100
A = Abundant	>100

See next page for table.

TAXA	Upper Panhandle						Lower Panhandle						Moremi Game Reserve										Chief's Island								
	OK1-01	OK1-02	OK1-03	OK1-04	OK1-05	OK1-06	OK1-07	OK1-08	OK1-09	OK1-11	OK1-12	OK1-13	OK1-15	OK1-16	OK1-17	OK1-18	OK1-20	OK1-23	OK1-24	OK1-25	OK1-26	OK1-27	OK1-28	OK1-30	OK1-31	OK1-32	OK1-34	OK1-35	OK1-36	OK1-37	OK1-38
HIRUDINEA																															
Family Glossiphoniidae																															
Helobdella conifera																									P	P	P				
Batracobdelloides tricarinata						P																				P					
unidentified glossiphoniid						P																									
Family Hirudinidae																															
Asiaticobdella fenestrata									P			P					P								P						
GASTROPODA																															
Family Viviparidae																															
Bellamya capillata		P																													
Family Ampullariidae																															
Pila occidentalis			P					P																							
Lanistes ovum			FC					P				P		P								P		P	P		P				
Family Bithyniidae																															
Gabiella kisalensis			P																												
Family Thiariidae																															
Melanoides victoriae													FC	P																	
Cleopatra elata		P	FC	P		P							P	P																	
Family Succineidae																															
Oxyloma patentissima		FC	C				P						P																		
Family Urocyclidae																															
Elisolimax sp.			FC																												
Family Ancylidae																															
Ferrissia cf. *victoriensis*																								P			P				
Family Lymnaeidae																															
Lymnaea natalensis		P	FC			P	P		P			P	P	P			P					P			P	P	P				P
Family Planorbidae																															
Afrogyrus coretus			P						FC				P														P				

continued

TAXA	Upper Panhandle						Lower Panhandle						Moremi Game Reserve										Chief's Island								
	OK1-01	OK1-02	OK1-03	OK1-04	OK1-05	OK1-06	OK1-07	OK1-08	OK1-09	OK1-11	OK1-12	OK1-13	OK1-15	OK1-16	OK1-17	OK1-18	OK1-20	OK1-23	OK1-24	OK1-25	OK1-26	OK1-27	OK1-28	OK1-30	OK1-31	OK1-32	OK1-34	OK1-35	OK1-36	OK1-37	OK1-38
Segmentorbis angustus																															P
Bulinus globosus		P						P				P		P								FC	P		P						P
Ceratophallus natalensis	P		P																				P			P					P
Biomphalaria pfeifferi		P	P			P	P		P			P	C	P	P		P						P		P	P	P				
Bulinus depressus	P	P	P			P			P	P		P	P	P			P				P	P	P			P	P				P
Bulinus scalaris																				P	P							P			
BIVALVIA																															
Family Unionidae																															
Coelatura kunenensis				P	P								P	P																	
Family Mutelidae																															
Mutela zambesiensis								P					P																		
Family Corbiculidae																															
Corbicula fluminalis				P												P															
Family Sphaeriidae																															
Sphaerium capense									FC	P		P		P																	
Sphaerium incomitatum										P		P	FC	P			P														
Eupera ferruginea	P	P	P																												
Eupera parasitica																P															
Pisidium sp.																P															
EPHEMEROPTERA																															
Family Oligoneuriidae																															
Elassoneuria ?grandis	P	P							P																						
Family Polymitrarcyidae																															
Povilla adusta	P																														
Family Baetidae																															
Cloeon nr. *virgiliae*	P	P						P										P	P	P			P		FC						
Pseudocloeon piscis				P		P							P	P		P								P	FC	P	P				

continued

TAXA	Upper Panhandle						Lower Panhandle						Moremi Game Reserve										Chief's Island								
	OK1-01	OK1-02	OK1-03	OK1-04	OK1-05	OK1-06	OK1-07	OK1-08	OK1-09	OK1-11	OK1-12	OK1-13	OK1-15	OK1-16	OK1-17	OK1-18	OK1-20	OK1-23	OK1-24	OK1-25	OK1-26	OK1-27	OK1-28	OK1-30	OK1-31	OK1-32	OK1-34	OK1-35	OK1-36	OK1-37	OK1-38
Family Caenidae																															
new genus & species		P				P		P					P	P																	
DECAPODA																															
Family Atyidae																															
Caridina africana	P	C	C	FC		P	P						A	P	P		FC														
Family Potamonautidae																															
Potamonautes bayonianus	P	P		P																											
HETEROPTERA																															
Family Veliidae																															
Microvelia ?major					P				P																						
Rhogovelia sp.	A	C																	FC												
Family Gerridae																															
Aquarius stappersi							P															P									
Limnogonus capensis	FC	P			P	P						P																			
Limnogonus nigrescens																													P		
Limnogonus nigriventris								C																							
Naboandelus sp.									P																						
Family Corixidae																															
Micronecta scutellaris	C	FC	A					A										FC			FC	FC						A		P	
Stenocorixa protrusa	P		P						P			P																			
Sigara meridionalis																		P													
Sigara pectoralis								P				P																			
Sigara wahlbergi								P										P													
Sigara sp.																							P								
Family Notonectidae																															
Anisops apicalis	P					P	FC	C	FC		FC	P					P		P	P			P		P	P					
Anisops gracilis					P		P																								
Anisops sardea																		P	FC	FC	P							FC		A	

continued

TAXA	Upper Panhandle						Lower Panhandle						Moremi Game Reserve										Chief's Island								
	OK1-01	OK1-02	OK1-03	OK1-04	OK1-05	OK1-06	OK1-07	OK1-08	OK1-09	OK1-11	OK1-12	OK1-13	OK1-15	OK1-16	OK1-17	OK1-18	OK1-20	OK1-23	OK1-24	OK1-25	OK1-26	OK1-27	OK1-28	OK1-30	OK1-31	OK1-32	OK1-34	OK1-35	OK1-36	OK1-37	OK1-38
Anisops sp.1																															
Anisops sp.2																														P	
Anisops sp.3																														P	
Anisops sp.								P																							
Enithares chinai						P	P	P	P			P							P	P											
Plea pullula																	P														
Family Belostomatidae																															
Appasus capensis													C										P	P	P						
Appasus nepoides	FC	P	P	P		P		P	P			P	FC					P	P	P								P			
Appasus ?ampliatus			P						P			P					P						P								
Appasus grassei							P										P						P								
Limnogeton fieberi						P																									
Poissonia longifemorata																	P														
Family Naucoridae																															
Centipocoris africana																		P													
Naucoris obscuratus							P	P																							
Macrocoris convexus												P																			
Macrocoris flavicollis												P																			
Laccocoris limicola																	P														
Family Ranatridae																															
Laccotrephes fabricii																												P			
Laccotrephes sp.																												P			
Ranatra parvipes																			P	P			P		P			P			
Ranatra sp.							P	P				P	P				P				P	P									
Family Hydrometridae																															
Hydrometra albolineolata							P	P	P			P																			

Appendix 4

Checklist of Dytiscidae (Predaceous Diving Beetles, Order Coleoptera) of the Okavango Delta from Bilardo & Rocchi (1987)

Chris C. Appleton

Localities at which specimens were collected:
Linyanti = Linyanti Swamp (Chobe National Park),
Savuti = Savuti River (Chobe National Park),
Moremi = Moremi Game Reserve,
Xakanaxa = Moremi Game Reserve (Xakanaxa),
Ngamiland = Ngamiland (San-tan-wani),
Toteng = Maun (Toteng),
Thamalakane = Maun (Thamalakane River),
Botletle = Botletle River (Makalambedi).

Dytiscidae	Linyanti	Savuti	Moremi	Xakanaxa	Ngamiland	Toteng	Thamalakane	Botletle
Bidessus complicatus Sharp	X		X					
Bidessus pergranulum Bint.			X	X				
Bidessus seydeli Bist.			X					
Bidessus seydeli Regim.			X	X			X	X
Canthydrus notula Er.	X	X	X			X	X	X
Canthydrus quadrivittatus Boh.	X	X						
Canthydrus rossanae Bil. & Roc.	X	X	X					
Cybister ertli Zim.	X							
Cybister guignoti Gschw.			X				X	
Cybister marginicollis Boh.			X					
Cybister senegalensis Aube	X	X	X					X
Cybister vicinus Zim.	X							
Cybister vulneratus Klug		X	X					
Cybister tripunctatus Cast.	X	X	X					
Eretes sticticus (L.)		X						
Herophydrus gigas								X
Herophydrus mutatus Ge. & Har.		X	X			X	X	X
Herophydrus obscurus Sharp			X		X	X	X	X
Hydaticus bivittatus Castelnau			X					X
Hydaticus dorsiger Aube			X					
Hydaticus galla Guerin			X					
Hydaticus servillianus Aube			X		X			
Hydrocanthus micans Wehncke			X					
Hydrocoptus africanus Gschw.	X	X	X	X				
Hydrocoptus angolensis Peschet			X	X				
Hydrocoptus garambanus Guignot	X	X	X	X	X			X

continued

Dytiscidae	Linyanti	Savuti	Moremi	Xakanaxa	Ngamiland	Toteng	Thamalakane	Botletle
Hydroglyphus aethiopicus (Reg.)			X					
Hydroglyphus kalaharii (Pederzani)		X	X	X	X		X	
Hydroglyphus lineolatus (Boh.)		X	X	X		X		X
Hydroglyphus transvaalensis (Reg.)			X					
Hydroglyphus zanzibarensis (Reg.)	X							
Hydrovatus badeni Sharp		X						X
Hydrovatus glomeratus Guig.	X	X					X	X
Hydrovatus hamatus Guig.		X			X			
Hydrovatus insolitus Guig.				X				
Hydrovatus lacnaeus Guig.	X		X					
Hydrovatus laticornis Reg.			X		X			
Hydrovatus marlieri Guig.		X	X	X				
Hydrovatus nefandus O-Cooper		X	X					X
Hydrovatus nepos Guig.		X	X	X	X		X	X
Hydrovatus noctivagus Guig.		X						
Hydrovatus oblongipennis Reg.	X							
Hydrovatus obsoletus Peschet		X						
Hydrovatus recticuliceps Reg.		X						
Hydrovatus senegalensis Reg.		X						
Hydrovatus similaris Bil. & Roc.	X							
Hydrovatus simoni Reg.		X	X		X			X
Hydrovatus sitistus O-Cooper		X						X
Hydrovatus sporas Guig.		X	X		X			
Hydrovatus uncus Balfour-Browne		X						X
Hydrovatus verisae Bil. & Roc.			X					
Hyphydrus impressus Klug	X		X					X
Hyphydrus residuus O. Cooper			X			X	X	X
Laccophilus concisus Guig.			X				X	
Laccophilus continentalis Gschw.	X		X					
Laccophilus evanescens Reg.		X						X
Laccophilus secundus Reg.			X					X
Laccophilus simplicistriatus Gschw.			X					X
Laccophilus vermicolosus Gerst.								X
Methles cribratellus Guig.		X		X	X			X
Methles spinosus Sharp	X	X						
Philodytes umbrinus (Motsch.)			X					X
Rhanticus congestus (Klug)	X							X
Rhantus concolerans (Wall.)			X					
Synchortus desaegeri Gschw.			X					
Synchortus simplex Sharp	X	X	X					
Uvarus baoulicus (Guig.)			X					X
Yola babaulti Pechet			X					
Yola dohrni Sharp			X	X			X	X
Yola tuberculata Reg.		X	X	X	X	X	X	X

Appendix 5

Odonata recorded from the Okavango Delta

Jens Kipping

Comprehensive collections of Odonata were made by JK at the geo-reference sites in the Upper Panhandle (UPH) but following his return to Maun on June 9th, only occasional specimens were collected in the other three focal areas. A further list was however compiled by JK from the HOORC site at the western end of Chief's Island, a habitat typical of much of the CHI focal area. These records are combined into a systematic checklist of species known from the delta but to avoid confusion regarding distribution patterns across the delta, this list is given below and is excluded from Appendix 3, the main species-list.
This appendix is divided into four sections. Section 1 lists the species collected by JK in the UPH focal area; section 2 lists those collected by other team members in the LPH, MGR and CHI focal areas; section 3 gives the combined checklist and section 4 contains ecological notes by JK on habitat use by Odonata at the HOORC site on Chief's Island.

1. SPECIES COLLECTED IN THE UPH FOCAL AREA

Twenty-one species were recorded from geo-reference sites in the UPH focal area:

OK1-01-INV01
Aethiothemis discrepans
Crocothemis erythraea
Trithemis hecate
Trithemis stictica
Pseudagrion deningi

OK1-04-INV09
Pseudagrion sjoestedti jacksoni

OK1-03-INV07
Crocothemis erythraea
Pseudagrion deningi

OK1-03-INV08
Aethiothemis discrepans
Anax imperator
Brachythemis leucosticta
Crocothemis erythraea
Trithemis annulata
Diplocodes lefebvrei
Agriocnemis exilis
Ceriagrion glabrum
Ceriagrion suave
Ischnura senegalensis
Pseudagrion deningi

OK1-04-INV09
Crocothemis erythraea
Macromia sp.
Paragomphus genei
Pseudagrion sjoestedti jacksoni

OK1-06-INV14
Aethiothemis discrepans
Anax imperator
Brachythemis leucosticta
Crocothemis erythraea
Trithemis annulata
Trithemis arteriosa
Trithemis hecate
Diplocodes lefebvrei
Ischnura senegalensis
Pseudagrion deningi

OK1-06-INV15 & INV16
Pseudagrion deningi

OK1-07-INV17
Anax imperator
Ischnura senegalensis
Pseudagrion deningi

River bank with reeds close to Drotsky's Cabins (18° 24' 50.1" S; 21° 53' 07.7" E – not a geo-reference site)
Pseudagrion sjoestedti jacksoni

River bank at Xaro River Lodge (18° 25' 24.7" S : 21° 56' 21.7" E not a geo-reference site)
Aethiothemis discrepans
Lestinogomphus angustus
Trithemis aconita
Pseudagrion deningi
Pseudagrion sjoestedti jacksoni
Pseudagrion sudanicum sublacteum

2. Species recorded from the LPH, MGR and CHI focal areas

LPH focal area
OK1-08-INV19
Ischnura senegalensis
Brachythemis leucosticta

OK1-09-INV22
Brachythemis leucosticta
Urothemis edwardsi

MGR focal area
OK1-23-INV38
Agriocnemis exilis
Pseudagrion sp.
Crocothemis erythraea
Ischnura senegalensis

OK1-26-INV41
Agriocnemis exilis
Brachythemis leucosticta

CHI focal area
OK1-36-INV50
Lestes pinheyi

3. Checklist of Odonata recorded from the Okavango Delta

Based on his collection at the HOORC study site at the western end of Chief's Island (S 19° 32' 36.1", E 23° 10' 35.6") between April and June 2000, JK compiled a list of 40 species likely to be found in the MGR and CHI focal areas. Thirteen of these (32.5%) were also recorded from the UPH sites and are indicated by an asterisk while a further eight were only recorded from UPH sites and are indicated by a double asterisk. The total for the delta is thus 48 species though, because these collections were made in autumn and winter (i.e. between April and June 2000), more should be expected in collections in spring and summer. These species are listed below, arranged according to Pinhey (1976).

Order Odonata
Suborder Zygoptera
Family Lestidae
Lestes pinheyi
Family Coenagriidae
*Ceriagrion glabrum**
Ceriagrion katamborae
*Ceriagrion suave**
Pseudagrion assegaii
Pseudagrion coelestis
*Pseudagrion deningi**
*Pseudogrion sjoestedti jacksoni***
*Pseudogrion sudanicum sublacteum***
*Ischnura senegalensis**
*Agriocnemis exilis**
Agriocnemis gratiosa
Agriocnemis ruberrima albifrons
Agriocnemis victoris
Suborder Anisoptera
Family Gomphidae
Gomphida dundoensis
Ictinogomphus ferox
*Lestinogomphus angustus***
*Paragomphus genei***
Family Aeshnidae
*Anax imperator mauricianus**
Anax tristis
Gynacantha villosa
Family Libellulidae
Orthetrum brachiale
Orthetrum chrysostigma
Orthetrum icteromelan cinctifrons
Orthetrum trinacria
Hemistigma albipuncta
*Diplacodes lefebvrei**
Diplacodes okavangoensis
*Crocothemis erythraea**
Crocothemis assignata
*Brachythemis leucosticta**
Sympetrum fonscolombii
*Trithemis aconita***
*Trithemis annulata**
*Trithemis arteriosa**
*Trithemis hecate***
Trithemis monardi
Trithemis stictica
Rhyothemis fenestrina
Rhyothemis mariposa
Rhyothemis semihyalina
Tholymis tillarga
Pantala flavescens
Tramea basilaris
*Aethiothemis discrepans***
Macromia sp.**
*Urothemis edwardsi**
Parazyxomma flavicans

4. Ecological notes on habitat use by Odonata at the HOORC site

The river at the HOORC site is 3-4m deep with a 5m wide band of *Nymphaea nouchali* along either bank. Outside this is a belt of sedges dominated by *Schoenoplectus* sp. up to 1.5m high and in water 1-2m deep. Beyond this is a seasonally flooded grassland area dominated by low cover, e.g. *Pycreus nitidus* and grasses. Behind the island are lagoons up to 1m deep fringed with tall reeds and sedges. The central open area is dominated by *N. nouchali* and *Potamogeton* leaves on the surface and submerged *Utricularia* stands beneath. Similar habitats occur elsewhere around Chief's Island and in the Xakanaxa focal area as well so that many of these species may be expected to occur in both.

Although most species did not appear to be associated with particular habitat types, some were and these are listed separately below.

Species associated with particular habitat types

i. **Margins of Boro River channel (3-4m depth) with *Nymphaea nouchali* leaves on the surface**
   - *Pseudagrion deningi* and *P. coelestis* were the most common of the *Pseudagrion* species; both used *N. nouchali* leaves for laying eggs and for support during emergence. Several were caught in funnel traps as they emerged from the water.
   - *Brachythemis leucosticta* is common in the delta at both vegetated and unvegetated sites. However it requires floating leaves both as a resting place and as a perch during mating.
   - *Rhyothemis semihyalina* was the most common of the three species of *Rhyothemis* recorded. It was often observed resting on *N. nouchali* leaves.
   - Exuviae of *Urothemis edwardsi* and *U. assignata* were found on *N. nouchali* leaves.

ii. **Seasonally flooded grassland between fringing reeds and dry land**
   - *Agriocnemis exilis* was the most common and smallest zygopteran present and emerged throughout the observation period (April to June).
   - *Agriocnemis victoria* and *A. exilis* were restricted to dense stands of small sedges.
   - *Pseudagrion deningi* and *P. coelestes* also occurred in this habitat type.
   - *Ischnura senegalensis* was very common species in flooded grassland habitats.

iii. **Shallow lagoons (±1m depth) with floating *N. nouchali* leaves and submerged vegetation (*Utricularia* sp.)**
   - *Ceriagrion glabrum* was locally very common and was observed perching on small sedges.
   - *Anax imperator mauricianus* was observed ovipositing over submerged plants. It uses reeds as a site for mating. Males were often seen patrolling over the vegetation.
   - *Crocothemis erythraea* was probably the most common species in the delta. Exuviae and larvae were found in submerged vegetation.
   - *Diplacodes lefebvrei* was a common species; males often perched on floating *N. nouchali* leaves, waiting for females.
   - *Diplacodes okavangoensis* was a scarce species and is endemic to the delta.
   - *Hemistigma albipuncta* was another common species which together with *Lestes pinheyi* were the most characteristic of this habitat type. Frequently seen perched on reed stems but did not use *N. nouchali* leaves.
   - *Lestes pinheyi* was also common and its exuviae were found on the smaller sedges. Adults use tall reeds as resting and mating sites.

Appendix 6

Locality descriptions of plots sampled for vegetation during the 2000 AquaRAP survey

W. N. Ellery and Budzanani Tacheba

Plot # refers to the plot number assigned during the field survey (VEG #) and not the plot number assigned during the data analysis phase. Three plots were assigned 2 numbers in error (VEG 83, VEG 84 and VEG 85 as VEG 128, VEG 129 and VEG 130 respectively), and these are repeated here.

GeoRef	VEG #	Locality	Latitude (S)	Longitude (E)	Date	Remarks	Habitat type	Bottom type
OK1-01	VEG1	Upper Panhandle	18 24' 26.8"	21 53' 08.4"	07-Jun-00	Approx. 1km upstream from Drotsky's Cabins.	*Echinochloa pyramidalis* dominated backswamp	Clay substratum with local sandy inlet; Small side channel through clayey channel margin with fast flow, giving way to extensive backswamp / floodplain.
OK1-01	VEG2	Upper Panhandle	18 24' 26.8"	21 53' 08.4"	07-Jun-00	Approx 1km upstream from Drotsky's Cabins.	*Pennisetum glaucocladum* dominated channel fringe	Elevated levee of clay substratum with local sandy deposits;
OK1-02	VEG3	Upper Panhandle	18 24' 39.6"	21 52' 51.0"	07-Jun-00	Approx 0.5km upstream from Drotsky's Cabins.	Small open water body dominated by *Nymphaea nouchali* and with margin of floating mats of grasses	Organic detritus on sand
OK1-02	VEG4	Upper Panhandle	18 24' 39.6"	21 52' 51.0"	07-Jun-00	Approx 0.5km upstream from Drotsky's Cabins.	Papyrus swamp fringing the open water body at VEG3	Peat
OK1-02	VEG5	Upper Panhandle	18 24' 37.5"	21 52' 54.1"	07-Jun-00	Approx 0.5km upstream from Drotsky's Cabins.	Linear open water body sub-parallel to the main river, dominated by *Ceratophyllum demersum*	Organic detritus on sand
OK1-02	VEG6	Upper Panhandle	18 24' 40.8"	21 52' 48.2"	07-Jun-00	Approx 0.5km upstream from Drotsky's Cabins.	Open water hippo trail and margin adjacent to mainland	Sand, with floating mats of vegetation at the water surface
OK1-02	VEG7	Upper Panhandle	18 24' 50.1"	21 53' 07.7"	07-Jun-00	Approx 10m upstream of boat landing at Drotsky's Cabins.	*Persicaria senegalensis* beds in the channel margin	Sand, with floating mats of vegetation at the water surface
OK1-03	VEG8	Upper Panhandle	18 24' 50.1"	21 53 07.6"	08-Jun-00	Backwater lake and adjacent floodplain upstream of Mohembo	Lake fringe vegetation dominated by *Phragmites mauritianus*	Clay
OK1-03	VEG9	Upper Panhandle	18 24' 50.1"	21 53 07.6"	08-Jun-00	Backwater lake and adjacent floodplain upstream of Mohembo	Seasonal floodplain grassland dominated by *Vossia cuspidata*	Clay
OK1-03	VEG10	Upper Panhandle	18 24' 50.1"	21 53 07.6"	08-Jun-00	Backwater lake and adjacent floodplain upstream of Mohembo	Open water area	Organic detritus on sand

continued

GeoRef	VEG #	Locality	Latitude (S)	Longitude (E)	Date	Remarks	Habitat type	Bottom type
OK1-03	VEG11	Upper Panhandle	18 16’ 19.8”	21 47’ 36.8”	08-Jun-00	Floodplain due north of pontoon crossing at Mohembo	Elevated ground on seasonal floodplain	Sand
OK1-03	VEG12	Upper Panhandle	18 16’ 19.8”	21 47’ 36.8”	08-Jun-00	Floodplain due north of pontoon crossing at Mohembo	Depression on seasonal floodplain	Sand
OK1-04	VEG13	Upper Panhandle	18 16’ 19.8”	21 48’ 35.3”	08-Jun-00	Mid-channel sandbar downstream of Mohembo	Recently formed sandbar in mid-channel	Sand
OK1-04	VEG14	Upper Panhandle	18 16’ 19.8”	21 48’ 35.3”	08-Jun-00	Mid-channel sandbar downstream of Mohembo	Recently formed sandbar in mid-channel	Sand
OK1-05A	VEG15	Upper Panhandle	18 20’ 28.7”	21 50’ 09.1”	08-Jun-00	Point bar west of Shakawe	Very recently formed & colonized point bar	Sand
OK1-05A	VEG16	Upper Panhandle	18 20’ 28.7”	21 50’ 09.1”	08-Jun-00	Point bar west of Shakawe	Depression behind point bar and onto the next scroll bar	Sand
OK1-05B	VEG17	Upper Panhandle	18 21’ 45.6”	21 51’ 17.7”	08-Jun-00	Channel margin vegetation fringing channel downstream of Shakawe	*Cyperus papyrus* swamp in the channel fringe	Peat
OK1-05B	VEG18	Upper Panhandle	18 21’ 45.6”	21 51’ 17.7”	08-Jun-00	Channel margin vegetation fringing channel downstream of Shakawe	*Vossia cuspidata* beds in the channel fringe	Sandy channel bed
OK1-05B	VEG19	Upper Panhandle	18 21’ 45.6”	21 51’ 17.7”	08-Jun-00	Channel margin vegetation fringing channel downstream of Shakawe	*Phragmites mauritianus* behind *Vossia cuspidata* beds in the channel fringe	Clay
OK1-06	VEG20	Upper Panhandle	18 26’ 22.9”	21 54’ 41.9”	09-Jun-00	Irrigation farm intake	Shallow backwater channel with open water habitat	Sand
OK1-06	VEG21	Upper Panhandle	18 26’ 22.9”	21 54’ 41.9”	09-Jun-00	Irrigation farm intake	Shallow emergent *Vossia cuspidata* beds in the open water margin	Sand
OK1-06	VEG22	Upper Panhandle	18 26’ 22.9”	21 54’ 41.9”	09-Jun-00	Irrigation farm intake	*Cyperus papyrus* swamp in the fringe of the open water area	Peat
OK1-06A	VEG23	Upper Panhandle	18 25’ 40.4”	21 55’ 30.1”	09-Jun-00	Open water area several km downstream of irrigation farm intake	*Trapa natans* beds in the channel margin backwater	Fine organic ooze on sand
OK1-06B	VEG24	Upper Panhandle	18 25’ 49.8”	21 55’ 38.5”	09-Jun-00	Small side channel leading from Okavango River	*Vossia cuspidata* beds in the margin of a small open water area	Coarse organic matter overlying clay
OK1-07	VEG25	Upper Panhandle	18 24’ 18.9”	21 58’ 17.6”	09-Jun-00	Shallow lake north of the Kgaelatogha Channel	*Cyperus papyrus* beds fringing the lake	Peat
OK1-07	VEG26	Upper Panhandle	18 24’ 18.9”	21 58’ 17.6”	09-Jun-00	Shallow lake north of the Kgaelatogha Channel	Open water lake	Organic detritus on sand; water depth = 3.2m
OK1-07	VEG27	Upper Panhandle	18 24’ 18.9”	21 58’ 17.6”	09-Jun-00	Shallow lake north of the Kgaelatogha Channel	Floating sedge beds fringing the lake	Free-floating vegetation rafts
OK1-07	VEG28	Upper Panhandle	18 24’ 18.9”	21 58’ 17.6”	09-Jun-00	Shallow lake north of the Kgaelatogha Channel	Open water lake	Organic detritus on sand; water depth > 2.5m

continued

GeoRef	VEG #	Locality	Latitude (S)	Longitude (E)	Date	Remarks	Habitat type	Bottom type
OK1-07	VEG29	Upper Panhandle	18 24' 18.9"	21 58' 17.6"	09-Jun-00	Shallow lake north of the Kgaelatogha Channel	Open water lake fringing a hippo path	Organic detritus on sand; water depth > 2.5m
OK1-07	VEG30	Upper Panhandle	18 24' 18.9"	21 58' 17.6"	09-Jun-00	Shallow lake north of the Kgaelatogha Channel	Open water lake	Organic detritus on sand; water depth > 3m
OK1-07	VEG31	Upper Panhandle	18 24' 18.9"	21 58' 17.6"	09-Jun-00	Shallow lake north of the Kgaelatogha Channel	Floating sedge beds marginal to the lake	Free-floating vegetation rafts rooted in fine organic detritus
OK1-08	VEG32	Guma	18 57' 13.2"	22 22' 21.3"	11-Jun-00	Floodplain due west of new campsite at Guma Lediba (Lake)	Deepest region of the shallow floodplain	Sand
OK1-08	VEG33	Guma	18 57' 13.2"	22 22' 21.3"	11-Jun-00	Floodplain due west of new campsite at Guma Lediba (Lake)	Shallow floodplain grassland	Sand
OK1-08	VEG34	Guma	18 57' 13.2"	22 22' 21.3"	11-Jun-00	Floodplain due west of new campsite at Guma Lediba (Lake)	Elevated infrequently flooded grassland between the floodplain and riparian forest	Sand
OK1-08	VEG35	Guma	18 57' 13.2"	22 22' 21.3"	11-Jun-00	Floodplain due west of new campsite at Guma Lediba (Lake)	Riparian forest	Sand
OK1-09A	VEG36	Guma	18 57' 41.5"	22 23' 08.3"	11-Jun-00	Eastern bank of SE section of Guma Lediba (Lake)	*Cyperus papyrus* fringing the lake	Peat
OK1-09B	VEG37	Guma	18 57' 41.5"	22 23' 08.3"	11-Jun-00	Eastern bank of SE section of Guma Lediba (Lake)	Floating mats of vegetation marginal to the lake	Organic detritus mat over water and sand
OK1-09B	VEG38	Guma	18 57' 41.5"	22 23' 08.3"	11-Jun-00	Eastern bank of SE section of Guma Lediba (Lake)	*Cyperus papyrus* swamp fringing the lake	Peat
OK1-09B	VEG39	Guma	18 57' 41.5"	22 23' 08.3"	11-Jun-00	Eastern bank of SE section of Guma Lediba (Lake)	Open water dominated by *Trapa natans*	Organic detritus ooze overlying sand
OK1-9	VEG40	Guma	18 57' 30.6"	22 23' 12.0"	11-Jun-00	Northern margin of SE section of Guma Lediba (Lake)	*Typha capensis* & *Cyperus papyrus* beds fringing the lake	Peat
OK1-10	VEG41	Guma	18 57' 21.4"	22 22' 39.1"	11-Jun-00	Inlet at northern end of Guma Lediba (Lake)	*Pycreus mundii* floating mat marginal to the lake	Organic detrital mat over water and sand
OK1-10	VEG42	Guma	18 57' 21.4"	22 22' 39.1"	11-Jun-00	Inlet at northern end of Guma Lediba (Lake)	*Cyperus papyrus* fringing the lake	Peat
OK1-10	VEG43	Guma	18 57' 21.4"	22 22' 39.1"	11-Jun-00	Inlet at northern end of Guma Lediba (Lake)	Sand bank at inlet	Sand
OK1-11	VEG44	Guma	18 57'21.4"	22 22' 39.7"	12-Jun-00	Guma Lediba (Lake), Water Affairs boat landing	Island vegetation	Sand
OK1-11	VEG45	Guma	18 57'21.4"	22 22' 39.7"	12-Jun-00	Guma Lediba (Lake), Water Affairs boat landing	Shallow lake margin	Sand
OK1-12	VEG46	Guma	18 57'30.4"	22 24' 02.3"	12-Jun-00	Artificial channel from Guma Lediba (Lake) to Okavango River	*Cyperus papyrus* dominated channel fringe	Peat
OK1-12	VEG47	Guma	18 57'30.4"	22 24' 02.3"	12-Jun-00	Artificial channel from Guma Lediba (Lake) to Okavango River	*Miscanthus junceus* dominated backswamp	Peat

continued

GeoRef	VEG #	Locality	Latitude (S)	Longitude (E)	Date	Remarks	Habitat type	Bottom type
OK1-13	VEG48	Guma	18 51'34.6"	22 24' 21.7"	12-Jun-00	Northem edge of shallow lake between Ngoga River and Guma Lediba (Lake)	Lake fringe	Peat
OK1-13	VEG49	Guma	18 51'34.6"	22 24' 21.7"	12-Jun-00	Northem edge of shallow lake between Ngoga River and Guma Lediba (Lake)	Shallow lake / open water margin	Organic ooze overlying sand
OK1-extra	VEG50	Guma	18 52' 19.7"	22 23' 33.2"	12-Jun-00	Island floodplain off main channel	Shallow grass and sedge floodplain north of island	Peat overlying sand
OK1-extra	VEG51	Guma	18 52' 25.9"	22 24' 20.0"	12-Jun-00	Left bank of Thaoge River, north of Guma Lediba (Lake)	*Miscanthus junceus* backswamp	Peat
OK1-14	VEG52	Guma	18 57'04.8"	22 22'23.0"	12-Jun-00	Shallow depression north of New Guma Camp	Shallow floodplain depression	Fine sand
OK1-extra	VEG53	Guma	18 57'04.8"	22 22'23.0"	12-Jun-00	Shallow depression north of New Guma Camp	Shallow floodplain grassland	Fine sand
OK1-extra	VEG54	Guma	18 57'04.8"	22 22'23.0"	12-Jun-00	Shallow depression north of New Guma Camp	Small termite-mound island set within the floodplain	Sand and termite mound
OK1-extra	VEG55	Moremi	19 07'39.8"	23 21'26.7"	14-Jun-00	Sandbank in channel between Xakanaxa and Gadikwe Madiba (Lakes)	Sandbank dominated by *Potamogeton thunbergii* and *Typha capensis*	Sand
OK1-15	VEG56	Moremi	19 09'44.5"	23 14'29.4"	14-Jun-00	Gadikwe Lediba (Lake) at nesting site of herons & storks	Floating mat of vegetation on the lake margin	Organic detrital mat over water and sand
OK1-15	VEG57	Moremi	19 09'44.5"	23 14'29.4"	14-Jun-00	Gadikwe Lediba (Lake) at nesting site of herons & storks	*Ficus verruculosa* lake fringe supporting heronry	Peat
OK1-15	VEG58	Moremi	19 09'44.5"	23 14'29.4"	14-Jun-00	Gadikwe Lediba (Lake)	Middle of lake	Organic ooze overlying sand
OK1-15	VEG59	Moremi			14-Jun-00	Gadikwe Island	Riparian woodland	Sand
OK1-16	VEG60	Moremi	19 09'54.8"	23 14'40.7"	14-Jun-00	Eastern edge of Gadikwe Lediba (Lake) fringing HATAB Island	Lake margin	Organic detritus overlying sand
OK1-16	VEG61	Moremi	19 09'54.8"	23 14'40.7"	14-Jun-00	Eastern edge of Gadikwe Lediba (Lake) fringing HATAB Island	Island/swamp fringe dominated by *Ficus verruculosa*	Peat overlying sand
OK1-17	VEG62	Moremi	19 09'20.1"	23 15'33.2"	14-Jun-00	Channel approx. 500 m east of Gadikwe Island	Channel dominated by *Nesaea naussicalis*	Organic detritus overlying sand
OK1-17	VEG63	Moremi	19 09'20.1"	23 15'33.2"	14-Jun-00	Channel approxi. 500 m east of Gadikwe Island	Channel fringe dominated by *Miscanthus junceus*	Peat
OK1-18	VEG64	Moremi	19 09'22.1"	23 16'12.8"	14-Jun-00	Channel between Gadikwe and Xakanaxa Madiba (Lakes)	Channel fringe dominated by *Ficus verruculosa* and *Syzygium cordatum*	Peat
OK1-18	VEG65	Moremi	19 09'22.1"	23 16'12.8"	14-Jun-00	Channel between Gadikwe and Xakanaxa Madiba (Lakes)	Fast flowing channel with *Nesaea crassicaulis* and *Rotala myriophylloides* beds	Organic detritus overlying sand
OK1-19	VEG66	Moremi	19 08'58.2"	23 16'44.4"	14-Jun-00	Sandbank between Gadikwe and Xakanaxa Madiba (Lakes)	Backswamp dominated by *Miscanthus junceus* and *Imperata cylindrica*	Peat

continued

GeoRef	VEG #	Locality	Latitude (S)	Longitude (E)	Date	Remarks	Habitat type	Bottom type
OK1-19	VEG67	Moremi	19 08'58.2"	23 16'44.4"	14-Jun-00	Sandbank between Gadikwe and Xakanaxa Madiba (Lakes)	Sparsely vegetated sandbank	Sand
OK1-20	VEG68	Moremi	19 08'17.0"	23 22'33.9"	14-Jun-00	Cross-section of Northern part of Xakanaxa Lediba (Lake)	Back swamp dominated by *Eleocharis dulcis* and *Pycreus nitidus*	Floating organic detritus
OK1-20	VEG69	Moremi	19 08'17.0"	23 22'33.9"	14-Jun-00	Cross-section of Northern part of Xakanaxa Lediba (Lake)	Lake fringe dominate by *Miscanthus junceus*	Peat
OK1-20	VEG70	Moremi	19 08'17.0"	23 22'33.9"	14-Jun-00	Cross-section of Northern part of Xakanaxa Lediba (Lake)	Lake margin; water depth 1.5-2m	Organic detritus overlying sand
OK1-20	VEG71	Moremi	19 08'17.0"	23 22'33.9"	14-Jun-00	Cross-section of Northern part of Xakanaxa Lediba (Lake)	Middle of lake; water depth >2m	Organic detritus overlying sand
OK1-20	VEG72	Moremi	19 08'17.0"	23 22'33.9"	14-Jun-00	Cross-section of Northern part of Xakanaxa Lediba (Lake)	Lake margin; water depth 1.5-2m.	Organic detritus overlying sand
OK1-20	VEG73	Moremi	19 08'17.0"	23 22'33.9"	14-Jun-00	Cross-section of Northern part of Xakanaxa Lediba (Lake)	Lake fringe dominated by *Miscanthus junceus*	Peat
OK1-20	VEG74	Moremi	19 08'17.0"	23 22'33.9"	14-Jun-00	Cross-section of Northern part of Xakanaxa Lediba (Lake)	Back swamp dominated by *Eleocharis dulcis*, *Miscanthus junceus* and *Pycreus nitidus*.	Organic soils overlying sand
OK1-21	VEG75	Moremi	19 08'17.0"	23 23'44.0"	14-Jun-00	South of the Xakanaxa Lediba (Lake)	Open water dominated by *Schoenoplactus corymbosus* and *Cyperus articulatus*	Organic soils overlying sand
OK1-22	VEG76	Moremi	19 11'25.7"	23 23'46.7"	14-Jun-00	Backswamps south of Xakanaxa Lediba (Lake)	Shallow open backswamp	Organic soils overlying sand
OK1-22	VEG77	Moremi	19 11'25.7"	23 23'46.7"	14-Jun-00	Lake fringe in the southern part of Xakanaxa Lediba (Lake)	*Miscanthus junceus* dominated lake fringe	Peat
OK1-22	VEG78	Moremi	19 11'25.7"	23 23'46.7"	14-Jun-00	Lake edge in the southern part of Xakanaxa Lediba (Lake)	Shallow (1.2m) lake margin	Organic detritus overlying sand
OK1-23	VEG79	Moremi	19 12'15.2"	23 27' 36.8"	15-Jun-00	Paradise Pools	Short emergent vegetation in open water margin. Strong sulphur smell.	Organic soils overlying sand
OK1-23	VEG80	Moremi	19 12'15.2"	23 27' 36.8"	15-Jun-00	Paradise Pools	*Miscanthus junceus* dominated vegetation fringing open water lake	Peat overlying sand
OK1-23	VEG81	Moremi	19 12'15.2"	23 27' 36.8"	15-Jun-00	Paradise Pools	Terrestrial vegetation	Sand
OK1-24	VEG82	Moremi	19 12'12.7"	23 27' 39.3"	15-Jun-00	Saline Pan close to Paradise Pools	Saline pan with many dead mopane trees, and trona deposited on soil surface.	Sand
OK1-extra	VEG83	Moremi	19 11'01.9"	23 24' 59.5"	16-Jun-00	Xakanaxa Campsite	Open riparian woodland	Sand c.f. plot 128 in Appendix 8 for species composition
OK1-extra	VEG84	Moremi	19 11'01.9"	23 24' 59.5"	16-Jun-00	Xakanaxa Campsite	Open riparian woodland	Sand c.f. plot 129 in Appendix 8 for species composition
OK1-extra	VEG85	Moremi	19 11'01.9"	23 24' 59.5"	16-Jun-00	Xakanaxa Campsite	Open riparian woodland	Sand c.f. plot 130 in Appendix 8 for species composition

continued

GeoRef	VEG #	Locality	Latitude (S)	Longitude (E)	Date	Remarks	Habitat type	Bottom type
OK1-25	VEG86	Moremi	19 11'36.5"	23 24'55.8"	16-Jun-00	Old Xakanaxa Airstrip	Seasonal floodplain dominated by *Imperata cylindrica*	Sand
OK1-25	VEG87	Moremi	19 11'36.5"	23 24'55.8"	16-Jun-00	Old Xakanaxa Airstrip	Shallow, seasonally flooded pool dominated by *Cyperus articulatus*	Sand
OK1-26	VEG88	Moremi	19 13'19.1"	23 24'54.8"	16-Jun-00	Road to 4th Bridge, near junction with Maya Pan Road of HATAB	Seasonally flooded *Colophospermum mopane* woodland	Clay
OK1-26	VEG89	Moremi	19 13'19.1"	23 24'54.8"	16-Jun-00	Road to 4th Bridge, near junction with Maya Pan Road of HATAB	Seasonally flooded *Colophospermum mopane* woodland	Clay
OK1-26	VEG90	Moremi	19 13'19.1"	23 24'54.8"	16-Jun-00	Road to 4th Bridge, near junction with Maya Pan Road of HATAB	Seasonally flooded grassland dominated by *Cynodon dactylon*	Sand
OK1-27	VEG91	Moremi	19 12'30.6"	23 24'11.1"	16-Jun-00	Jesse's Pool	Seasonally flooded grassland dominated by *Cynodon dactylon*	Sand
OK1-27	VEG92	Moremi	19 12'30.6"	23 24'11.1"	16-Jun-00	Jesse's Pool	Seasonally flooded pan	Sand
OK1-28	VEG93	Chief's Island	19 32'38.9"	23 03'50.2"	18-Jun-00	Island between Oddball's and Xaxaba on south side of Boro River.	Shallow floodplain grassland and sedgeland	Organic soil overlying sand
OK1-28	VEG94	Chief's Island	19 32'38.9"	23 03'50.2"	18-Jun-00	Island between Oddball's and Xaxaba on south side of Boro River.	Riparian woodland	Sand
OK1-30	VEG95	Chief's Island	19 31'56.8"	23 04'52.2"	18-Jun-00	Wildlife Campsite Island Floodplain	Shallow floodplain grassland fringing island; water depth <0.2m	Organic soil overlying sand
OK1-30	VEG96	Chief's Island	19 31'56.8"	23 04'52.2"	18-Jun-00	Wildlife Campsite Island Floodplain	Floodplain grassland; water depth 0.5m	Organic soil overlying sand
OK1-30	VEG97	Chief's Island	19 31'56.8"	23 04'52.2"	18-Jun-00	Wildlife Campsite Island Floodplain	Open water habitat; water depth 1.6m	Organic detritus overlying sand
OK1-31	VEG98	Chief's Island	19 31'36.5"	23 05'46.4"	19-Jun-00	East of Oddballs	Open water habitat; water depth 1.5m	Organic detritus overlying sand
OK1-31	VEG99	Chief's Island	19 31'36.5"	23 05'46.4"	19-Jun-00	East of Oddballs	Open water habitat; water depth 1.3m	Organic detritus overlying sand
OK1-31	VEG100	Chief's Island	19 31'36.5"	23 05'46.4"	19-Jun-00	East of Oddballs	Open water habitat; water depth 1.3m	Organic detritus overlying sand
OK1-31	VEG101	Chief's Island	19 31'36.5"	23 05'46.4"	19-Jun-00	East of Oddballs	Shallow seasonal floodplain; water depth 0.3m	Organic soil overlying sand
OK1-31	VEG102	Chief's Island	19 31'36.5"	23 05'46.4"	19-Jun-00	East of Oddballs	Open water / floodplain; water depth 0.8m	Organic soil overlying sand
OK1-31	VEG103	Chief's Island	19 31'36.5"	23 05'46.4"	19-Jun-00	East of Oddballs	Open water / floodplain; water depth 0.6m	Organic soil overlying sand
OK1-32	VEG104	Chief's Island	19 31'36.4"	23 06'22.3"	19-Jun-00	North of Delta Camp; shallow open water habitat	Open water habitat; water depth 1.8m	Organic detritus overlying sand
OK1-32	VEG105	Chief's Island	19 31'36.4"	23 06'22.3"	19-Jun-00	North of Delta Camp; shallow open water habitat	Open water habitat; water depth 1.6m	Organic detritus overlying sand

continued

GeoRef	VEG #	Locality	Latitude (S)	Longitude (E)	Date	Remarks	Habitat type	Bottom type
OK1-32	VEG106	Chief's Island	19 31'36.4"	23 06'22.3"	19-Jun-00	North of Delta Camp; shallow open water habitat	Open water habitat; water depth 1.3m	Organic detritus overlying sand
OK1-32	VEG107	Chief's Island	19 31'37.0"	23 06'19.2"	19-Jun-00	North of Delta Camp; floodplain & shallow open water habitat	Open water / floodplain; water depth 0.5m	Organic soil overlying sand
OK1-32	VEG108	Chief's Island	19 31'36.4"	23 06'22.3"	19-Jun-00	North of Delta Camp; floodplain & shallow open water habitat	Floodplain grassland fringing open water habitat	Sand
OK1-33	VEG109	Chief's Island	19 32'27.9"	23 06'14.4"	19-Jun-00	Delta Camp	Open water / floodplain; water depth 0.6m	Organic soil overlying sand
OK1-33	VEG110	Chief's Island	19 32'33.7"	23 06'06.7"	19-Jun-00	Delta Camp	Open water / floodplain; water depth 0.5m	Organic soil overlying sand
OK1-33	VEG111	Chief's Island	19 32'46.6"	23 06'03.3"	19-Jun-00	2.2km south east of Oddballs Island: Transect from island edge to shallow open water habitat	Floodplain grassland near waters edge; water depth 0.2m	Organic soil overlying sand
OK1-33	VEG112	Chief's Island	19 32'46.6"	23 06'03.3"	19-Jun-00	2.2km south east of Oddballs Island: Transect from island edge to shallow open water habitat	Emergent and floating-leaved vegetation in floodplain / open water habitat	Organic detritus overlying sand
OK1-33	VEG113	Chief's Island	19 32'46.6"	23 06'03.3"	19-Jun-00	2.2km south east of Oddballs Island: Transect from island edge to shallow open water habitat	Emergent and floating-leaved vegetation in open water habitat	Organic detritus overlying sand
OK1-33	VEG114	Chief's Island	19 32'46.6"	23 06'03.3"	19-Jun-00	2.2km south east of Oddballs Island: Transect from island edge to shallow open water habitat	Emergent and floating-leaved vegetation in open water habitat	Organic detritus overlying sand
OK1-34	VEG114A	Chief's Island	19 32'10.8"	E23 05'14.5"	19-Jun-00	Shallow area of open water 800m from Oddballs	Shallow stream and open water; water depth 1.5m	Organic detritus overlying sand
OK1-34	VEG115	Chief's Island	19 32'10.8"	E23 05'14.6"	19-Jun-00	Shallow area of open water 800m from Oddballs	Shallow stream and open water; water depth 1.6m	Organic detritus overlying sand
OK1-34	VEG116	Chief's Island	19 32'10.8"	E23 05'14.7"	19-Jun-00	Shallow area of open water 800m from Oddballs	Shallow stream and Shallow area of open water; water depth 1.7m	Organic detritus overlying sand
OK1-35	VEG117	Chief's Island	19 31'17.5"	23 06'15.6"	20-Jun-00	Saline pan in island centre, approx. 1.7 km east of Oddballs	Saline pan with *Eragrostis* sp. and *Cyperus dives*.	Sand
OK1-35	VEG118	Chief's Island	19 31'17.5"	23 06'15.6"	20-Jun-00	Saline pan in island centre, approx. 1.7 km east of Oddballs	Saline pan margin with *Eragrostis* sp. and *Cyperus dives*.	Sand
OK1-36	VEG119	Chief's Island	19 32'08.5"	23 05'56.8"	20-Jun-00	At Southern end of Delta/ Oddballs runway	Shallow floodplain	Sand
OK1-36	VEG120	Chief's Island	19 32'08.5"	23 05'56.8"	20-Jun-00	At Southern end of Delta/ Oddballs runway	Shallow floodplain	Sand
OK1-36	VEG121	Chief's Island	19 32' 08.5"	23 05'56.8"	20-Jun-00	At Southern end of Delta/ Oddballs runway	Floodplain margin / terrestrial habitat	Sand

continued

GeoRef	VEG #	Locality	Latitude (S)	Longitude (E)	Date	Remarks	Habitat type	Bottom type
OK1-37	VEG122	Chief's Island	19 32'13.5"	23 05'54.1"	20-Jun-00	Shallow cacrete barrow pit at sothern end of Delta/ Oddballs runway	Tea coloured excavation	Sand
OK1-extra	VEG 123 (PAN 1)	Upper Panhandle	18 25'25.6"	21 56'21.4"	09-Jun-00	Island edge adjacent to Okavango River	Riparian woodland	Sand
OK1-extra	VEG 124 (DROT 1)	Upper Panhandle	18 24'49.7"	21 53'08.1"	10-Jun-00	Drotsky's Cabins	Riparian woodland	Sand
OK1-extra	VEG 125 (DROT 2)	Upper Panhandle	18 24'49.7"	21 53'08.1"	10-Jun-00	Drotsky's Cabins	Riparian woodland	Sand
OK1-extra	VEG 126 (GUMA 1)	Guma	18 57'21.0"	22 22'24.6"	12-Jun-00	Guma (New camp) boat landing	Riparian woodland	Sand
OK1-extra	VEG 127 (XAKA 1)	Moremi	19 11'01.9"	23 24'59.5"	16-Jun-00	Xakanaxa Campsite	Open riparian woodland	Sand
OK1-extra	VEG 128 (XAKA 2)	Moremi	19 11'01.9"	23 24'59.5"	16-Jun-00	Xakanaxa Campsite	Open riparian woodland	Sand
OK1-extra	VEG 129 (XAKA 3)	Moremi	19 11'01.9"	23 24'59.5"	16-Jun-00	Xakanaxa Campsite	Open riparian woodland	Sand
OK1-extra	VEG 130 (ODD 1)	Chief's Island	19 31'46.6"	23 05'25.2"	20-Jun-00	New Oddballs Camp	Riparian woodland	Sand
OK1-extra	VEG 131 (ODD 2)	Chief's Island	19 31'46.6"	23 05'25.2"	20-Jun-00	New Oddballs Camp	Riparian woodland	Sand
OK1-extra	VEG 132 (ODD 3)	Chief's Island	19 31'46.6"	23 05'25.2"	20-Jun-00	New Oddballs Camp	Riparian woodland	Sand

Appendix 7

Plant species recorded from the Okavango Delta

W. N. Ellery

The column marked 'PAS' refers to the list compiled by Mr. P.A. Smith in the Okavango Ecozoning Report (SMEC 1989). The column marked 'NBI' refers to the list obtained from the PRECIS list from the Pretoria National Herbarium. The column marked 'SA List' refers to whether the plant is listed in Arnold and de Wet (1993).

Key to abbreviations:

Distribution

D	Dryland habitats
RWP	Rain water pans
IFG	Intermittently flooded grassland
DRW	Dryland riverine woodland
FG	Flooded grassland
SS	Seasonal swamps
PS	Permanent swamps
TA/S	Tolerant of salinity/alkalinity
Aq. T	Aquatic tree

SA List = List of plants for southern Africa (Arnold and de Wet 1993), which was used in this study for nomenclatural purposes.
N = Not present on the list of plants for southern Africa (Arnold and de Wet 1993).
PAS = List compiled by Mr. P.A. Smith for the SMEC (1989) Report.
NBI = National Botanical Institute, Pretoria Herbarium Database.

Growth form

Aq. cr.	Aquatic creeper
Aq. emerg.	Emergent aquatic
Aq. ff.	Free-floating aquatic
Aq. fl. lv	Floating-leaved aquatic
Aq. fl. stm	Floating-stemmed aquatic
Aq. shr.	Aquatic shrub
Aq. subm.	Submerged aquatic
C	Creeper
Ep.	Epiphyte
GC	Ground creeper
Geop.	Geophyte
Gram.	Graminoid
H	Herb
H Wetl.	Herbaceous wetland plant
HC	Herbaceous creeper
Shr.	Shrublet
Shrblt.	Shrublet
T	Tree
WC	Woody climber

Species name	Distribution	Growth form	PAS	NBI	SA List
Bryophytes					
BARTRAMIACEAE					
Philonotis dregeana (C.Mnll.) A.Jaeger				NBI	
Philonotis falcata (Hook.) Mitt.				NBI	
Philonotis hastata (Duby) Wijk & Margad.				NBI	
BRYACEAE					
Bryum dichotomum Hedw.				NBI	N
DICRANACEAE					
Campylopus savannarum (C. Mull.) Mitt.				NBI	
ERPODIACEAE					
Erpodium beccarii C. Mull.				NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
FABRONIACEAE					
Fabronia pilifera Hornsch.				NBI	
POTTIACEAE					
Didymodon ceratodonteus (C. Mull.) Dix				NBI	
RICCIACEAE					
Riccia cavernosa Hoffm. emend. *Raddi*				NBI	
Riccia okahandjana S.W.Arnell				NBI	N
Ricciocarpos natans (L.) Corda				NBI	
Pteridophytes					
ADIANTACEAE					
Pellaea boivinii Hook.				NBI	
AZOLLACEAE					
Azolla pinnata R.Br.	PS, SS	Aq. ff.	PAS	NBI	
DENNSTAEDTIACEAE					
Microlepia speluncae (L.) T.Moore	FG	H	PAS		
MARSILEACEAE					
Marsilea coromandelina Willd.	RWP	H		NBI	
Marsilea macrocarpa Presl.	RWP	H	PAS		
Marsilea minuta L.	RWP	H	PAS	NBI	
Marsilea nubica A.Braun var. *gymnocarpa* (Lepr. ex A.Braun) Launert	RWP	H	PAS	NBI	
Marsilea vera Launert	RWP	H	PAS		
Marsilea villifolia Bremek. & Oberm. ex Alston & Schelpe	RWP	H		NBI	
PARKERIACEAE					
Ceratopteris cornuta (P.Beauv.) Lepr.	PS, SS	Aq. subm. & emerg.		NBI	
SALVINIACEAE					
Salvinia molesta D.S. Mitchell	PS, SS	Aq. ff.	PAS		
THELYPTERIDACEAE					
Thelypteris confluens (Thunb.) Morton	PS, SS	Aq. emerg.	PAS	NBI	
Thelypteris interrupta (Willd.) K.Iwats.	PS, SS	Aq. emerg.	PAS	NBI	
Monocotyledons					
ALISMATACEAE					
Burnatia enneandra P.Micheli	PS, SS	Aq. emerg.	PAS	NBI	
Caldesia reniformis (D.Don) Makino	PS, SS	Aq. fl.	PAS	NBI	
Limnophyton angolense Buchenau	PS, SS	Aq. emerg.	PAS	NBI	
Wisneria schweinfurthii Hook.f.	PS, SS	Aq. subm.	PAS	NBI	
AMARYLLIDACEAE					
Ammocharis tinneana (Kotschy & Peyr.) Milne-Redh. & Schweick.	D	H Geop.	PAS	NBI	
Crinum carolo-schmidtii Dinter	FG	H Geop.	PAS	NBI	
Crinum crassicaule Baker	FG, D	H Geop.	PAS	NBI	
Crinum euchrophyllum I.Verd.	FG, D	H Geop.	PAS	NBI	
Crinum foetidum I.Verd.	FG, D	H Geop.		NBI	
Crinum lugardiae N.E.Br.	D	H Geop.	PAS		
Pancratium tenuifolium Hochst. ex A.Rich.	D	H Geop.	PAS	NBI	
Scadoxus multiflorus (Martyn) Raf. subsp. multiflorus	D	H Geop.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
APONOGETONACEAE					
Aponogeton junceus Lehm. ex Schlechtend. subsp. *rehmannii* (Oliv.) Oberm.	RWP	Aq. fl. lv.	PAS		
ARECACEAE					
Hyphaene petersiana Klotzsch	D	T	PAS		
Phoenix reclinata Jacq.	PS, SS	Aq. T	PAS	NBI	
COMMELINACEAE					
Aneilema hockii De Wild.	D	H	PAS	NBI	
Commelina africana L. var. *krebsiana* (Kunth) C.B.Clarke	D	H	PAS	NBI	
Commelina benghalensis L.	D	H	PAS	NBI	
Commelina diffusa Burm.f. subsp. *diffusa*	SS, FG	Aq. emerg.	PAS	NBI	
Commelina diffusa Burm.f. subsp. *scandens* (C.B.Clarke) Oberm.	PS, SS	Aq. emerg.	PAS	NBI	
Commelina eckloniana Kunth.	D	H	PAS		
Commelina erecta L.	D	H		NBI	
Commelina fluviatilis Brenan	PS, FG	Aq. emerg.	PAS	NBI	
Commelina forskaolii Vahl	D	H	PAS	NBI	
Commelina petersii Hassk.	D	H	PAS		
Commelina subulata Roth	RWP	H	PAS	NBI	
Commelina zambesica C.B.Clarke	FG, D	H	PAS	NBI	
Cyanotis foecunda Hassk.	D	H	PAS	NBI	
Floscopa glomerata (Willd. ex Schult. & Schult.f.) Hassk.	PS, SS	Aq. emerg.	PAS	NBI	
Floscopa leiothyrsa Brenan	PS, SS	Aq. emerg.	PAS	NBI	
CYPERACEAE					
Abildgaardia burchellii (Fic. & Hiern) K.Lye	FG, D	Gram.	PAS		N
Abildgaardia hispidula (Vahl) K.Lye	FG, D	Gram.	PAS		N
Abildgaardia trabeculata (C.B.Cl.) K.Lye	FG, D	Gram.	PAS		N
Bolboschoenus maritimus (L.) Palla	RWP, FG	Gram.		NBI	
Bulbostylis contexta (Nees) M.Bodard	FG	Gram.		NBI	
Bulbostylis hispidula (Vahl) R.W.Haines	FG	Gram.		NBI	
Bulbostylis trabeculata C.B.Clarke	FG	Gram.		NBI	
Carex cognata Kunth var. *cognata*	PS, SS	Gram.	PAS	NBI	
Cladium mariscus (L.) Pohl subsp. *jamaicense* (Crantz) Knk.	PS, SS	Gram.	PAS	NBI	
Courtoisina cyperoides (Roxb.) subsp. *africanus* (C.B.Cl. ex. Kuekenth.) Vorster	RWP	Gram.	PAS		N
Cyperus alopecuroides Rottb.	PS, SS	Gram.	PAS	NBI	
Cyperus amabilis Vahl.	FG, D	Gram.	PAS		
Cyperus articulatus L.	PS, SS	Gram.	PAS	NBI	
Cyperus compressus L.	SS, FG	Gram.	PAS	NBI	
Cyperus denudatus L.f.	PS, SS	Gram.	PAS	NBI	
Cyperus difformis L.	RWP	Gram.	PAS	NBI	
Cyperus digitatus Roxb. subsp. *auricomus* (Sieber ex Spreng.) Knk.	SS	Gram.	PAS	NBI	
Cyperus distans L.f.	FG, D	Gram.	PAS		
Cyperus dives Delile	PS, SS	Gram.	PAS	NBI	
Cyperus esculentus L. var. *esculentus*	FG, D	Gram.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Cyperus fulgens C.B.Clarke var. *contractus* Knk.	PS, SS	Gram.		NBI	
Cyperus fulgens C.B.Clarke var. *fulgens*	PS, SS	Gram.		NBI	
Cyperus haspan L.		Gram.		NBI	
Cyperus imbricatus Retz.	SS	Gram.	PAS	NBI	
Cyperus kirkii C.B.Cl.	FG	Gram.	PAS		N
Cyperus laevigatus L.	PS, SS TA/S	Gram.	PAS	NBI	
Cyperus latifolius Poir.	PS, SS	Gram.	PAS	NBI	
Cyperus leptocladus Kunth	SS, FG	Gram.	PAS		
Cyperus longus L. var. *longus*	SS, IFG	Gram.	PAS	NBI	
Cyperus longus L. var. *tenuiflorus* (Rottb.) Boeck.	SS, IFG	Gram.		NBI	
Cyperus maculatus Boeck.	SS, FG	Gram.	PAS	NBI	
Cyperus margaritaceus Vahl	FG, D	Gram.	PAS	NBI	
Cyperus mwinilungensis Podlech	PS, SS	Gram.	PAS	NBI	
Cyperus palmatus Vorster	FG, D TA/S	Gram.	PAS		N
Cyperus papyrus L.	PS	Gram.	PAS	NBI	
Cyperus pectinatus Vahl	PS, SS	Gram.	PAS	NBI	
Cyperus rotundus L. subsp. r*otundus* var. *rotundus*	FG, D	Gram.	PAS	NBI	
Cyperus sphaerospermus Schrad.	PS, IFG	Gram.		NBI	
Cyperus tenuispica Steud.	FG, D	Gram.	PAS	NBI	
Cyperus zollingeri Steud.	FG, D	Gram.	PAS	NBI	
Eleocharis acutangula (Roxb.) Schult.	PS, SS	Gram.	PAS	NBI	
Eleocharis atropurpurea (Retz.) J.& C.Presl	FG	Gram.	PAS	NBI	
Eleocharis brainii Svenson	FG	Gram.	PAS		N
Eleocharis caduca (Delile) Schult.	FG	Gram.	PAS	NBI	N
Eleocharis dulcis (Burm.f.) Hensch.	PS, SS	Gram.	PAS	NBI	
Eleocharis marginulata Steud.	PS, SS	Gram.	PAS		N
Eleocharis naumanniana Boeck.	PS, SS	Aq. subm.	PAS	NBI	
Eleocharis palustris R.Br.	PS, SS	Gram.		NBI	
Eleocharis retroflexa (Poir.) Urb. subsp. *subtilissima* (Nelmes) Lye	PS, SS	Gram.		NBI	
Eleocharis variegata (Poir.) C.Presl	PS, SS	Gram.	PAS	NBI	
Fimbristylis bisumbellata (Forssk.) Bub.	FG	Gram.	PAS		
Fimbristylis complanata (Retz.) Link	PS, SS	Gram.	PAS	NBI	
Fimbristylis dichotoma (L.) Vahl	PS, SS	Gram.	PAS	NBI	
Fimbristylis longiculmis Steud.	PS, SS	Gram.	PAS		
Fimbristylis squarrosa Vahl	PS, SS	Gram.	PAS	NBI	
Fuirena ciliaris (L.) Roxb. var. *ciliaris*	SS	Gram.	PAS	NBI	
Fuirena leptostachya Oliv. var. *leptostachya*	SS, IFG	Gram.	PAS	NBI	
Fuirena pubescens (Poir.) Kunth	PS, SS	Gram.	PAS	NBI	
Fuirena stricta Steud.	PS, SS	Gram.	PAS	NBI	
Fuirena umbellata Rottb.	PS, SS	Gram.	PAS	NBI	
Isolepis sepulcralis Steud.	FG	Gram.	PAS	NBI	
Kyllinga alata Nees	IFG, D	Gram.	PAS		
Kyllinga alba Nees	IFG, D	Gram.	PAS	NBI	
Kyllinga albiceps (Ridley) Rendle	RWP	Gram.	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Kyllinga erecta Schumach.	PS, SS	Gram.	PAS	NBI	
Kyllinga intricata Cherm.	PS, SS	Gram.	PAS	NBI	
Lipocarpha abietina Goetgh.	PS, SS	Gram.		NBI	
Lipocarpha atra Ridley var. atra	PS, SS	Gram.	PAS		N
Lipocarpha chinensis (Osbeck) Kern	PS, SS	Gram.	PAS	NBI	
Lipocarpha hemisphaerica (Roth) Goetge.	RWP	Gram.		NBI	
Mariscus chersinus N.E.Br.		Gram.		NBI	
Mariscus cyperoides (Roxb.) A.Dietr. subsp. *africanus* (C.B.Clarke ex Knk.) Podlech		Gram.		NBI	
Mariscus dubius (Rottb.) Knk. ex C.E.C.Fisch.	D	Gram.	PAS	NBI	
Mariscus fulgens (C.B.Cl.) Vorster ms	D	Gram.	PAS		N
Mariscus hamulosus (M.Bieb.) Hooper		Gram.		NBI	
Mariscus laxiflorus Turrill	D	Gram.	PAS	NBI	
Mariscus squarrosus (L.) C.B.Clarke		Gram.		NBI	
Mariscus sumatrensis (Retz.) J.Raynal		Gram.		NBI	
Pycreus aethiops C.B.Clarke	PS, SS	Gram.	PAS	NBI	
Pycreus chrysanthus (Boeck.) C.B.Clarke	RWP	Gram.	PAS	NBI	
Pycreus flavescens (L.) Rchb.	PS, SS	Gram.	PAS	NBI	
Pycreus macranthus (Boeck.) C.B.Clarke	PS, FG	Gram.	PAS	NBI	
Pycreus macrostachyos (Lam.) J.Raynal	SS, FG, RWP	Gram.	PAS	NBI	
Pycreus mundii Nees	PS, SS	Gram.	PAS	NBI	
Pycreus nitidus (Lam.) J.Raynal	PS, SS	Gram.	PAS	NBI	
Pycreus okavangensis Podlech	SS, FG, RWP	Gram.	PAS	NBI	
Pycreus pelophilus (Ridl.) C.B.Clarke	FG, RWP	Gram.	PAS	NBI	
Pycreus polystachyos (Rottb.) P.Beauv. var. *polystachyos*	SS, FG	Gram.	PAS	NBI	
Pycreus pumilus	FG, RWP	Gram.	PAS		
Pycreus unioloides (R.Br.) Urb.	PS, FG	Gram.	PAS	NBI	
Pycreus waillyi Cherm.		Gram.		NBI	N
Rhynchospora brownii Roem. & Schult.	PS, SS	Gram.	PAS	NBI	
Rhynchospora candida (Nees) Boeck.	PS	Gram.	PAS	NBI	
Rhynchospora corymbosa (L.) Britton	PS, SS	Gram.	PAS	NBI	
Rhynchospora holoschoenoides (Rich.) Herter	PS, FG	Gram.	PAS	NBI	
Rhynchospora perrieri Cherm.	PS, FG	Gram.	PAS	NBI	
Schoenoplectus brachyceras (A.Rich.) Lye		Gram.		NBI	N
Schoenoplectus confusus (N.E.Br.) K.Lye var. *rogersïi* (N.E.Br.) K.Lye	SS	Gram.	PAS		
Schoenoplectus corymbosus (Roth ex Roem. & Schult.) J.Raynal	PS, SS	Gram.	PAS	NBI	
Schoenoplectus erectus (Poir.) Palla ex J.Raynal	SS, FG, RWP	Gram.	PAS	NBI	
Schoenoplectus lateriflorus (J.F.Gmel.) Lye		Gram.		NBI	
Schoenoplectus maritimus (L.) K.Lye	RWP	Gram.	PAS		N
Schoenoplectus muricinux (C.B.Clarke) J.Raynal	FG, RWP	Gram.	PAS	NBI	
Schoenoplectus praelongatus (Poir.) J.Raynal		Gram.		NBI	
Schoenoplectus senegalensis (Hochst. ex Steud.) Palla ex J.Raynal	RWP	Gram.	PAS	NBI	
Scirpus cubensis Poeppig & Kunth ex Kunth	PS, SS	Gram.	PAS	NBI	
Scirpus microcephalus (Steud.) Dandy	FG, D	Gram.	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Scleria distans Poir.	PS, SS	Gram.	PAS	NBI	N
Scleria dregeana Kunth	PS, SS	Gram.	PAS	NBI	
Scleria lacustris C.H.Wright in Sauvalle	PS, SS	Gram.	PAS	NBI	
Scleria melanomphala Kunth	PS, SS	Gram.	PAS	NBI	
Scleria unguiculata E.A.Rob.	PS, SS	Gram.	PAS	NBI	
Scleria veseyfitzgeraldii E.A.Rob.	PS, SS	Gram.	PAS	NBI	
Websteria confervoides (Poir.) Hooper	PS, SS	Aq. subm.	PAS	NBI	
DIOSCOREACEAE					
Dioscorea asteriscus Burkill	DRW	HC	PAS		
ERIOCAULACEAE					
Eriocaulon cinereum R.Br.	FG	H	PAS		
Eriocaulon setaceum L.	PS, SS	Aq. subm.	PAS	NBI	
Eriocaulon welwitschii Rendle	FG	H	PAS	NBI	
ERIOSPERMACEAE					
Eriospermum bakerianum Schinz subsp. bakerianum				NBI	
HYDROCHARITACEAE					
Lagarosiphon cordofanus Casp.	PS, SS	Aq. subm.	PAS	NBI	
Lagarosiphon ilicifolius Oberm.	PS, SS	Aq. subm.	PAS	NBI	
Lagarosiphon major (Ridl.) Moss ex Wager	PS, SS	Aq. subm.		NBI	
Lagarosiphon muscoides Harv.	RWP	Aq. subm.	PAS		
Ottelia kunenensis (Gnrke) Dandy	PS, SS	Aq. subm.	PAS	NBI	
Ottelia muricata (C.H.Wright) Dandy	PS, SS	Aq. subm.	PAS	NBI	
Ottelia ulvifolia (Planch.) Walp.	PS, SS	Aq. subm.	PAS	NBI	
Vallisneria aethiopica Fenzl	PS, SS	Aq. subm.	PAS	NBI	
IRIDACEAE					
Ferraria glutinosa (Baker) Rendle				NBI	
Lapeirousia bainesii Bak.	D	H Geop.	PAS		
Lapeirousia schimperi (Asch. & Klatt) Milne-Redh.	RWP, D	H Geop.	PAS	NBI	
JUNCACEAE					
Juncus rigidus Desf.	FG TA/S	Gram.	PAS		
LEMNACEAE					
Lemna aequinoctialis Welw.	PS, SS, RWP	Aq. ff.	PAS	NBI	
Lemna gibba L.	PS, SS, RWP	Aq. ff.		NBI	
Lemna minor L.	PS, SS, RWP	Aq. ff.	PAS		
Spirodela polyrrhiza (L.) Schleid.	PS, SS	Aq. ff.	PAS	NBI	
Wolffiella arrhiza (L.) Horkel ex. Wimm.	PS, SS, RWP	Aq. ff.	PAS		N
Wolffiella hyalina (Delile) Monod	RWP	Aq. ff.	PAS	NBI	
Wolffiella repanda (Helgelm.) Monod	RWP	Aq. ff.	PAS		N
Wolffiella welwitschii (Hegelm.) Monod	PS, SS	Aq. ff.	PAS	NBI	
LILIACEAE					
Albuca melleri Baker	D	H Geop.	PAS	NBI	
Aloe greatheadii Schonland var. *greatheadii*	D	H		NBI	
Aloe x esculenta Leach	D	H	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Aloe zebrina Baker	D	H	PAS	NBI	
Camptorrhiza strumosa (Baker) Oberm.	D	H Geop.	PAS	NBI	
Chlorophytum papillosum Rendle	D	H Geop.	PAS		
Chlorophytum trachycarpum Oberm.	D	H Geop.	PAS		
Dipcadi bakerianum Bolus	D	H Geop.	PAS	NBI	
Dipcadi glaucum (Ker Gawl.) Baker	D	H Geop.	PAS	NBI	
Dipcadi gracillimum Baker	D	H Geop.		NBI	
Dipcadi longifolium (Lindl.) Baker	D	H Geop.	PAS	NBI	
Dipcadi marlothii Engl.	D	H Geop.	PAS		
Gloriosa superba L.	D	H Geop.	PAS	NBI	
Ledebouria revoluta (L.f.) Jessop	D	H Geop.	PAS	NBI	
Ledebouria undulata (Jacq.) Jessop	D	H Geop.		NBI	
Litanthus pusillus Harv.	D	H Geop.	PAS	NBI	
Ornithogalum seineri (Engl. & K.Krause) Oberm.	D	H Geop.		NBI	
Ornithogalum tenuifolium Delaroche subsp. *tenuifolium*	FG	H Geop.	PAS		
Protasparagus africanus (Lam.) Oberm.	D	H	PAS		
Protasparagus aspergillus (Jessop) Oberm.	D	H	PAS		
Protasparagus cooperi (Bak.) Oberm.	D	H	PAS	NBI	
Protasparagus laricinus (Burch.) Oberm.	D	H	PAS	NBI	
Protasparagus nelsii (Schinz) Oberm.	D	H	PAS	NBI	
Protasparagus nodulosus Oberm. ?	D	H	PAS	NBI	
Protasparagus racemosus (Willd.) Oberm.	D	H	PAS	NBI	
Sansevieria aethiopica Thunb.	D	H	PAS		
Sansevieria pearsonii N.E.Br.	D	H	PAS		
Scilla nervosa (Burch.) Jessop	D	H Geop.	PAS		
Trachyandra arvensis (Schinz) Oberm.	D	H	PAS	NBI	
Trachyandra laxa (N.E.Br.) Oberm. var. *rigida* (Suess.) Roessler	D	H		NBI	
Urginea epigea R.A.Dyer	D	H Geop.		NBI	
Urginea sanguinea Schinz	D	H Geop.	PAS	NBI	
Urginea zambesiaca Baker	D	H Geop.	PAS		
NAJADACEAE					
Najas horrida A. Br.	PS, SS	Aq. subm.	PAS	NBI	
ORCHIDACEAE					
Ansellia africana Lindl.	D	Ep.	PAS		
Eulophia angolensis (Rchb.f.) Summerh.	PS, SS	Aq. emerg.	PAS	NBI	
Eulophia clavicornis Lindl. var. *nutans* (Sond.) A.V.Hall	D	H		NBI	
Eulophia horsfallii (Bateman) Summerh.	PS, SS	Aq. emerg.		NBI	
Eulophia latilabris Summerh.	PS, SS	Aq. emerg.	PAS	NBI	
Eulophia speciosa (R.Br. ex Lindl.) Bolus	D	H	PAS	NBI	
Eulophia tanganyikensis Rolfe	PS, SS	Aq. emerg.	PAS		
Habenaria chlorotica Reichb.f.	PS, SS	Aq. emerg.	PAS		
Habenaria filicornis Lindl.	PS, SS	Aq. emerg.	PAS	NBI	
Habenaria ichneumonea (Sw.) Lindl.	PS, SS	Aq. emerg.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Habenaria pasmithii G.Will.	PS, SS	Aq. emerg.	PAS	NBI	N
Habenaria schimperiana Hochst. ex A.Rich.	PS, SS	Aq. emerg.	PAS		
Zeuxine africana Reichb.f.	PS, SS	Aq. emerg.	PAS		
POACEAE					
Acrachne racemosa (Roem. & Schult.) Ohwi	D	Gram.	PAS	NBI	
Acroceras macrum Stapf	SS, FG	Gram.	PAS	NBI	
Andropogon brazzae Franch.	PS, FG	Gram.	PAS	NBI	
Andropogon eucomus Nees	FG	Gram.	PAS	NBI	
Andropogon gayanus Kunth var. *polycladus* (Hack.) Clayton	D	Gram.	PAS	NBI	
Andropogon huillensis Rendle	FG	Gram.	PAS	NBI	
Andropogon laxatus Stapf	FG	Gram.	PAS	NBI	
Anthephora pubescens Nees	D	Gram.	PAS	NBI	
Aristida adscensionis L.	D	Gram.	PAS	NBI	
Aristida canescens Henr.	D	Gram.	PAS		
Aristida congesta Roem. & Schult. subsp. *barbicollis* (Trin. & Rupr.) De Winter	D	Gram.	PAS	NBI	
Aristida engleri Mez.	D	Gram.	PAS		
Aristida hordeacea Kunth	D	Gram.	PAS		
Aristida junciformis Trin. & Rupr. subsp. *junciformis*	FG	Gram.	PAS	NBI	
Aristida meridionalis Henrard	D	Gram.	PAS	NBI	
Aristida mollissima Pilg.	D	Gram.	PAS		
Aristida pilgeri Henrard	FG, D	Gram.	PAS	NBI	
Aristida scabrivalvis Hack. subsp. *contracta* (De Winter) Melderis	D	Gram.	PAS	NBI	
Aristida spectabilis Hack.	D	Gram.		NBI	
Aristida stipitata Hack. subsp. *graciliflora* (Pilg.) Melderis	IFG, D	Gram.	PAS	NBI	
Aristida stipitata Hack. subsp. *robusta* (Stent & J.M.Rattray) Melderis	IFG, D	Gram.	PAS	NBI	
Aristida stipitata Hack. subsp. *spicata* (De Winter) Melderis	IFG, D	Gram.	PAS	NBI	
Aristida stipoides Lam.	D	Gram.	PAS	NBI	
Bothriochloa bladhii (Retz.) S.T.Blake	D	Gram.	PAS	NBI	
Bothriochloa insculpta (A.Rich.) A.Camus	D	Gram.	PAS	NBI	
Bothriochloa radicans (Lehm.) A.Camus	D	Gram.		NBI	
Brachiaria arrecta (T.Durand & Schinz) Stent	SS, FG	Gram.	PAS	NBI	
Brachiaria brizantha (A.Rich) Stapf	D	Gram.	PAS		
Brachiaria deflexa (Schumach.) C.E.Hubb. ex Robyns	D	Gram.	PAS	NBI	
Brachiaria dura Stapf var. *dura*	FG	Gram.	PAS	NBI	
Brachiaria eruciformis (J.E.Sm.) Briseb.	D	Gram.	PAS		
Brachiaria grossa Stapf	D	Gram.	PAS	NBI	
Brachiaria humidicola (Rendle) Schweick.	FG	Gram.	PAS	NBI	
Brachiaria nigropedata (Ficalho & Hiern) Stapf	D	Gram.	PAS	NBI	
Brachiaria rugulosa Stapf	SS, FG	Gram.	PAS		
Brachiaria xantholeuca (Schinz) Stapf	D	Gram.	PAS	NBI	
Cenchrus ciliaris L.	D	Gram.	PAS	NBI	
Chloris gayana Kunth	FG	TA/S	PAS	NBI	
Chloris virgata Sw.	D	Gram.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Cymbopogon caesius (Hook & Arn.) Stapf	FG	Gram.	PAS		
Cymbopogon excavatus (Hochst.) Stapf ex Burtt Davy	D	Gram.		NBI	
Cymbopogon nardus (L.) Rendle	FG	Gram.	PAS		
Cynodon dactylon (L.) Pers.	FG, D	Gram.	PAS	NBI	
Dactyloctenium aegyptium (L.) Willd.	D	Gram.	PAS	NBI	
Dactyloctenium giganteum Fisher & Schweick.	D	Gram.	PAS	NBI	
Diandrochloa namaquensis (Nees) De Winter	FG, D	Gram.		NBI	
Diandrochloa pusilla (Hack.) De Winter	FG, RWP	Gram.	PAS		
Dichanthium annulatum (Forssk.) Stapf var. *papillosum* (A.Rich.) de Wet & Harlan	FG	Gram.		NBI	
Digitaria accuminatissima Stapf	D	Gram.	PAS		
Digitaria debilis (Desf.) Willd.	SS, FG	Gram.	PAS	NBI	
Digitaria eriantha Steud.	D	Gram.	PAS	NBI	
Digitaria eylesii C.E.Hubb.	SS, FG	Gram.	PAS	NBI	
Digitaria longiflora (Retz.) Pers.	FG	Gram.	PAS		
Digitaria maniculata Stapf	FG	Gram.	PAS	NBI	
Digitaria milanjiana (Rendle) Stapf	D	Gram.	PAS	NBI	
Digitaria natalensis Stent	D	Gram.		NBI	
Digitaria perrottetii (Kunth) Stapf	D	Gram.	PAS	NBI	
Digitaria remotigluma (De Winter) Clayton	FG	Gram.	PAS		
Digitaria sanguinalis (L.) Scop.	SS, FG	Gram.	PAS	NBI	
Digitaria seriata Stapf	D	Gram.	PAS	NBI	
Digitaria velutina (Forssk.) P.Beauv.	D	Gram.	PAS	NBI	
Digiteria scalarum (Schweinf.) Choiv.	SS, FG	Gram.	PAS		
Diplachne fusca (L.) P.Beauv. ex Roem. & Schult.	RWP	Gram.	PAS	NBI	
Diplachne gigantea Launert	PS, SS	Gram.	PAS		
Echinochloa colona (L.) Link	RWP	Gram.	PAS	NBI	
Echinochloa crus-galli (L.) P.Beauv.	PS, SS	Gram.		NBI	
Echinochloa crus-pavonis (Kunth) Schult.	PS, SS	Gram.	PAS		
Echinochloa haploclada (Stapf) Stapf	PS, SS	Gram.	PAS		
Echinochloa holubii (Stapf) Stapf	PS, SS	Gram.		NBI	
Echinochloa jubata Stapf	PS, SS	Gram.	PAS	NBI	
Echinochloa pyramidalis (Lam.) Hitchc. & Chase	PS	Gram.	PAS	NBI	
Echinochloa stagnina (Retz.) P.Beauv.	PS, SS	Gram.	PAS	NBI	
Eleusine coracana (L.) Gaertn. subsp. *africana* (Kenn.-O'Byrne) Hilu & de Wet	D	Gram.	PAS	NBI	
Elionurus muticus (Spreng.) Kuntze	FG	Gram.	PAS		
Elymandra grallata (Stapf) Clayton	FG, D	Gram.	PAS	NBI	
Elytrophorus globularis Hack.	RWP	Gram.	PAS	NBI	
Enneapogon cenchroides (Roem. & Schult.) C.E.Hubb.	D	Gram.	PAS	NBI	
Enneapogon desvauxii P.Beauv.	D	Gram.	PAS	NBI	
Enteropogon macrostachyus (A.Rich.) Benth.	D	Gram.	PAS	NBI	
Enteropogon rupestris (J.A.Schmidt) A.Chev.	D	Gram.	PAS	NBI	
Entolasia imbricata Stapf	SS	Gram.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Eragrostis annulata Rendle ex Scott-Elliot	D	Gram.		NBI	
Eragrostis aspera (Jacq.) Nees	D	Gram.	PAS	NBI	
Eragrostis barrelieri Daveau	D	Gram.	PAS	NBI	
Eragrostis cilianensis (All.) F.T.Hubb.	D	Gram.	PAS	NBI	
Eragrostis cylindriflora Hochst.	D	Gram.	PAS	NBI	
Eragrostis dinteri Stapf	D	Gram.	PAS		
Eragrostis echinochloidea Stapf	D	Gram.	PAS	NBI	
Eragrostis heteromera Stapf	D	Gram.	PAS	NBI	
Eragrostis inamoena K.Schum.	FG	Gram.	PAS	NBI	
Eragrostis japonica (Thunb.) Trin.	FG	Gram.	PAS		
Eragrostis lappula Nees	FG	Gram.	PAS	NBI	
Eragrostis lehmanniana Nees var. lehmanniana	D	Gram.		NBI	
Eragrostis membranacea Hack. ex Schinz	FG, D	Gram.		NBI	
Eragrostis minor Host	D	Gram.	PAS		
Eragrostis pallens Hack.	D	Gram.	PAS	NBI	
Eragrostis pilgeriana Dinter ex Pilg.	D	Gram.	PAS	NBI	
Eragrostis pilosa (L.) P.Beauv.	D	Gram.	PAS	NBI	
Eragrostis porosa Nees	D	Gram.	PAS	NBI	
Eragrostis procumbens Nees	D	Gram.	PAS		
Eragrostis pseudosclerantha Chiov.	D	Gram.	PAS	NBI	
Eragrostis rigidior Pilg.	FG, D	Gram.	PAS	NBI	
Eragrostis rotifer Rendle	RWP	Gram.	PAS	NBI	
Eragrostis sarmentosa (Thunb.) Trin.	FG	Gram.	PAS	NBI	
Eragrostis stapfii De Winter	D	Gram.	PAS		
Eragrostis superba Peyr.	D	Gram.	PAS	NBI	
Eragrostis trichophora Coss. & Durieu	IFG	Gram.	PAS	NBI	
Eragrostis viscosa (Retz.) Trin.	FG, RWP	Gram.	PAS	NBI	
Eragrostis x pseud - obtusa De Winter	D	Gram.	PAS		
Eriochrysis pallida Munro	PS, SS	Gram.	PAS	NBI	
Eulalia aurea (Bory) Kunth	FG	Gram.	PAS	NBI	
Hemarthria altissima (Poir.) Stapf & C.E.Hubb.	SS, FG	Gram.	PAS	NBI	
Heteropogon contortus (L.) Roem. & Schult.	D	Gram.	PAS	NBI	
Hyparrhenia dichroa (Steud.) Stapf	FG, D	Gram.		NBI	
Hyparrhenia nyassae (Rendle) Stapf	FG, D	Gram.	PAS	NBI	
Hyparrhenia rufa (Nees) Stapf var. rufa	SS, FG	Gram.	PAS	NBI	
Hyperthelia dissoluta (Nees ex Steud.) Clayton	FG, D	Gram.	PAS	NBI	
Imperata cylindrica (L.) Raeusch.	FG	Gram.	PAS	NBI	
Ischaemum afrum (J.F.Gmel.) Dandy	FG	Gram.		NBI	
Ischaemum fasciculatum Brongn.	FG	Gram.	PAS		
Leersia denudata Launert	PS, SS	Gram.	PAS		
Leersia friesii Melderis	PS, SS	Gram.	PAS	NBI	
Leersia hexandra Sw.	PS, SS	Gram.	PAS	NBI	
Leptocarydion vulpiastrum (De Not.) Stapf	D	Gram.	PAS	NBI	
Megaloprotachne albescens C.E.Hubb.	D	Gram.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Melinis repens (Willd.) Zizka subsp. *grandiflora* (Hochst.) Zizka	D	Gram.	PAS		
Melinis repens (Willd.) Zizka subsp. *repens*	D	Gram.	PAS		
Microchloa indica (L.f.) P.Beauv.	D	Gram.	PAS	NBI	
Microchloa kunthii Desv.	D	Gram.	PAS	NBI	
Miscanthus junceus (Stapf) Pilg.	PS, FG	Gram.	PAS	NBI	
Odyssea paucinervis (Nees) Stapf	IFG TA/S	Gram.	PAS	NBI	
Oplismenus burmannii (Retz.) P.Beauv.	DRW	Gram.	PAS	NBI	
Oplismenus hirtellus (L.) Beauv.	DRW	Gram.	PAS		
Oplismenus undulatifolius (Ard.) Roem. & Schult.	DRW	Gram.		NBI	
Oryza breviligulata A.Chev. & Roehr.	RWP	Gram.	PAS		
Oryza longistaminata A.Chev. & Roehr.	PS, SS	Gram.	PAS	NBI	
Oryzidium barnardii C.E.Hubb. & Schweick.	RWP	Gram.	PAS	NBI	
Panicum atrosanguineum A.Rich.	D	Gram.	PAS	NBI	
Panicum coloratum L. var. *coloratum*	FG	Gram.	PAS	NBI	
Panicum dregeanum Nees	FG	Gram.	PAS	NBI	
Panicum fluviicola Steud.	PS, SS	Gram.	PAS	NBI	
Panicum funaense Vanderyst		Gram.		NBI	
Panicum heterostachyum Hack.	D	Gram.	PAS	NBI	
Panicum hymeniochilum Nees	PS	Gram.	PAS	NBI	
Panicum impeditum Launert	RWP	Gram.	PAS		
Panicum kalaharense Mez	D	Gram.	PAS	NBI	
Panicum maximum Jacq.	D	Gram.	PAS	NBI	
Panicum parvifolium Lam.	PS, SS	Gram.	PAS	NBI	
Panicum pilgerianum (Schweick.) Clayton	RWP	Gram.	PAS		
Panicum porphyrrhizos Steud.	D	Gram.	PAS		
Panicum repens L.	Fg	Gram.	PAS	NBI	
Panicum repentellum Napper	RWP	Gram.	PAS	NBI	
Panicum schinzii Hack.	RWP	Gram.	PAS		
Panicum stapfianum Fourc.	D	Gram.	PAS		
Panicum subalbidum Kunth	SS	Gram.	PAS	NBI	
Panicum trichonode Launert & Renvoize	D	Gram.	PAS	NBI	
Paspalidium obtusifolium (Delile) N.D.Simpson	SS, FG	Gram.	PAS	NBI	
Paspalum scrobiculatum L.	SS, FG	Gram.	PAS	NBI	
Pennisetum glaucocladum Stapf & C.E.Hubb.	PS, FG	Gram.		NBI	
Pennisetum macrourum Trin.	PS, FG	Gram.	PAS		
Perotis leptopus Pilg.	D	Gram.		NBI	
Perotis patens Gand.	D	Gram.	PAS	NBI	
Phragmites australis (Cav.) Steud.	PS, IFG	Gram.	PAS	NBI	
Phragmites mauritianus Kunth	PS, IFG	Gram.	PAS	NBI	
Pogonarthria fleckii (Hack.) Hack.	D	Gram.	PAS	NBI	
Pogonarthria squarrosa (Roem. & Schult.) Pilg.	D	Gram.	PAS	NBI	
Sacciolepis africana C.E.Hubb. & Snowden	PS, SS	Gram.	PAS	NBI	
Sacciolepis interrupta (Willd.) Stapf	PS, SS	Gram.	PAS		
Sacciolepis typhura (Stapf) Stapf	PS, SS	Gram.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Schizachyrium jeffreysii (Hack.) Stapf	FG, D	Gram.	PAS	NBI	
Schizachyrium sanguineum (Retz.) Alston	FG, D	Gram.	PAS	NBI	
Schmidtia kalahariensis Stent	D	Gram.	PAS	NBI	
Schmidtia pappophoroides Steud.	D	Gram.	PAS	NBI	
Setaria homonyma (Steud.) Chiov.	D	Gram.	PAS	NBI	
Setaria orthosticha Herm.	D	Gram.	PAS		
Setaria pumila (Poir.) Roem. & Schult.	D	Gram.	PAS		
Setaria sagittifolia (A.Rich.) Walp.	D	Gram.	PAS	NBI	
Setaria sphacelata (Schumach.) Moss var. *sericea* (Stapf) Clayton	FG	Gram.	PAS	NBI	
Setaria sphacelata (Schumach.) Moss var. *sphacelata*	FG	Gram.	PAS	NBI	
Setaria ustilata de Wit	D	Gram.		NBI	
Setaria verticillata (L.) P.Beauv.	D	Gram.	PAS	NBI	
Sorghastrum friesii (Pilg.) Pilg.	FG	Gram.		NBI	
Sorghastrum nudipes Nash	FG	Gram.	PAS		
Sorghum arundinaceum (Desv.) Stapf.	FG, RWP	Gram.	PAS		
Sorghum bicolor (L.) Moench subsp. *arundinaceum* (Desv.) de Wet & Harlan	D	Gram.		NBI	
Sporobolus acinifolius Stapf	FG TA/S	Gram.	PAS	NBI	
Sporobolus africanus (Poir.) Robyns & Tournay	D	Gram.	PAS		
Sporobolus cordofanus (Steud.) Coss.	D	Gram.	PAS		
Sporobolus coromandelianus (Retz.) Kunth	D	Gram.		NBI	
Sporobolus festivus A.Rich.	D	Gram.	PAS	NBI	
Sporobolus fimbriatus (Trin.) Nees	D	Gram.	PAS	NBI	
Sporobolus ioclados (Trin.) Nees	FG	Gram.	PAS	NBI	
Sporobolus macranthelus Chiov.	D	Gram.	PAS	NBI	
Sporobolus natalensis (Steud.) Dur. & Schinz	FG	Gram.	PAS		
Sporobolus panicoides A.Rich.	D	Gram.	PAS		
Sporobolus pyramidalis P.Beauv.	D	Gram.	PAS	NBI	
Sporobolus salsus Mez	D	Gram.		NBI	
Sporobolus spicatus (Vahl) Kunth	FG TA/S	Gram.	PAS	NBI	
Sporobolus tenellus (Spreng.) Kunth	FG TA/S	Gram.	PAS		
Sporobolus unglumis Stent & Rattray	D	Gram.	PAS		
Stipagrostis hirtigluma (Trin. & Rupr.) de Winter	D	Gram.	PAS		
Stipagrostis uniplumis (Licht.) De Winter var. *uniplumis*	D	Gram.	PAS	NBI	
Themeda triandra Forssk.	FG	Gram.	PAS	NBI	
Trachypogon spicatus (L.f.) Kuntze	FG	Gram.	PAS	NBI	
Tragus berteronianus Schult.	D	Gram.	PAS	NBI	
Tragus racemosus (L.) All.	D	Gram.	PAS	NBI	
Tricholaena monachne (Trin.) Stapf & C.E.Hubb.	D	Gram.	PAS	NBI	
Trichoneura grandiglumis (Nees) Ekman	D	Gram.	PAS		
Tripogon minimus (A.Rich.) Steud.	D	Gram.	PAS		
Triraphis purpurea Hack.	D	Gram.	PAS		
Triraphis schinzii Hack.	D	Gram.	PAS	NBI	
Tristachya rehmannii Hack.	FG	Gram.	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Urochloa brachyura (Hack.) Stapf	D	Gram.	PAS	NBI	
Urochloa mosambicensis (Hack.) Dandy	D	Gram.	PAS	NBI	
Urochloa oligotricha (Fig. & De Not.) Henrard	D	Gram.	PAS	NBI	
Urochloa stolonifera (Gooss.) Chippind.	D	Gram.		NBI	
Urochloa trichopus (Hochst.) Stapf	D	Gram.	PAS	NBI	
Vetiveria nigritana (Benth.) Stapf	FG, RWP	Gram.	PAS	NBI	
Vossia cuspidata (Roxb.) Griff.	PS, FG	Aq. fl. stm.	PAS	NBI	
Willkommia sarmentosa Hack.	D	Gram.	PAS	NBI	
PONTEDERIACEAE					
Eichhornia natans (P.Beauv.) Solms	PS, SS	Aq. subm.	PAS	NBI	
Heteranthera callifolia Rchb. ex Kunth	RWP	Aq. emerg.	PAS	NBI	
POTAMOGETONACEAE					
Potamogeton octandrus Poir.	PS, SS	Aq. subm.	PAS	NBI	
Potamogeton pusillus L.	PS, SS	Aq. subm.		NBI	
Potamogeton schweinfurthii A.W.Benn.	PS, SS	Aq. subm.	PAS	NBI	
Potamogeton thunbergii Cham. & Schltdl.	PS, SS	Aq. fl. lv.	PAS	NBI	
Potamogeton trichoides Cham. & Schltdl.	PS, SS	Aq. subm.	PAS	NBI	
TYPHACEAE					
Typha capensis (Rohrb.) N.E.Br.	PS, SS	Aq. emerg.	PAS	NBI	
VELLOZIACEAE					
Xerophyta humilis (Baker) T.Durand & Schinz	D	H	PAS	NBI	
XYRIDACEAE					
Xyris anceps Lam.	PS, SS	Aq. emerg.		NBI	
Xyris capensis Thunb.	PS, SS	Aq. emerg.	PAS	NBI	
ZANNICHELLIACEAE					
Zannichellia palustris L.				NBI	
Dicotyledons					
ACANTHACEAE					
Asystasia gangetica (L.) T.Anderson	D	H	PAS	NBI	
Asystasia schimperi T. Anders	D	H	PAS		
Barleria lancifolia T.Anderson	D	Shrblt		NBI	
Barleria lugardii C.B.Cl	D	Shrblt	PAS		
Barleria mackenii Hook.f.	D	Shrblt	PAS	NBI	
Barleria senensis Klotzsch	D	Shrblt	PAS	NBI	
Blepharis caloneura S. Moore	D	H	PAS		
Blepharis diversispina (Nees) C.B.Clarke	D	H	PAS	NBI	
Blepharis integrifolia (L.f.) E.Mey. ex Schinz var. integrifolia	D	H	PAS	NBI	
Blepharis leendertziae Oberm.	D	H	PAS	NBI	
Blepharis maderaspatensis (L.) B.Heyne ex Roth subsp. *maderaspat*ensis var. *maderaspatensis*	D	H		NBI	
Blepharis maderaspatensis (L.) B.Heyne ex Roth subsp. *rubiifolia* (Schumach.) Napper	D	H	PAS	NBI	
Blepharis pruinosa Engl.	D	H	PAS		
Dicliptera hirta K.Balkwill	D	H		NBI	N

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Dicliptera spinulosa Hochst. ex K.Balkwill	D	H		NBI	N
Dicliptera verticillata (Forssk.) C.B.Cl.	D	H	PAS		N
Duosperma crenatum (Lindau) P.G.Mey	D	H	PAS		
Dyschoriste radicans (Hochst ex. Rich) Nees	D	H	PAS		
Hygrophila pilosa Burkill	PS, SS	Aq. emerg.		NBI	
Hygrophila pobeguinii Benoist	PS, SS	Aq. emerg.	PAS	NBI	
Hygrophila prunelloides (S.Moore) Heine	PS, SS	Aq. emerg. & submer.	PAS	NBI	
Hypoestes forskaolii (Vahl) R.Br.	D	H	PAS	NBI	
Justicia anselliana (Nees) T.Anderson	D	H		NBI	
Justicia betonica L.	D	H	PAS	NBI	
Justicia dinteri S.Moore	D	H		NBI	
Justicia glabra Koen. ex Roxb.	D	H	PAS	NBI	
Justicia heterocarpa T.Anderson subsp. *dinteri* (S.Moore) Hedr.	D	H	PAS	NBI	N
Justicia kirkiana T.Anderson	D	H	PAS	NBI	
Justicia odora (Forssk.) Vahl	D	H	PAS	NBI	
Lepidagathis scabra C.B.Cl.	D	H	PAS		
Megalochlamys marlothii (Engl.) Lindau				NBI	
Monechma debile (Forssk.) Nees	D	H	PAS	NBI	
Monechma divaricatum (Nees) C.B.Clarke	D	H	PAS	NBI	
Nelsonia canescens (Lam.) Spreng.	FG, D TA/S	H	PAS	NBI	
Peristrophe bicalyculata (Retz.) Nees	D	H		NBI	
Peristrophe paniculata (Forssk.) Brummitt	D	H	PAS	NBI	N
Petalidium engleranum (Schinz) C.B.Clarke				NBI	
Ruellia otaviensis P.G. Mey.	D	Shrblt.	PAS		
Ruellia otaviensis P.G.Mey.	D	Shrblt.		NBI	
Ruellia patula Jacq.	D	Shrblt.	PAS	NBI	
Ruspolia decurrens (Hochst. ex Nees) Milne-Redh.	D	Shrblt.		NBI	
Ruspolia seticalyx (C.B.Clarke) Milne-Redh.	D	Shrblt.	PAS	NBI	
Thunbergia aurea N.E.Br.	D	H		NBI	
Thunbergia reticulata A.Rich.	D	HC	PAS		N
AIZOACEAE					
Sesuvium hydaspicum (Edgew.) M.L. Goncalves	D	H	PAS		
Sesuvium nyasicum (Bak.) M.L. Goncalves	D	H	PAS		N
Trianthema salsoloides Fenzl ex Oliv. var. *salsaloides*	D	H	PAS	NBI	
Zaleya pentandra (L.) Jeffrey				NBI	
AMARANTHACEAE					
Achyranthes aspera L. var. aspera	D	H		NBI	
Achyranthes aspera L. var. pubescens (Moq.) Townsend	D	H	PAS		
Achyranthes aspera L. var. sicula L.	D	H	PAS		
Aerva javanica (Burm.f.) Juss. ex J.A. Schultes	D	H	PAS	NBI	
Aerva lanata (L.) Juss. ex J.A.Schult.	D	H		NBI	
Aerva leucura Moq.	D	H	PAS	NBI	
Alternanthera pungens Humb. Bonpl. & Kunth	D	H	PAS	NBI	
Alternanthera sessilis (L.) DC.	PS, SS	Aq. emerg.	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Amaranthus hybridus L. subsp. cruentus (L.) Thell.	D	H	PAS	NBI	
Amaranthus hybridus L. subsp. hybridus var. *hybridus*	D	H		NBI	
Amaranthus praetermissus Brenan	D	H	PAS	NBI	
Amaranthus spinosus L.	D	H	PAS		
Amaranthus thunbergii Moq.	D	H	PAS	NBI	
Celosia trigyna L.	FG, D	H	PAS	NBI	
Centrostachys aquatica (R.Br.) Wall. Ex Moq.	SS	Aq. emerg.	PAS		
Cyathula orthacantha (Hochst. ex Asch.) Schinz	D	H	PAS	NBI	
Gomphrena celosioides Mart.	D	H	PAS		
Guilleminea densa (Willd.) Moq.	D	H	PAS	NBI	
Hermbstaedtia fleckii (Schinz) Baker & C.B.Clarke	D	H		NBI	
Hermbstaedtia odorata (Burch.) T.Cooke var. *odorata*	D	H	PAS	NBI	
Hermbstaedtia scabra Schinz	D	H	PAS	NBI	
Kyphocarpa angustifolia (Moq.) Lopr.	D	H	PAS	NBI	
Nelsia quadrangula (Engl.) Schinz	D	H	PAS		
Pupalia lappacea (L.) A.Juss. var. *lappacea*	D	H		NBI	
Pupalia lappacea (L.) A.Juss. var. *velutina* (Moq.) Hook.f.	D	H	PAS		
Pupalia micrantha Hauman	D	H	PAS		
Sericorema remotiflora (Hook.f.) Lopr.	D	H	PAS		
ANACARDIACEAE					
Lannea schweinfurthii (Engl.) Engl. var. *stuhlmannii* (Engl.) Kokwaro	DRW	T		NBI	
Lannea schweinfurthii (Engl.) Engl. var. *tomentosa* (Dunkley) Kokwaro	DRW	T	PAS		
Rhus pyroides Burch. var. *pyroides*	D	Shr.	PAS	NBI	
Rhus quartiniana A.Rich.	DRW	Shr./T	PAS	NBI	
Rhus tenuinervis Engl.	D	Shr./T	PAS	NBI	
Sclerocarya birrea (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro	DRW	T	PAS	NBI	
ANNONACEAE					
Annona stenophylla Engl. & Diels. Subsp. *nana* (Exell) N.K.B. Robson	D	Shrblt.	PAS		
Friesodielsia obovata (Benth.) Verdc.	DRW	Shr.	PAS		
Hexalobus monopetalus (A.Rich.) Engl. & Diels var. *monopetalus*				NBI	
APIACEAE					
Centella asiatica (L.) Urb.	PS, SS	Aq. emerg.	PAS	NBI	
Ciclospermum leptophyllum (Pers.) Eichler	FG, D	H	PAS	NBI	
Conium chaerophylloides (Thunb.) Sond.	FG, D	H		NBI	
Hydrocotyle ranunculoides L.f.	PS, SS	Aq. emerg.	PAS		
Hydrocotyle verticillata Thunb.	PS, SS	Aq. emerg.	PAS	NBI	
APOCYNACEAE					
Baissea wulfhorstii Schinz	D	HC	PAS		
Carissa bispinosa (L.) Desf. ex Brenan subsp. bispinosa	DRW	Shr.		NBI	
Carissa edulis Vahl	DRW	Shr.	PAS	NBI	
Diplorhynchus condylocarpon (Muell. Arg.) Pichon	D	Shr./T	PAS		
ASCLEPIADACEAE					
Asclepias decipiens N.E.Br.	FG, D	H		NBI	
Asclepias fruticosa L.	D	H	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Asclepias rostrata N.E.	FG, D	H	PAS	NBI	
Asclepias tomentosa Burch.	D	H	PAS	NBI	N
Caralluma schweinfurthii A.Berger	D	H	PAS		N
Ceropegia lugardae N.E.Br	D	HC	PAS		
Ceropegia nilotica Kotschy	D	HC	PAS		
Cynanchum schistoglossum Schltr.	D	HC	PAS	NBI	
Dregea macrantha Klotzsch	D	HC	PAS	NBI	
Duvalia polita N.E.Br.	D	H	PAS		
Fockea multiflora K.Schum.				NBI	
Gymnema sylvestre (Retz.) Schult.	D	HC	PAS	NBI	
Orbeopsis caudata (N.E.Br.) Leach subsp. *rhodesica* (Leach) Leach	D	H	PAS		
Orthanthera jasminiflora (Decne.) Schinz	D	GC	PAS	NBI	
Pachycymbium lugardii (N.E. Br.) M. Gilbert	D	H	PAS		
Pachycymbium rogserii (L. Bol.) M. Gilbert	D	H	PAS		
Pentarrhinum insipidum E.Mey.	D	HC	PAS		
Pergularia daemia (Forssk.) Chiov. var. *daemia*	D	HC	PAS	NBI	
Periglossum mossambicense Schltr.	D	H Geop.	PAS	NBI	
Sarcostemma viminale (L.) R.Br. subsp. *viminale*	D	HC	PAS	NBI	
Stapelia kwebensis N.E.Br.	D	H	PAS		
ASTERACEAE					
Acanthospermum hispidum DC.	D	H	PAS	NBI	
Achyrocline stenoptera (DC.) Hilliard & B.L.Burtt	SS, FG	H	PAS	NBI	
Adenostemma caffrum DC.	PS, SS	Aq. emerg.	PAS	NBI	
Ambrosia artemisiifolia L.	FG, D	H	PAS	NBI	
Bidens pilosa L.	D	H	PAS	NBI	
Bidens schimperi Sch.Bip. ex Walp.	D	H	PAS	NBI	
Blainvillea gayana Cass.	D	H	PAS	NBI	
Blumea alata (D.Don) DC.	D	H	PAS		
Blumea aurita (L.f.) DC.	D	H	PAS		
Blumea gariepina DC.	D	H	PAS		
Blumea solidaginoides (Poir.) DC	FG, D	H	PAS		N
Calostephane divaricata Benth.	D	H	PAS		
Conyza aegyptiaca (L.) Aiton	D	H	PAS	NBI	
Conyza albida Spreng.	D	H		NBI	
Conyza bonariensis (L.) Cronq.	D	H	PAS		
Crassocephalum x picridifolium (DC.) S.Moore	PS, SS	Aq. emerg.	PAS	NBI	
Denekia capensis Thunb.	FG, D	H	PAS	NBI	
Dicoma schinzii O.Hoffm.	D	H	PAS	NBI	
Dicoma tomentosa Cass.	D	H	PAS	NBI	
Eclipta prostrata (L.) L.	PS, SS	Aq. emerg.		NBI	
Emilia ambifaria (S.Moore) C.Jeffrey	D	H	PAS	NBI	
Emilia tenellula (S.Moore) C.Jeffrey	PS, SS	Aq. emerg.	PAS		
Epaltes gariepina (DC.) Steetz	FG, D	H	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Erlangea misera (Oliv. & Hiern) S.Moore	D	H	PAS	NBI	
Ethulia conyzoides L.f. subsp. conyzoides	PS, SS	Aq. emerg.	PAS	NBI	
Felicia anthemidodes (Hiern) Mendon_a	D	H		NBI	
Felicia clavipilosa Grau subsp. clavipilosa	D	H	PAS		
Flaveria bidentis (L.) Kuntze	D	H	PAS	NBI	
Galinsoga parviflora Cav.	D	H	PAS	NBI	
Geigeria englerana Muschl.	D	H	PAS		
Geigeria ornativa O.Hoffm.	D	H	PAS		
Geigeria schinzii O.Hoffm. subsp. *rhodesiana* (S.Moore) Merxm.	FG, D	H	PAS	NBI	
Gnaphalium polycaulon Pers.	FG, D	H	PAS	NBI	
Grangea anthemoides O.Hoffm.	FG, D	H	PAS		
Helichrysum argyrosphaerum DC.	D	H	PAS	NBI	
Helichrysum candolleanum Buek	D	H	PAS		
Helichrysum lineare DC.	D	H	PAS	NBI	
Helichrysum spiciforme DC.	FG, D	H	PAS		
Hirpicium bechuanense (S.Moore) Roessler				NBI	
Hirpicium gorterioides (Oliv. & Hiern) Roessler subsp. *gorterioides*	D	H	PAS	NBI	
Kleinia longiflora DC.	D	H	PAS		
Launaea rarifolia (Oliv. & Hiern) Boulos var. *rarifolia*	FG, D	H	PAS	NBI	
Melanthera scandens (Schumach. & Thonn.) Roberty subsp. *madagascariensis* (Baker) Wild	PS, SS	Aq. emerg.	PAS	NBI	
Melanthera triternata (Klatt) Wild				NBI	
Mikania natalensis DC.	PS, SS	Aq. cr.	PAS		
Mikania sagittifera B.L.Rob.	PS, SS	Aq. cr.		NBI	
Nicolasia costata (Klatt) Thell.	FG, D	H	PAS	NBI	
Nicolasia pedunculata S.Moore	RWP	H	PAS		
Nicolasia stenoptera (O.Hoffman.) Merxm. subsp. *makarikariensis* (Brem. & Oberm.) Merxm.	RWP, FG	H	PAS		
Nidorella resedifolia DC. subsp. resedifolia	FG, D	H	PAS	NBI	
Pechuel-Loeschea leubnitziae (Kuntze) O.Hoffm.	D	Woody H	PAS	NBI	
Pegolettia senegalensis Cass.	D	H	PAS	NBI	
Philyrophyllum schinzii O.Hoffm.	D	H	PAS	NBI	
Pseudognaphalium luteo - album (L.) Hiliard & Burtt.	FG	H	PAS		
Pseudognaphalium oligandrum (DC.) Hilliard & B.L.Burtt	FG	H	PAS	NBI	
Senecio abruptus Thunb.				NBI	
Senecio apiifolius (DC.) Benth. & Hook.f. ex O.Hoffm.	FG, D	H	PAS	NBI	
Senecio cryphiactis O.Hoffm.	D	H	PAS	NBI	
Senecio leptocephalus Mattf.				NBI	
Senecio strictifolius Hiern	PS, SS	Aq. emerg.	PAS	NBI	
Sonchus asper (L.) Hill subsp. asper	FG, D	H	PAS	NBI	
Sonchus oleraceus L.	FG, D	H	PAS	NBI	
Sphaeranthus flexuosus O.Hoffm. ex De Wild.	FG, RWP	H Wetl.	PAS	NBI	
Sphaeranthus humilis O.Hoffm.	FG, RWP	H Wetl.		NBI	
Sphaeranthus peduncularis DC.	FG, RWP	H Wetl.	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Tagetes minuta L.	D	H	PAS		
Tithonia rotundifolia (Mill.) S.F.Blake	D	H	PAS	NBI	
Verbesina encelioides (Cav.) Benth. & Hook. var. *encelioides*	D	H	PAS	NBI	
Vernonia amygdalina Delile	PS, SS	Aq. shr.	PAS	NBI	
Vernonia anthelmintica (L.) Willd.	D	H		NBI	
Vernonia aurantiaca (O.Hoffm.) N.E.Br.	D	HC	PAS	NBI	
Vernonia fastigiata Oliv & Hiern	D	H	PAS		
Vernonia glabra (Steetz) Vatke var. *glabra*	FG, D	H	PAS	NBI	
Vernonia poskeana Vatke & Hildebr. subsp. *botswanica* Pope	D	H	PAS		
Xanthium strumarium L.	D	H	PAS	NBI	
BALANITACEAE					
Balanites aegyptiaca (L.) Delile var. aegyptiaca	D	T	PAS	NBI	
Balanites maughamii Sprague	D	T		NBI	
BIGNONIACEAE					
Catophractes alexandri D.Don	D	Shr.	PAS	NBI	
Kigelia africana (Lam.) Benth.	D	T	PAS	NBI	
Markhamia zanzibarica (Bojer ex DC.) K.Schum.	D	Shr./T	PAS	NBI	
Rhigozum brevispinosum Kuntze	D	Shr.	PAS	NBI	
BOMBACACEAE					
Adansonia digitata L.	D	T	PAS	NBI	
BORAGINACEAE					
Cordia monoica Roxb.	D	Shr.	PAS		
Cordia sinensis Lam.	D	Shr.		NBI	
Ehretia amoena Klotzsch	D	Shr.	PAS	NBI	
Ehretia obtusifolia Hochst. ex DC.	D	Shr.	PAS	NBI	
Ehretia rigida (Thunb.) Druce	D	Shr.	PAS	NBI	
Heliotropium giessii Friedr.-Holzh.	D	H		NBI	
Heliotropium ovalifolium Forssk.	FG, D	H	PAS	NBI	
Heliotropium steudneri Vatke	FG, D	H	PAS		
Heliotropium strigosum Willd.	D	H	PAS	NBI	
Heliotropium zeylanicum (Burm.f.) Lam.	D	H		NBI	
BRASSICACEAE					
Coronopus integrifolius (DC.) Spreng.	FG, RWP	H	PAS	NBI	
BURSERACEAE					
Commiphora africana (A.Rich.) Engl.	D	T	PAS	NBI	
Commiphora angolensis Engl.	D	Shr.	PAS	NBI	
Commiphora glandulosa Schinz	D	T	PAS	NBI	
Commiphora pyracanthoides Engl.	D	Shr.	PAS	NBI	
CABOMBACEAE					
Brasenia schreberi J.F.Gmel.	PS, SS	Aq. fl. lv	PAS	NBI	
CAMPANULACEAE					
Gunillaea rhodesica (Adamson) Thulin	SS, FG	H	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Wahlenbergia banksiana A.DC.	FG	H	PAS	NBI	
Wahlenbergia napiformis (A.DC.) Thulin	FG	H	PAS	NBI	
Wahlenbergia ramoissima (Hemsl.) Thulin subsp. *lateralis* (V.Brehm.) Thulin	FG	H	PAS		
CAPPARACEAE					
Boscia albitrunca (Burch.) Gilg & Gilg-Ben. var. *albitrunc*a	D	T	PAS	NBI	
Boscia foetida Schinz subsp. *matabelensis* Pest.	D	Shr.	PAS	NBI	
Boscia foetida Schinz subsp. rehmanniana (Pestal.) Toelken	D	T		NBI	1
Boscia mossambicensis Klotzsch	D	Shr.	PAS	NBI	
Cadaba termitaria N.E.Br.	D	Shr.	PAS	NBI	
Capparis tomentosa Lam.	D	WC	PAS	NBI	
Cleome angustifolia Forssk. subsp. *petersiana* (Klotzsch ex Sond.) Kers	D	H	PAS	NBI	
Cleome gynandra L.	D	H	PAS	NBI	
Cleome hirta (Klotzsch) Oliv.	D	H	PAS	NBI	
Cleome iberidella Welw. Ex Oliv.	PS, SS	H	PAS		
Cleome monophylla L.	D	H	PAS		
Cleome rubella Burch.	D	H	PAS	NBI	
Maerua angolensis DC.	D	Shr./T	PAS	NBI	
Maerua juncea Pax subsp. crustata	D	Shr./T	PAS		
Maerua juncea Pax subsp. juncea	D	Shr.		NBI	
CARYOPHYLLACEAE					
Polycarpaea corymbosa (L.) Lam.	D	H	PAS	NBI	
Polycarpon prostratum (Forssk.) Aschers & Schweinf.	FG	H	PAS		
CELASTRACEAE					
Cassine aethiopica Thunb.	DRW	T	PAS		
Cassine matabelicum (Loes.) Steedman	DRW	T	PAS	NBI	
Cassine transvaalensis (Burtt Davy) Codd	DRW	T	PAS	NBI	
Hippocratea africana (Willd.) Loes. var. *richardiana* (Cambess.) N.Robson	DRW	WC	PAS	NBI	
Maytenus heterophylla (Eckl. & Zeyh.) N.Robson	D	Shr./T		NBI	
Maytenus senegalensis (Lam.) Exell	D	Shr./T	PAS	NBI	
Salacia luebbertii Loes.	D	Shrblt.	PAS		
CERATOPHYLLACEAE					
Ceratophyllum demersum L. var. *demersum forma demersum*	PS, SS	Aq. subm.	PAS	NBI	
CHENOPODIACEAE					
Chenopodium album L.	D	H		NBI	
Chenopodium ambrosioides L.	FG, D	H	PAS	NBI	
Chenopodium hederiforme (Murr) Aellen var. dentatum Aellen		H		NBI	
Chenopodium olukondae (Murr) Murr	FG, D	H		NBI	
Chenopodium opulifolium Schrad ex. Koch. Ziz.	D	H	PAS		
Suaeda plumosa Aellen				NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
CLUSIACEAE					
Garcinia livingstonei T.Anderson	DRW	T	PAS	NBI	
COMBRETACEAE					
Combretum adenogonium Steud. ex A.Rich.	D	T		NBI	
Combretum albopunctatum Suess.	D	Shr./WC	PAS	NBI	
Combretum apiculatum Sond. subsp. *apiculatum*	D	T	PAS	NBI	
Combretum collinum Fresen. subsp. *gazense* (Swynn. & Baker f.) Okafor	D	Shr./T	PAS	NBI	
Combretum engleri Schinz	D	Shr.	PAS		
Combretum hereroense Schinz	D	T	PAS	NBI	
Combretum imberbe Wawra	D	T	PAS	NBI	
Combretum molle R.Br. ex G.Don	D	T		NBI	
Combretum mossambicense (Klotzsch) Engl.	D	Shr./WC	PAS	NBI	
Combretum psidioides Welw. subsp. *psidioides*	D	T	PAS		
Combretum schumannii Engl.	D	T		NBI	
Combretum zeyheri Sond.	D	T	PAS	NBI	
Terminalia prunioides M.A.Lawson	D	T	PAS	NBI	
Terminalia sericea Burch. ex DC.	D	Shr./T	PAS	NBI	
CONVOLVULACEAE					
Astripomoea lachnosperma (Choisy) A.Meeuse	D	H	PAS	NBI	
Evolvulus alsinoides (L.) L. var. *linifolius* (L.) Baker	D	H	PAS	NBI	
Ipomoea adenioides Schinz	D	HC		NBI	
Ipomoea aquatica Forssk.	PS, SS	Aq. fl. stm	PAS	NBI	
Ipomoea arachnosperma Welw.	D	HC	PAS	NBI	
Ipomoea bolusiana Schinz	D	HC		NBI	
Ipomoea chloroneura Hallier f.	D	HC	PAS		
Ipomoea coptica (L.) Roth ex Roem. & Schult. var. *coptica*	D	HC	PAS	NBI	
Ipomoea dichroa Hoscht. ex. Choisy	D	HC	PAS		N
Ipomoea eriocarpe R. Br.	D	HC	PAS		
Ipomoea hackeliana (Schinz) Hallier f.	D	HC		NBI	
Ipomoea hochstetteri House	D	HC	PAS		
Ipomoea magnusiana Schinz	D	HC	PAS	NBI	
Ipomoea obscura (L.) Ker Gawl. var. *fragilis* (Choisy) A.Meeuse	D	HC		NBI	
Ipomoea obscura (L.) Ker Gawl. var. *obscura*	D	HC	PAS		
Ipomoea ochracea (Lindl.) G.Don	D	HC	PAS		N
Ipomoea pes-tigridis L. var. pes-tigridis	D	HC	PAS	NBI	
Ipomoea plebeia R.Br. subsp. africana A.Meeuse	D	HC	PAS	NBI	
Ipomoea rubens Choisy	PS, SS	Aq. cr.	PAS	NBI	
Ipomoea shirambensis Baker				NBI	
Ipomoea sinensis (Desr.) Choisy subsp. *blepharosepala* (Hochst. ex A.Rich.) Verdc. ex A.Meeuse	D	HC	PAS	NBI	
Ipomoea tuberculata Ker - Gawl	D	HC	PAS		
Jacquemontia tamnifolia (L.) Griseb.	D	HC	PAS		
Merremia pinnata (Hochst. ex Choisy) Hallier f.	D	HC	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Merremia tirdentata (L.) Hallier f. subsp. *angustifolia* (Jacq.) Van Ooststr. var. *angustifolia*	D	GC	PAS	NBI	
Merremia verecunda Rendle	D	HC	PAS		
Seddera suffruticosa (Schinz) Hallier f.	D	Woody GC	PAS	NBI	
CUSCUTACEAE					
Cuscuta australis R.Br.		HC	PAS	NBI	
Cuscuta campestris Yunck.		HC	PAS	NBI	
CRASSULACEAE					
Kalanchoe brachyloba Wele. ex. Britten	D	H	PAS		
Kalanchoe lanceolata (Forssk.) Pers.	D	H	PAS	NBI	
Kalanchoe paniculata Harv.	D	H		NBI	
CUCURBITACEAE					
Acanthosicyos naudinianus (Sond.) C.Jeffrey	D	GC	PAS	NBI	
Corallocarpus bainesii (Hook.f.) A.Meeuse	D	HC		NBI	
Ctenolepis cerasiformis (Stocks) Hook.f.	D	Shr.	PAS	NBI	
Cucumis africanus L.f.	D	GC	PAS		
Cucumis anguria L.	D	HC	PAS	NBI	
Cucumis metuliferus E.Mey. ex Naudin	D	HC	PAS	NBI	
Cucumis zeyheri sond.	D	GC	PAS		
Kedrostis foetidissima (Jacq.) Cogn.	D	HC	PAS	NBI	
Kedrostis hirtella (Naudin) Cogn.	D	HC	PAS	NBI	
Lagenaria siceraria (Molina) Standl.	D	HC	PAS	NBI	
Lagenaria sphaerica (Sond.) Naudin	D	HC	PAS	NBI	
Momordica balsamina L.	D	HC	PAS	NBI	
Momordica kirkii (Hook.f.) C.Jeffrey	D	HC	PAS		
Mukia maderaspatana (L.) M.J.Roem.	PS, SS	Aq. cr.	PAS		
Oreosyce africana Hook.f.				NBI	
Trochomeria debilis (Sond.) Hook.f.	D	HC	PAS	NBI	
Zehneria marlothii (Cogn.) R.& A.Fern.	D	HC	PAS	NBI	
DICHAPETALACEAE					
Dichapetalum cymosum (Hook.) Engl.	D	Shrblt.	PAS	NBI	
DROSERACEAE					
Aldrovanda vesiculosa L.	PS, SS	Aq. ff. subm.	PAS	NBI	
Drosera madagascariensis DC.	PS, SS	Aq. emerg.	PAS	NBI	
EBENACEAE					
Diospyros austro-africana De Winter var. *rubriflora* (De Winter) De Winter	D	Shrblt.		NBI	
Diospyros chamaethamnus Mildbr.	D	Shrblt.	PAS		
Diospyros lycioides Desf. subsp. *lycioides*	DRW	Shr.	PAS	NBI	
Diospyros lycioides Desf. subsp. *sericea* (Bernh.) De Winter	DRW	Shr.	PAS	NBI	
Diospyros mespiliformis Hochst. ex A.DC.	DRW	T	PAS	NBI	
Euclea crispa (Thunb.) Gnrke subsp. *crispa*	D	Shr./T		NBI	
Euclea divinorum Hiern	D	Shr./T	PAS	NBI	
Euclea undulata Thunb. var. *myrtina* (Burch.) Hiern	D	Shr./T		NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
ELATINACEAE					
Bergia ammannioides B.Heyne ex Roth	PS, SS	Aq. emerg.	PAS	NBI	
Bergia capensis L.	RWP	Aq. emerg.	PAS	NBI	
Bergia pentheriana Keissl.	FG	GC	PAS	NBI	
Bergia polyantha Sond.	FG, RWP	H	PAS	NBI	
Bergia spathulata Schinz	FG	H	PAS		N
Elatine triandra Schkuhr	SS	Aq. subm.	PAS	NBI	
EUPHORBIACEAE					
Acalypha ciliata Forssk.	D	H	PAS	NBI	
Acalypha indica L.	D	H	PAS	NBI	
Acalypha ornata Hochst. ex A.Rich.	D	Shr.	PAS	NBI	
Acalypha villicaulis Hochst. ex A.Rich.	D	H		NBI	
Antidesma venosum E. Mey. Ex Tul.	DRW	T	PAS	NBI	
Caperonia serrata Presl.	PS, SS	Aq. emerg.	PAS		N
Cephalocroton mollis Klotzsch	D	Shr.	PAS		
Chamaesyce hirta (L.) Millsp.	D	H		NBI	
Chamaesyce inaequilatera (Sond.) Sojsk.	D	H		NBI	
Chamaesyce mossambicensis (Klotzsch & Garcke) Koutnik	D	H		NBI	
Chamaesyce prostrata (Aiton) Small	D	H		NBI	
Chamaesyce serpens (H.B.K) Small	D	H	PAS		
Croton gratissimus Burch. var. *gratissimus*	D	Shr./T	PAS	NBI	
Croton megalobotrys Mnll.Arg.	DRW	T	PAS	NBI	
Croton menyhartii Pax	D	Shr.	PAS	NBI	
Erythrococca menyharthii (Pax) Prain	D	Shr.	PAS		
Euphorbia crotonoides Boiss. subsp. *crotonoides*	D	H	PAS	NBI	
Euphorbia ingens E.Mey ex.Boiss	DRW	T	PAS		
Euphorbia monteirii Hook.f.subsp. *monteirii*	D	Shrblt.	PAS		
Euphorbia prostrata Ait.	D	H	PAS		N
Euphorbia tirucalli L.	D	Shr./T	PAS	NBI	N
Excoecaria bussei (Pax) Pax	DRW	T	PAS		
Jatropha seineri Pax var. seineri	D	Geop.	PAS	NBI	
Micrococca mercurialis (L.) Benth	D	H	PAS		
Phyllanthus angolensis Muell. Arg.	D	H	PAS		
Phyllanthus burchellii Mnll.Arg.	D	H		NBI	
Phyllanthus fraternus Webster subsp. *togoensis* Brunel & Roux	D	H		NBI	N
Phyllanthus pentandrus Schumach. & Thonn.	D	H	PAS	NBI	
Phyllanthus reticulatus Poir.	DRW	Shr.	PAS	NBI	
Pseudolachnostylis maprouneifolia Pax. var. dekindtii	D	T	PAS	NBI	
Pterococcus africanus (Sond.) Pax & K.Hoffm.				NBI	
Ricinus communis L.	D	Shr.		NBI	
Schinziophyton rautanenii (Schinz) Radcliffe-Sm.	D	T	PAS		
Securinega virosa (Roxb. ex Willd.)	D	Shr.	PAS	NBI	
Tragia okanyua Pax	D	HC		NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
FABACEAE					
FABACEAE: MIMOSOIDEAE					
Acacia arenaria Schinz	D	Shr.	PAS		
Acacia ataxacantha DC	D	Shr./T	PAS		
Acacia erioloba E.Mey.	D	T	PAS	NBI	
Acacia erubescens Welw. Ex Oliv.	D	T	PAS		
Acacia fleckii Schinz	D	Shr./T	PAS	NBI	
Acacia galpinii Burtt Davy	D	T	PAS	NBI	
Acacia hebeclada DC. subsp. *chobiensis* (O.B.Mill.) A.Schreib.	FG	Shr./T	PAS	NBI	
Acacia hebeclada DC. subsp. *hebeclada*	FG, RWP, D	Shr./T	PAS	NBI	
Acacia karroo Hayne	D	T	PAS	NBI	
Acacia luederitzii Engl. var. *luederitzii*	D	T	PAS	NBI	
Acacia luederitzii Engl. var. *retinens* (Sim) J.H.Ross & Brenan	D	T		NBI	
Acacia mellifera (Vahl) Benth. subsp. *detinens* (Burch.) Brenan	D	Shr.	PAS	NBI	
Acacia nigrescens Oliv.	D	T	PAS	NBI	
Acacia nilotica (L.) Willd. Ex Del. Subsp. *kraussiana* (Benth.) Brenan	D	T	PAS		
Acacia sieberiana DC. var. *woodii* (Burtt Davy) Keay & Brenan	FG	T	PAS	NBI	
Acacia tortilis (Forssk.) Hayne subsp. *heteracantha* (Burch.) Brenan	D	Shr./T	PAS	NBI	
Acacia tortilis (Forssk.) Hayne subsp. *spirocarpa* (Hochst. ex A.Rich.) Brenan var. spirocarpa	D	T	PAS	NBI	
Albizia anthelmintica (A. Rich.) Brongn.	D	T	PAS		
Albizia harveyi E.Fourn.	D	T	PAS	NBI	
Albizia versicolor Welw. ex Oliv.	D	T	PAS	NBI	
Dichrostachys cinerea (L.) Wight & Arn. subsp. *africana* Brenan & Brummitt var. *africana*	D	Shr.	PAS	NBI	
Elephantorrhiza goetzei (Harms) Harms subsp. *goetzei*	D	Geop.	PAS	NBI	
Faidherbia albida (Del.) A.Chev.	D	T	PAS		
Mimosa pigra L.	PS, SS	Aq. shr.	PAS	NBI	
Neptunia oleracea Lour.	SS, RWP	Aq. fl. stm.	PAS	NBI	
FABACEAE: CAESALPINOIDEAE					
Baikiaea plurijuga Harms	D	T	PAS		
Bauhinia petersiana Bolle subsp. *macrantha* (Oliv.) Brummitt & J.H.Ross	D	Shr./T	PAS	NBI	
Bauhinia urbaniana Schinz	D	Shr.	PAS		
Burkea africana Hook.		Shr./T	PAS		
Chamaecrista absus (L.) Irwin & Barneby	D	H		NBI	
Chamaecrista biensis (Steyaert) Lock	D	H		NBI	
Chamaecrista capensis (Thunb.) E.Mey. var. *capensis*	D	H		NBI	
Chamaecrista falcinella (Oliv.) Lock var. *parviflora* (Steyaert) Lock	D	H		NBI	
Chamaecrista mimosoides (L.) Greene	D	H		NBI	
Colophospermum mopane (J.Kirk ex Benth.) J.Kirk ex J.Leonard	D	Shr./T	PAS	NBI	
Dialium engleranum Henriq.	D	T	PAS		
Erythrophleum africanum (Welw.ex. Benth.) Harms	D	T	PAS		
Guibourtia coleosperma (Benth.) J. Leonard	D	T	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Peltophorum africanum Sond.	D	T	PAS		
Piliostigma thonningii (Schumach.) Milne-Redh.	D	T	PAS	NBI	
Senna occidentalis (L.) Link	D	Woody H		NBI	
FABACEAE: PAPILIONOIDEAE					
Abrus precatorius L. subsp. *africanus* Verdc.	D	HC	PAS	NBI	
Aeschynomene cristata Vatke var. *cristata*	PS, SS	Aq. emerg.	PAS	NBI	
Aeschynomene fluitans Peter	PS, SS	Aq. fl. stm.	PAS	NBI	
Aeschynomene indica L.	PS, SS, RWP	Aq. emerg.	PAS	NBI	
Aeschynomene nilotica Taub.	PS, SS	Aq. emerg.	PAS		
Baphia massaiensis Taub. subsp. *obovata* (Schinz) Brummitt var. *obovata*	D	Shr./T	PAS	NBI	
Bolusia rhodesiana Corbishley	D	H	PAS		N
Crotalaria barkae Schweinf. subsp. *barkae*	D	H	PAS	NBI	
Crotalaria damarensis Engl.	D	H	PAS		
Crotalaria laburnifolia L. subsp. *australis* (Baker f.) Polhill	D	Woody H		NBI	
Crotalaria laburnifolia L. subsp. *laburnifolia* (Baker f.) Polhill	D	Woody H	PAS		
Crotalaria ochroleuca G. Don.	D	H	PAS		
Crotalaria pisicarpa Welw.ex. Bak.	D	H	PAS		
Crotalaria platysepala Harv.	D	H	PAS	NBI	
Crotalaria podocarpa DC.	D	H	PAS		
Crotalaria spartioides DC.	D	H		NBI	
Crotalaria sphaerocarpa Perr. ex DC. subsp. *sphaerocarpa*	D	H	PAS	NBI	
Crotalaria steudneri Schweinf.	D	H	PAS	NBI	
Desmodium salicifolium (Poir.) DC. var. *salicifolium*	PS, SS	Aq. emerg.	PAS	NBI	
Indigofera astragalina DC.	D, FG	H	PAS	NBI	
Indigofera bainesii Baker	D	Shrblt.	PAS	NBI	
Indigofera charlieriana Schinz var. *charlieriana*	D	H	PAS	NBI	
Indigofera charlieriana Schinz var. *lata* J.B.Gillett	D	H	PAS	NBI	
Indigofera colutea (Burm.f.) Merr.	D	H		NBI	
Indigofera costata Guill. & Perr.subsp. *macra* (E.Mey.) Gillett	D	H		NBI	
Indigofera daleoides Benth. ex Harv. var. *daleoides*	D	H	PAS	NBI	
Indigofera filipes Benth. ex Harv.	D	H	PAS	NBI	
Indigofera flavicans Baker	D	H	PAS	NBI	
Indigofera gairdneriae Hutch. ex Bak.f.	D	H	PAS		
Indigofera hochstetteri Bak. subsp. *streyana* (Merxm.) A.Schreib	D	H	PAS		
Indigofera hofmanniana Schinz	D	H		NBI	
Indigofera parviflora Heyne ex Wight & Arn var. *parviflora*	D	H	PAS		
Indigofera parviflora Heyne ex Wight & Arn. var. *parviflorum*	D	H		NBI	
Indigofera praticola Baker f.	D	H	PAS	NBI	
Indigofera rhytidocarpa Benth. ex Harv. subsp. rhytidocarpa	D	H	PAS		
Indigofera tinctoria L. var. arcuata J.B.Gillett	D	H	PAS	NBI	
Indigofera trita L.f. subsp. *scabra* (Roth) de Kort & G.Thijsse	D	H		NBI	
Indigofera trita L.f. subsp. *subulata* (Vahl. ex Poir) Ali	D	H	PAS		
Lablab purpureus (L.) Sweet subsp. *purpureus*	D	HC		NBI	
Lablab purpureus (L.) Sweet subsp. *uncinatus* Verdc.	D	HC	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Lessertia benguellensis Baker f.	D	H	PAS	NBI	
Lonchocarpus capassa Rolfe	D	T	PAS	NBI	
Lonchocarpus nelsii (Schinz) Heering & Grimme subsp. *nelsii*	D	Shr./T	PAS	NBI	
Macrotyloma axillare (E.Mey.) Verdc. var. *axillare*	D	HC		NBI	
Macrotyloma daltonii (Webb) Verdc.	D	HC	PAS		
Macrotyloma uniflorum (Lam.) Verdc. var. *stenocarpum* (Brenan) Verdc.	D	HC	PAS	NBI	
Mundulea sericea (Willd.) A.Chev.	D	Shr.	PAS	NBI	
Neonotonia wightii (Arn.) J.A.Lackey	D	HC	PAS	NBI	
Neorautanernia amboensis Schinz	D	Shrblt.	PAS		
Otoptera burchellii DC.	D	HC	PAS	NBI	
Pterocarpus angolensis DC.	D	T	PAS		
Ptycholobium biflorum (E.Mey.) Brummitt subsp. *angolensis* (Baker) Brummitt	D	H		NBI	
Ptycholobium contortum (N.E.Br.) Brummitt	D	H	PAS	NBI	
Requienia sphaerosperma DC.	D	H	PAS	NBI	
Rhynchosia holosericea Schinz	D	HC		NBI	
Rhynchosia minima (L.) DC. var. *minima*	D	HC	PAS	NBI	
Rhynchosia minima (L.) DC. var. *prostrata* (Harv.) Meikle	D	HC		NBI	
Rhynchosia totta (Thunb.) DC. var. *totta*	D	HC	PAS	NBI	
Rhynchosia venulosa (Hiern.) K. Schum.	D	HC	PAS		
Sesbania bispinosa (Jacq.) W.Wight var. *bispinosa*	PS, SS, RWP	Aq. emerg.	PAS	NBI	
Sesbania brevipedunculata J.B.Gillet	PS, SS, RWP	Aq. emerg.	PAS		
Sesbania cinerascens Welw. ex Baker	PS, SS	Aq. emerg.	PAS	NBI	
Sesbania microphylla E.Phillips & Hutch.	PS, SS	Aq. emerg.	PAS	NBI	
Sesbania rostrata Bremek. & Oberm.	PS, SS	Aq. emerg.	PAS	NBI	
Sesbania sesban (L.) Merr. subsp. *sesban* var. *zambesiaca* J.B.Gillett	D	H		NBI	
Tephrosia lupinifolia DC.	D	H	PAS	NBI	
Tephrosia pumila (Lam.) Pers. var. *pumila*	D	H	PAS		
Tephrosia purpurea (L.) Pers. subsp. *leptostachya* (DC.) Brummitt var. *leptostachya*	D	H	PAS	NBI	
Tephrosia purpurea (L.) Pers. subsp. *leptostachya* (DC.) Brummitt var. *pubescens* (Bak.)	D	H	PAS		
Vigna luteola (Jacq.) Benth.	PS, SS	Aq. cr.	PAS	NBI	
Vigna oblongifolia A.Rich. var. *parviflora* (Baker) Verdc.	D	HC	PAS	NBI	
Vigna unguiculata (L.) Walp. subsp. *dekindtiana* (Harms) Verdc.	D	H	PAS	NBI	
Vigna unguiculata (L.) Walp. subsp. *unguiculata*	D	H		NBI	
Zornia glochidiata DC.	D	H	PAS	NBI	
FLACOURTIACEAE					
Flacourtia indica (Burm.f.) Merr.	D	Shr./T	PAS	NBI	
Oncoba spinosa Forssk. subsp. spinosa	DRW	Shr./T	PAS	NBI	
GENTIANACEAE					
Enicostemma hyssopifolium (Willd.) I.Verd.	FG, D	H	PAS	NBI	
Pycnosphaera buchananii (Bak.) N.E.Br.	PS, SS, FG	H	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Sebaea junodii Schinz	PS, SS, FG	H	PAS	NBI	
Sebaea microphylla (Edgew.) Knobl.	PS, SS	Aq. emerg.	PAS		
GERANIACEAE					
Monsonia angustifolia E.Mey. ex A.Rich.	D	H	PAS	NBI	
Monsonia glauca Knuth	D	H	PAS		
Monsonia senegalensis Guill. & Perr.	D	H		NBI	
HALORAGACEAE					
Laurembergia repens P.J.Bergius subsp. *brachypoda* (Hiern) Oberm.	PS, SS	Aq. emerg.		NBI	
Myriophyllum spicatum L.	PS, SS	Aq. subm.		NBI	
HYDNORACEAE					
Hydnora africana Thunb.	D	H Root parasite		NBI	
Hydnora johannis Beccari	D	H Root parasite	PAS		
ILLECEBRACEAE					
Corrigiola litoralis L. subsp. litoralis var. *litoralis*	FG, D	H	PAS	NBI	
Pollichia campestris Aiton	D	Shrblt.	PAS	NBI	
LAMIACEAE					
Acrotome angustifolia G. Tayl	D	H	PAS		
Acrotome inflata Benth.	D	H	PAS	NBI	
Becium filamentosum (Forssk.) Chiov.	D	Shrblt.		NBI	
Endostemon tereticaulis (Poir.) M.Ashby	D	H	PAS	NBI	
Hemizygia bracteosa (Benth.) Briq.	D	H	PAS	NBI	
Hemizygia petrensis (Hiern) M.Ashby	D	H		NBI	
Hoslundia opposita Vahl	D	H	PAS	NBI	
Hyptis pectinata (L.) Poit.	FG	H	PAS	NBI	
Hyptis spicigera Lam.	FG	H	PAS	NBI	
Leonotis nepetifolia (L.) R.Br.	D	H	PAS	NBI	
Leucas glabrata (Vahl) Sm. var. glabrata	D	H	PAS		
Leucas martinicensis (Jacq.) R.Br.	D	H	PAS	NBI	
Neohyptis paniculata (Baker) J.K.Morton	PS, SS	Aq. emerg.	PAS	NBI	
Ocimum canum Sims	D	H	PAS	NBI	
Plectranthus hereroensis Engl.	D	H	PAS		
Plectranthus tetensis (Bak.) Agnew	D	H	PAS		
Plectranthus tetragonus Gnrke	D	H	PAS	NBI	
Pycnostachys coerulea Hook.	PS, SS	Aq. emerg.	PAS	NBI	
LAURACEAE					
Cassytha filiformis L.		HC	PAS	NBI	
LENTIBULARIACEAE					
Utricularia arenaria A.DC.	FG	H Wetl.	PAS		
Utricularia benjaminiana Oliv.	PS, SS	Aq. ff.	PAS	NBI	
Utricularia cymbantha Oliver	PS, SS	Aq. ff.	PAS		
Utricularia foliosa L.	PS, SS	Aq. ff.	PAS	NBI	
Utricularia gibba L.	PS, SS	Aq. emerg.	PAS	NBI	
Utricularia inflexa Forssk.	PS, SS	Aq. ff.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Utricularia reflexa Oliv.	PS, SS	Aq. ff.	PAS	NBI	
Utricularia scandens Benj.	FG	H Wetl.	PAS	NBI	
Utricularia stellaris L.f.	PS, SS, RWP	Aq. ff.	PAS	NBI	
Utricularia subulata L.	FG	H Wetl.	PAS		
Utricularia tortilis Oliver	FG	H Wetl.	PAS		
LOBELIACEAE					
Lobelia angolensis Engl. & Diels	FG, RWP	H Wetl.	PAS	NBI	
Lobelia erinus L.	FG	H	PAS		
LOGANIACEAE					
Strychnos cocculoides Bak.	D	T	PAS		
Strychnos pungens Solered.	D	T	PAS		
LORANTHACEAE					
Erianthemum ngamicum (Sprague) Danser		Shr.	PAS		
Erianthemum virescens (N.E. Br.) Balle		Shr.	PAS		N
Plicosepalus kalachariensis (Schinz) Danser		Shr.	PAS	NBI	
Tapinanthus lugardii (N.E.Br.) Danser		Shr.	PAS	NBI	
Tapinanthus oleifolius (J.C.Wendl.) Danser		Shr.	PAS	NBI	
LYTHRACEAE					
Ammannia auriculata Willd.	RWP	H Wetl.	PAS		
Ammannia prieuriana Guill. & Perr.	RWP, FG	H Wetl.	PAS		
N*esaea crassicaulis* (Guill. & Perr.) Koehne	PS, SS	Aq. subm.	PAS	NBI	
Nesaea ondongana Koehne subsp. ondongana var. *evansiana* (Fernandes & Diniz) A.Fernandes	FG	H	PAS		
Nesaea ondongana Koehne subsp. *ondongana* var. *ondongana*	FG, RWP	H	PAS	NBI	
Nesaea radicans Guill. & Perr. var. *floribunda* (Sond.) A.Fern.	FG	H	PAS	NBI	
Nesaea radicans Guill. & Perr. var. *radicans*	FG	H	PAS		
Nesaea rigidula (Sond.) Koehne	FG, D	H	PAS		
Rotala dinteri Koehne	PS, SS, FG	H		NBI	
Rotala filiformis (Bellardi) Hiern	PS, SS, FG	H	PAS	NBI	
Rotala myriophylloides Welw. ex Hiern	PS, SS	Aq. subm.	PAS	NBI	
Rotala tenella (Guill. & Perr.) Hiern	RWP, FG	H	PAS		
MALPHIGIACEAE					
Sphedamnocarpus pruriens (Juss.) Szyszyl. subsp. *pruriens*	D	HC	PAS	NBI	
MALVACEAE					
Abutilon angulatum (Guill. & Perr.) Mast. var. *angulatum*	D	H	PAS	NBI	
Abutilon austro-africanum Hochr.	D	H	PAS	NBI	
Abutilon englerianum Ulbr.	D	H	PAS	NBI	
Abutilon fruticosum Guill. & Perr.	D	H	PAS	NBI	
Atbutilon hirum (Lam.) Sweet	D	H	PAS		
Abutilon ramosum (Cav.) Guill. & Perr.	D	H	PAS	NBI	
Abutilon rehmannii Bak.f.	D	H	PAS		
Gossypium herbaceum L. subsp. africanum (Watt) Vollesen	D	Shr.	PAS	NBI	
Hibiscus aethiopicus L. var. angustifolius (Eckl. & Zeyh.) Exell	FG, D	H		NBI	
Hibiscus caesius Garcke	D	H	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Hibiscus calyphyllus Cav.	D	Shrblt.	PAS	NBI	
Hibiscus cannabinus L.	FG, D	H	PAS	NBI	
Hibiscus diversifolius Jacq. subsp. *rivularis* (Bremek. & Oberm.) Exell	PS, SS	Aq. shr.	PAS	NBI	
Hibiscus dongolensis Delile	D	H	PAS	NBI	
Hibiscus lobatus (Murr.) Kuntze	D	H	PAS		
Hibiscus mastersianus Hiern	D	H	PAS		
Hibiscus mechowii Garcke				NBI	
Hibiscus micranthus L.f.	D	H	PAS	NBI	
Hibiscus praeteritus R.A.Dyer				NBI	
Hibiscus schinzii Gnrke	D	H	PAS	NBI	
Hibiscus sidiformis Baill.	D	H	PAS	NBI	
Hibiscus trionum L.	D	H	PAS		
Kosteletzkya buettneri Guerke	PS, SS	Aq. emerg.	PAS	NBI	
Pavonia burchellii (DC.) R.A.Dyer	D	H	PAS	NBI	
Pavonia senegalensis (Cav.) Leistner	D	GC	PAS	NBI	
Sida alba L.	FG, D	H	PAS	NBI	
Sida cordifolia L.	FG, D	H	PAS	NBI	
Sida ovata Forssk	FG, D	H	PAS		
Wissadula rostrata (Schumach.) Hook.f.	D	H	PAS	NBI	
MELASTOMATACEAE					
Dissotis debilis (Sond.) Triana var. *debilis*	FG	H	PAS	NBI	
MELIACEAE					
Ekebergia capensis Sparrm.	DRW	T	PAS	NBI	
MENISPERMACEAE					
Cissampelos mucronata A.Rich.	DRW	HC	PAS	NBI	
Cocculus hirsutus (L.) Diels	DRW	WC	PAS	NBI	
Tinospora caffra (Miers) Troupin	DRW	WC	PAS		
MENYANTHACEAE					
Nymphoides brevipedicellata (Vatke) Raynal	PS, SS	Aq. fl. lv	PAS		
Nymphoides indica (L.) Kuntze subsp. *occidentalis* A.Raynal	PS, SS	Aq. fl. lv	PAS	NBI	
Nymphoides rautanenii (N.E.Br.) A.Raynal	PS, SS	Aq. fl. lv		NBI	
Nymphoides thunbergiana (Griseb.) Kuntze	PS, SS	Aq. fl. lv	PAS	NBI	
MOLLUGINACEAE					
Gisekia africana (Lour.) Kuntze var. africana	FG, D	H	PAS	NBI	
Gisekia pharnaceoedes L. var. *pharnaceoides*	FG, D	H	PAS	NBI	
Glinus bainesii (Oliv.) Pax	FG, D	H		NBI	
Glinus lotoides L. var. *lotoides*	FG, D	H	PAS	NBI	
Glinus oppositifolius (L.) DC. var. *oppositifolius*	FG, RWP, D	H	PAS	NBI	
Hypertelis bowkeriana Sond.	RWP	H Wetl.	PAS	NBI	
Limeum aethiopicum Burm. subsp. *namaense* Friedrich var. namaense	D	H	PAS	NBI	
Limeum argute - carinatum Wawra & Peyr var. *kwebense* (N.E.Br.) Friedr.	D	H	PAS		
Limeum fenestratum (Fenzl) Heimerl var. *fenestratum*	D	H	PAS	NBI	
Limeum myosotis H.Walt. var. *myosotis*	D	H	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Limeum pterocarpum (J.Gay) Heimerl var. *pterocarpum*	D	H	PAS	NBI	
Limeum sulcatum (Klotzsch) Hutch. var. *sulcatum*	D	H	PAS		
Limeum viscosum (J.Gay) Fenzl subsp. *viscosum* var. *macrocarpum* Friedrich	D	H		NBI	
Limeum viscosum (J.Gay) Fenzl subsp. *viscosum* var. *viscosum*	D	H	PAS		
Mollugo cerviana (L.) Ser. ex DC. var. cerviana	D	H	PAS	NBI	N
Mollugo nudicaulis Lam.	D	H	PAS	NBI	
MORACEAE					
Ficus capreifolia Delile	DRW	Shr.	PAS	NBI	
Ficus pygmaea Welw. ex Hiern	PS, FG	Aq. shr.	PAS	NBI	
Ficus sycomorus L.	DRW	T	PAS	NBI	
Ficus thonningii Blume	DRW	T	PAS	NBI	
Ficus verruculosa Warb.	PS, SS	Aq. shr.	PAS	NBI	
MYRICACEAE					
Myrica serrata Lam.	PS, SS, FG	Aq. shr.	PAS	NBI	
MYRTACEAE					
Syzygium cordatum Hochst.	PS, SS	Aq. T		NBI	
Syzygium guineense (Willd.) DC.	PS, SS	Aq. T	PAS	NBI	
NYCTAGINACEAE					
Boerhavia coccinea Miller	D	H	PAS		
Boerhavia diffusa L.	D	H	PAS	NBI	
Commicarpus fallacissimus (Heimerl) Heimerl ex Oberm., Schweick. & I.Verd.	D	HC		NBI	
Commicarpus helenae (Schult.) Meikle	D	HC		NBI	
Commicarpus pilosus (Heimerl) Meikle	D	HC		NBI	
Commicarpus plumbagineus (Cav.) Standl.	D	HC	PAS	NBI	
NYMPHAEACEAE					
Nymphaea lotus L.	PS, SS	Aq. fl. lv	PAS	NBI	
Nymphaea nouchali Burm. f. var. *petersiana* (Klotzsch) Verdc.	PS, SS	Aq. fl. lv	PAS	NBI	
Nymphaea nouchali Burm.f. var. *caerulea* (Savigny) Verdc.	PS, SS	Aq. fl. lv		NBI	
Nymphaea nouchali Burm.f. var. *ovalifolia* (Conard) Verdc.	PS, SS	Aq. fl. lv		NBI	
OHHNACEAE					
Ochna cinnabarina Engl. & Gilg	D	Shr.	PAS	NBI	
Ochna pulchra Hook.	D	Shr./T	PAS	NBI	
OLACACEAE					
Olax dissitiflora Oliv.	D	T	PAS	NBI	
Ximenia americana L. var. americana	D	Shr.	PAS	NBI	
Ximenia americana L. var. microphylla Welw. ex Oliv.	D	Shr./T		NBI	
Ximenia caffra Sond. var. *caffra*	D	Shr./T	PAS		
OLEACEAE					
Jasminum fluminense Vell.	DRW	HC	PAS	NBI	
Jasminum stenolobum Rolfe	D	Shrblt.	PAS	NBI	
ONAGRACEAE					
Epilobium salignum Hausskn.	PS, SS	Aq. emerg.	PAS		

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Ludwigia abyssinica A.Rich.	PS, SS	Aq. emerg.	PAS	NBI	
Ludwigia erecta (L.) Hara	PS, SS	Aq. emerg.	PAS		
Ludwigia leptocarpa (Nutt.) Hara	PS, SS	Aq. emerg.	PAS	NBI	
Ludwigia octovalvis (Jacq.) P.H.Raven subsp. *brevisepala* (Brenan) P.H.Raven	PS, SS	Aq. emerg.	PAS	NBI	
Ludwigia octovalvis (Jacq.) P.H.Raven subsp. *octovalvis*	PS, SS	Aq. emerg.		NBI	
Ludwigia palustris (L.) Elliott	PS, SS	Aq. emerg.	PAS	NBI	
Ludwigia perennis L.	FG	H	PAS		
Ludwigia senegalensis (DC.) Torch	PS, SS	Aq. emerg.	PAS		
Ludwigia stenorraphe (Brenan) Hara subsp. *macrosepala* (Brenan) P.H.Raven	PS, SS	Aq. emerg.		NBI	
Ludwigia stolonifera (Guill. & Perr.) P.H.Raven	PS, SS	Aq. fl.stm	PAS	NBI	
OXALIDACEAE					
Oxalis corniculata L.	D	H	PAS	NBI	
Oxalis latifolia H.B.K.	D	H	PAS		
PAPAVERACEAE					
Argemone mexicana L.	D	H	PAS		
Argemone ochroleuca Sweet subsp. *ochroleuca*	D	H		NBI	
PEDALIACEAE					
Ceratotheca sesamoides Endl.	D	H	PAS		
Dicerocaryum eriocarpum (Decne.) Abels	D	GC	PAS	NBI	
Harpagophytum procumbens (Burch.) DC. ex Meisn. subsp. *procumbens*	D	GC	PAS	NBI	
Sesamum alatum Thonn.	D	H	PAS	NBI	
Sesamum triphyllum Welw. ex Aschers.	D	H	PAS		
PERIPLOCACEAE					
Tacazzea apiculata Oliv.	PS, SS, FG	Aq. cr.	PAS	NBI	
PHYTOLACCACEAE					
Lophiocarpus tenuissimus Hook.f.	D	H	PAS		
PLUMBAGINACEAE					
Plumbago zeylanica L.	DRW	Shrblt.	PAS	NBI	
POLYGALACEAE					
Polygala albida Schinz var. albida	D	H	PAS	NBI	
Polygala capillaris E.Mey. ex Harv.	FG	H	PAS	NBI	
Polygala erioptera DC.	D	H	PAS		
Polygala petitiana A.Rich. var. parviflora Exell	FG	H	PAS	NBI	
Polygala schinziana Chodat	D	H	PAS	NBI	
Securidaca longepedunculata Fresen	D	T	PAS		
POLYGONACEAE					
Oxygonum delagoense Kuntze	D	H	PAS	NBI	
Persicaria attenuata (R.Br.) Sojßk subsp. *africana* K.L.Wilson	PS, FG	Aq. emerg.		NBI	
Persicaria limbata (Meisn.) H.Hara	SS, FG	Aq. emerg.	PAS	NBI	
Persicaria senegalensis (Meisn.) Sojßk *forma albotomentosa* (R.A.Graham) K.L.Wilson	PS, SS	Aq. emerg.	PAS	NBI	
Persicaria senegalensis (Meisn.) Sojßk *forma senegalensis*	PS, SS	Aq. emerg.	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Persicaria serrulata (Lag.) Webb & Moq.	PS, FG	Aq. emerg.		NBI	
Polygonum meisnerianum Cham. & Schltdl.	PS, SS	Aq. emerg.	PAS	NBI	
Polygonum plebeium R.Br.	SS, FG	H. Wetl.	PAS	NBI	
PORTULACACEAE					
Portulaca hereroensis Schinz	D	H	PAS	NBI	
Portulaca kermesiana N.E. Br.	D	H	PAS		
Portulaca oleracea L.	D	H	PAS	NBI	
Portulacai quadrifda L.	D	H	PAS	NBI	
Talinum arnotii Hook.f.	D	H	PAS	NBI	
Talinum crispatulum Dinter ex V.Poelln.	D	H	PAS		
Talinum tenuissimum Dinter	D	H	PAS	NBI	
RANUNCULACEAE					
Clematis brachiata Thunb.	D	HC	PAS	NBI	
Ranunculus trichophyllus Chaix subsp. *drouetii* (Schultz) A.R.Clapham				NBI	
RHAMNACEAE					
Berchemia discolor (Klotzsch) Hemsl.	DRW	T	PAS	NBI	
Ziziphus mucronata Willd. subsp. *mucronata*	D	T	PAS	NBI	
ROSACEAE					
Rubus apetalus Poir.				NBI	
RUBIACEAE					
Gardenia brachythamnus (K.Schum.) Launert	D	Shrblt.	PAS		
Gardenia volkensii K.Schum. subsp. *spatulifolia* (Stapf & Hutch.) Verdc.	DRW	T	PAS	NBI	
Kohautia aspera (Heyne ex Roth.) Brem.	D	H	PAS		
Kohautia caespitosa Schnizl. subsp. *brachyloba* (Sond.) D.Mantell	D	H	PAS	NBI	
Kohautia virgata (Willd.) Bremek.	D	H	PAS	NBI	
Oldenlandia angolensis K.Schum. var. *angolensis*	PS, SS	Aq. emerg.	PAS	NBI	
Oldenlandia capensis L.f. var. *capensis*	FG	H	PAS	NBI	
Oldenlandia corymbosa L. var. *caespitosa* (Benth.) Verdc.	FG	H	PAS	NBI	
Oldenlandia corymbosa L. var. linearis (DC.) Verdc.	FG	H	PAS		
Oldenlandia lancifolia (Schumach.) DC. var. *scabridula* Bremek.	PS, SS, FG	Aq. emerg.	PAS	NBI	
Pavetta gardeniifolia A.Rich. var. *gardeniifolia*	DRW, D	Shr.		NBI	
Pavetta gardeniifolia A.Rich. var. *submentosa* K.Schum.	DRW, D	Shr.	PAS		
Pavetta harborii S.Moore	DRW	Shr.		NBI	
Pavetta schumanniana F.Hoffm. ex K.Schum.	DRW	Shr.	PAS		
Pavetta zeyheri Sond.	DRW	Shr.		NBI	
Pentodon pentandrus (Schumach. & Thonn.) Vatke var. *pentandrus*	PS, SS	Aq. emerg.	PAS	NBI	
Richardia scabra L.				NBI	
Spermacoce quadrisulcata (Bremek.) Verdc.	PS, SS	Aq. emerg.	PAS	NBI	
Spermacoce senensis (Klotzsch) Hiern	D	H	PAS		
Tricalysia junodii (Schinz) Brenan var. kirkii (Hook.f.) Robbr.	D	Shrblt.	PAS	NBI	
Vangueria cyanescens Robyns	D	Shr./T		NBI	
Vangueria infausta Burch. subsp. *infausta*	D	Shr./T	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
RUTACEAE					
Citropsis daweana Swingle & Kellerm.	D	Shr./T	PAS	NBI	
SALVADORACEAE					
Salvadora persica L. var. *persica*	D	T	PAS	NBI	
Salvadora persica L. var. *pubescens* Brenan	D	Shr.	PAS		
SAPINDACEAE					
Cardiospermum corindum L.	D	HC	PAS	NBI	
Cardiospermum halicacabum L. var. *halicacabum*	D	HC		NBI	
Cardiospermum halicacabum L. var. *microcarpum* (Kunth) Blume	D	HC	PAS	NBI	
SAPOTACEAE					
Manilkara mochisia (Bak.) Dubard	DRW	T	PAS		
SCROPHULARIACEAE					
Alectra orobanchoides Benth.	D	H	PAS	NBI	
Alectra sessiliflora (L.) Kuntze	FG	H	PAS		
Aptosimum decumbens Schinz	FG, D	H	PAS	NBI	
Aptosimum lugardiae (N.E.Br.) E.Phillips	D	H	PAS	NBI	N
Buchnera glabrata Benth.	D	H		NBI	
Buchnera randii S.Moore	D	H	PAS	NBI	
Craterostigma plantagineum Hochst.	D	H	PAS	NBI	
Cycnium tubulosum (L.f.) Engl. subsp. *tubulosum*	PS, SS	Aq. emerg.	PAS	NBI	
Diclis petiolaris Benth.	PS, SS	H Wetl.	PAS	NBI	
Limnophila ceratophylloides (Hiern) Skan	PS, SS	Aq. subm.	PAS	NBI	
Limnophila indica (L.) Druce	PS, SS	Aq. subm.	PAS	NBI	
Limosella australis R.Br.	PS, SS	Aq. emerg.		NBI	
Limosella grandiflora Benth.	PS, SS	Aq. emerg.		NBI	
Lindernia nana (Engl.) Roessler	RWP	H Wetl.	PAS		
Lindernia parviflora (Roxb.) Haines	FG, RWP	H Wetl.	PAS	NBI	
Mimulus gracilis R.Br.	PS, SS	Aq. emerg.	PAS	NBI	
Rhamphicarpa fistulosa (Hochst.) Benth.	PS, SS	Aq. emerg.	PAS	NBI	
Sopubia mannii Skan var. *tenuifolia* (Engl. & Gilg) Hepper	FG	H	PAS	NBI	
Striga asiatica (L.) Kuntze	D	H	PAS	NBI	
Striga bilabiata (Thunb.) Kuntze	FG, D	H	PAS	NBI	
Striga forbesii Benth.	FG, D	H	PAS	NBI	
Striga gesnerioides (Willd.) Vatke ex Engles	D	H	PAS		
Sutera elegantissima (Schinz) Skan	FG	H	PAS	NBI	
Torenia thouarsii (Cham. & Schltdl.) Kuntze	PS, SS	Aq. emerg.	PAS	NBI	
SELAGINACEAE					
Walafrida angolensis (Rolfe) Rolfe	FG	H	PAS		N
SIMABOURACEAE					
Kirkia acuminata Oliv.	D	T	PAS	NBI	
SOLANACEAE					
Datura innoxia Mill.	D	H	PAS	NBI	
Datura stramonium L.	D	H		NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
Lycium persicum	D	Shrblt.	PAS		N
Lycium shawii Roem. & Schult.	D	Shrblt.		NBI	
Physalis angulata L.	FG, D	H	PAS		
Solanum coccineum Jacq.	D	Shrblt.		NBI	
Solanum delagoense Dunal	D	Shrblt.	PAS	NBI	
Solanum kwebense N.E.Br.	D	Shrblt.		NBI	
Solanum leucophaeum Dunal	D	Shrblt.		NBI	
Solanum nigrum L.	FG, D	H	PAS	NBI	
Solanum nodiflorum Jacq.	D	H	PAS	NBI	
Solanum panduriforme E. Mey.	D	Shrblt.	PAS	NBI	
Solanum renschii Vatke	D	Shr.	PAS		
Withania somnifera (L.) Dunal	D	H	PAS	NBI	
SPHENOCLEACEAE					
Sphenoclea zeylanica Gaertn.				NBI	
STERCULIACEAE					
Hermannia eenii Baker f.	D	GC	PAS	NBI	
Hermannia glanduligera K.Schum.	FG, D	GC	PAS	NBI	
Hermannia guerkeana K. Schum.	D	Shrblt.	PAS		
Hermannia modesta (Ehrenb.) Mast.	D	H	PAS	NBI	
Hermannia quartiniana A.Rich. subsp. *stellulata* (K.Schum.) De Winter	D	GC	PAS	NBI	
Hermannia tomentosa (Turcz.) Schinz ex Engl.	D	GC	PAS	NBI	
Melhania acuminata Mast. var. *acuminata*	D	Shr.	PAS	NBI	
Melhania forbesii Planch. ex Mast.	D	Shr.	PAS	NBI	
Melhania rehmannii Szyszyl.	D	Shrblt.		NBI	
Melhania virescens (K.Schum.) K.Schum.	D	Shrblt.	PAS		
Melochia corchorifolia L.	FG	H	PAS	NBI	
Waltheria indica L.	D	Shrblt.	PAS	NBI	
THYMELIACEAE					
Gnidia polycephala (C.A.Mey.) Gilg	D	H		NBI	
TILIACEAE					
Corchorus tridens L.	D	H	PAS	NBI	
Corchorus trilocularis L.	FG, D	H	PAS		
Grewia avellana Hiern	D	Shr.	PAS	NBI	
Grewia bicolor Juss.	D	Shr.	PAS	NBI	
Grewia flava DC.	D	Shr.	PAS	NBI	
Grewia flavescens Juss. var. *flavescens*	D	Shr./WC	PAS	NBI	
Grewia flavescens Juss. var. *olukondae* (Schinz) Wild	D	Shr./WC	PAS	NBI	
Grewia retinervis Burret	D	Shr.		NBI	
Grewia schinzii K.Schum.	DRW	Shr./T	PAS	NBI	
Grewia subspathulata N.E.Br.	D	Shr.	PAS	NBI	
Triumfetta annua L. forma piligera Sprague & Hutch.	D	H		NBI	
Triumfetta pentandra A.Rich. var. *pentandra*	D	H	PAS	NBI	

continued

Species name	Distribution	Growth form	PAS	NBI	SA List
TRAPACEAE					
Trapa natans L. var. *bispinosa* (Roxb.) Makino	PS, SS	Aq. fl. lv.	PAS	NBI	
TURNERACEAE					
Tricliceras glanduliferum (Klotzsch) R.Fern.	D	H	PAS	NBI	
VAHLIACEAE					
Vahlia capensis (L.f.) Thunb. subsp. *vulgaris Bridson* var. *vulgaris*	FG, D	H	PAS		
VERBENACEAE					
Clerodendrum ternatum Schinz var. *ternatum*	D	Shrblt.	PAS	NBI	
Clerodendrum uncinatum Schinz	D	Shr.	PAS		
Lantana angolensis Moldenke	D	Shr.	PAS	NBI	
Lanmeatana rnsii Moldenke var. *latibracteolata Moldenke*	D	Shr.		NBI	
Lantana rugosa Thunb.	D	Shr.		NBI	
Phyla nodiflora (L.) Greene var. *nodiflora*	FG	H	PAS	NBI	
Priva cordifolia (L.f.) Druce	D	H	PAS		
VIOLACEAE					
Hybanthus densifolius Engl.	D	H	PAS		
VITACEAE					
Cyphostemma cirrhosum (Thunb.) Descoings ex. Willd. & Drum subsp. Transvaalense (Szyzyl.)	D	HC	PAS	NBI	
Cyphostemma congestum (Bak). Descoings ex Wild & Drum.	D	HC	PAS	NBI	
Cyphostemma currorii (Hook. f.)	D	HC		NBI	
Rhoicissus tridentata (L.f.) Wild & R.B.Drumm. subsp. *tridentata*	DRW	HC	PAS	NBI	
ZYGOPHYLLACEAE					
Fagonia isotricha Murb. var. *isotricha*				NBI	
Tribulus terrestris L.	D	H	PAS	NBI	

Appendix 8

Plant species found in each sample plot during the AquaRAP study of the Okavango Flora

W. N. Ellery

Both the numbers assigned to each plot during data analysis ("Plot #") and the field collection ("VEG#") have been assigned here. Sites are as follows: VEG 1-31 and VEG 124-126 are in the Upper Panhandle; VEG 32-54 and VEG 127 are at Guma; VEG 55-92 and VEG 128-130 at in Moremi; and VEG 93-122 and VEG 131-133 are in the vicinity of Chief's Island.

TWINSPAN No.	Plot/Species	Cover %
	Plot 1 = VEG1	
15	*Ceratophyllum demersum*	1
23	*Lagarosiphon muscoides*	1
47	*Floscopa glomerata*	1
74	*Pennistem glaucocladum*	1
88	*Echinochloa pyramidalis*	75
112	*Polygonum meisnerianum*	1
	Plot 2 = VEG2	
2	*Leersia hexandra*	1
4	*Cyperus papyrus*	3
11	*Oryza longistaminata*	1
17	*Ipomoea rubens*	1
47	*Floscopa glomerata*	3
74	*Pennistem glaucocladum*	75
84	*Chara* sp.	1
85	*Commelina* sp. 1	1
88	*Echinochloa pyramidalis*	18
101	*Brachiaria* sp. 1	1
118	*Vernonia glabra*	1
142	*Oldenlandia* sp.	1
146	*Potamogeton* sp.	1
157	*Panicum parvifolium*	1
158	*Nesaea crassicaulis*	1

TWINSPAN No.	Plot/Species	Cover %
	Plot 3 = VEG3	
1	*Nymphaea nouchali*	18
2	*Leersia hexandra*	8
4	*Cyperus papyrus*	8
47	*Floscopa glomerata*	1
55	*Azolla* sp.	1
76	*Sacchiolepis africana*	1
112	*Polygonum meisnerianum*	1
117	*Utricularia* sp. 1	1
159	*Vetiveria nigritana*	1
	Plot 4 = VEG4	
1	*Nymphaea nouchali*	1
4	*Cyperus papyrus*	75
55	*Azolla* sp.	1
108	*Ludwigia* sp.	1
112	*Polygonum meisnerianum*	1
117	*Utricularia* sp. 1	1
	Plot 5 = VEG5	
1	*Nymphaea nouchali*	1
4	*Cyperus papyrus*	1
10	*Ludwigia stolonifera*	1
12	*Vossia cuspidata*	8
15	*Ceratophyllum demersum*	18
23	*Lagarosiphon muscoides*	8

continued

TWINSPAN No.	Plot/Species	Cover %
43	*Aeschynomene fluitans*	1
117	*Utricularia* sp. 1	3
	Plot 6 = VEG6	
1	*Nymphaea nouchali*	1
4	*Cyperus papyrus*	8
10	*Ludwigia stolonifera*	1
12	*Vossia cuspidata*	3
17	*Ipomoea rubens*	1
18	*Pycreus mundii*	3
23	*Lagarosiphon muscoides*	1
32	*Persicaria senegalensis*	8
47	*Floscopa glomerata*	1
53	*Phragmities mauritianus*	3
103	*Echinochloa stagnina*	1
115	*Sesbania sesban*	1
	Plot 7 = VEG7	
12	*Vossia cuspidata*	1
17	*Ipomoea rubens*	3
32	*Persicaria senegalensis*	75
110	*Mikania sagittifera*	3
	Plot 8 = VEG8	
1	*Nymphaea nouchali*	3
4	*Cyperus papyrus*	3
12	*Vossia cuspidata*	18
17	*Ipomoea rubens*	8
23	*Lagarosiphon muscoides*	1
32	*Persicaria senegalensis*	3
43	*Aeschynomene fluitans*	1
53	*Phragmities mauritianus*	38
74	*Pennistem glaucocladum*	8
117	*Utricularia* sp. 1	3
	Plot 9 = VEG9	
12	*Vossia cuspidata*	75
32	*Persicaria senegalensis*	3
	Plot 10 = VEG10	
1	*Nymphaea nouchali*	8
23	*Lagarosiphon muscoides*	1
117	*Utricularia* sp. 1	1
	Plot 11 = VEG11	
3	*Cynodon dactylon*	1
7	*Schoenoplectus corymbosus*	3
22	*Nymphoides indica*	1

TWINSPAN No.	Plot/Species	Cover %
30	*Cyperus denudatus*	1
43	*Aeschynomene fluitans*	1
53	*Phragmities mauritianus*	1
75	*Rotala myriophylloides*	8
102	*Crinum* sp.	1
123	*Arrow leaf spongy*	8
132	*Eleocharis small*	1
149	*Cyperus laevigatus*	18
152	*Brachiaria humidicola*	3
159	*Vetiveria nigritana*	3
160	*Cyanotis foecunda*	18
161	*Paspalum* sp.	1
162	*Sporobolus africanus*	3
	Plot 12 = VEG12	
1	*Nymphaea nouchali*	3
7	*Schoenoplectus corymbosus*	3
11	*Oryza longistaminata*	38
22	*Nymphoides indica*	3
102	*Crinum* sp.	1
117	*Utricularia* sp. 1	18
123	*Arrow leaf spongy*	1
163	*Nitella* sp.	18
	Plot 13 = VEG13	
2	*Leersia hexandra*	3
10	*Ludwigia stolonifera*	1
12	*Vossia cuspidata*	3
17	*Ipomoea rubens*	18
53	*Phragmities mauritianus*	8
74	*Pennistem glaucocladum*	8
93	*Rhus quartiniana*	3
103	*Echinochloa stagnina*	1
112	*Polygonum meisnerianum*	18
115	*Sesbania sesban*	1
164	*Ethulia conyzoides*	1
	Plot 14 = VEG14	
2	*Leersia hexandra*	3
10	*Ludwigia stolonifera*	3
17	*Ipomoea rubens*	3
18	*Pycreus mundii*	1
32	*Persicaria senegalensis*	1
43	*Aeschynomene fluitans*	1
53	*Phragmities mauritianus*	18

continued

TWINSPAN No.	Plot/Species	Cover %
74	*Pennistem glaucocladum*	38
93	*Rhus quartiniana*	1
158	*Nesaea crassicaulis*	1
	Plot 15 = VEG15	
3	*Cynodon dactylon*	8
9	*Panicum repens*	3
11	*Oryza longistaminata*	1
12	*Vossia cuspidata*	18
17	*Ipomoea rubens*	1
18	*Pycreus mundii*	1
32	*Persicaria senegalensis*	1
43	*Aeschynomene fluitans*	1
47	*Floscopa glomerata*	3
53	*Phragmities mauritianus*	18
57	*Eragrostis inamoena*	1
75	*Rotala myriophylloides*	3
76	*Sacchiolepis africana*	18
85	*Commelina* sp. 1	3
88	*Echinochloa pyramidalis*	1
112	*Polygonum meisnerianum*	1
115	*Sesbania sesban*	1
140	*Myriophyllum spicatum*	1
165	*Digiteria debelis*	3
166	*Euphorbia* sp.	1
167	*Cyperus* sp. 1	1
168	Lythraceae sp. 1	3
169	*Hibiscus diversifolius*	3
	Plot 16 = VEG16	
2	*Leersia hexandra*	18
11	*Oryza longistaminata*	75
53	*Phragmities mauritianus*	3
117	*Utricularia* sp. 1	8
140	*Myriophyllum spicatum*	3
146	*Potamogeton* sp.	1
170	*Acacia hebeclada*	3
	Plot 17 = VEG17	
4	*Cyperus papyrus*	75
17	*Ipomoea rubens*	8
32	*Persicaria senegalensis*	18
60	*Syzygium guineense*	3
142	*Oldenlandia* sp.	1
	Plot 18 = VEG18	
4	*Cyperus papyrus*	1
12	*Vossia cuspidata*	8
17	*Ipomoea rubens*	1
74	*Pennistem glaucocladum*	8
88	*Echinochloa pyramidalis*	75
	Plot 19 = VEG19	
17	*Ipomoea rubens*	3
53	*Phragmities mauritianus*	75
	Plot 20 = VEG20	
1	*Nymphaea nouchali*	3
12	*Vossia cuspidata*	1
13	*Najas horrida*	18
15	*Ceratophyllum demersum*	75
23	*Lagarosiphon muscoides*	3
50	*Nymphaea lotus*	1
51	*Ottelia ulvifolia*	18
147	*Potamogeton pectinatus*	1
	Plot 21 = VEG21	
2	*Leersia hexandra*	3
3	*Cynodon dactylon*	1
4	*Cyperus papyrus*	3
9	*Panicum repens*	3
12	*Vossia cuspidata*	75
32	*Persicaria senegalensis*	1
49	*Lemna* sp.	1
115	*Sesbania sesban*	1
123	*Arrow leaf spongy*	1
171	*Hibiscus cannabinus*	8
172	*Cassia* sp.	1
	Plot 22 = VEG22	
4	*Cyperus papyrus*	75
17	*Ipomoea rubens*	3
32	*Persicaria senegalensis*	3
	Plot 23 = VEG23	
1	*Nymphaea nouchali*	8
10	*Ludwigia stolonifera*	3
12	*Vossia cuspidata*	8
15	*Ceratophyllum demersum*	18
23	*Lagarosiphon muscoides*	3
41	*Trapa natans*	38
	Plot 24 = VEG24	
4	*Cyperus papyrus*	1
12	*Vossia cuspidata*	75
88	*Echinochloa pyramidalis*	1

continued

TWINSPAN No.	Plot/Species	Cover %
	Plot 25 = VEG25	
4	*Cyperus papyrus*	75
21	*Ludwigia leptocarpa*	1
38	*Scirpus cubensis*	8
40	*Thelypteris interrupta*	8
55	*Azolla* sp.	1
	Plot 26 = VEG26	
13	*Najas horrida*	8
15	*Ceratophyllum demersum*	3
23	*Lagarosiphon muscoides*	1
50	*Nymphaea lotus*	38
111	*Ottelia muricata*	1
117	*Utricularia* sp. 1	8
147	*Potamogeton* sp.	1
	Plot 27 = VEG27	
4	*Cyperus papyrus*	8
17	*Ipomoea rubens*	1
18	*Pycreus mundii*	38
21	*Ludwigia leptocarpa*	8
23	*Lagarosiphon muscoides*	1
38	*Scirpus cubensis*	38
55	*Azolla* sp.	1
	Plot 28 = VEG28	
13	*Najas horrida*	8
15	*Ceratophyllum demersum*	18
23	*Lagarosiphon muscoides*	18
41	*Trapa natans*	1
50	*Nymphaea lotus*	38
	Plot 29 = VEG29	
50	*Nymphaea lotus*	3
	Plot 30 = VEG30	
13	*Najas horrida*	8
15	*Ceratophyllum demersum*	18
23	*Lagarosiphon muscoides*	3
50	*Nymphaea lotus*	18
	Plot 31 = VEG31	
4	*Cyperus papyrus*	18
10	*Ludwigia stolonifera*	3
12	*Vossia cuspidata*	1
18	*Pycreus mundii*	18
21	*Ludwigia leptocarpa*	3
38	*Scirpus cubensis*	38
55	*Azolla* sp.	1
117	*Utricularia* sp. 1	8
120	*Vigna luteola*	1
	Plot 32 = VEG32	
3	*Cynodon dactylon*	3
7	*Schoenoplectus corymbosus*	3
9	*Panicum repens*	8
57	*Eragrostis inamoena*	18
61	*Syzygium cordatum*	1
75	*Rotala myriophylloides*	18
102	*Crinum* sp.	3
140	*Myriophyllum spicatum*	18
	Plot 33 = VEG33	
7	*Schoenoplectus corymbosus*	1
9	*Panicum repens*	38
57	*Eragrostis inamoena*	8
61	*Syzygium cordatum*	1
69	*Cyperus longus*	1
102	*Crinum* sp.	3
	Plot 34 = VEG34	
9	*Panicum repens*	18
24	*Acacia nigrescens*	1
33	*Seteria sphacelata*	3
35	*Indigofera* sp. 1	1
57	*Eragrostis inamoena*	18
61	*Syzygium cordatum*	1
91	*Hibiscus* sp. 1	1
141	*Nidorella resedifolia*	1
152	*Brachiaria humidicola*	38
	Plot 35 = VEG35	
19	*Achyranthes aspera*	3
24	*Acacia nigrescens*	1
28	*Diospyrus mespiliformis*	3
33	*Seteria sphacelata*	1
48	*Garcinia livingstonei*	8
52	*Panicum maximum*	1
56	*Combretum hereroense*	1
61	*Syzygium cordatum*	8
64	*Abutilon angulatum*	1
72	*Jasminium fluminense*	1
79	*Abutilon* sp.	3
89	*Ficus sycomorus*	18

continued

TWINSPAN No.	Plot/Species	Cover %
93	*Rhus quartiniana*	18
107	*Kigelia africana*	1
122	Acanthaceae sp. 2	1
144	*Phoenix reclinata*	18
152	*Brachiaria humidicola*	1
156	*Ximenia americana*	1
173	*Antidesma venosum*	18
174	*Protasparagus africanus*	1
175	*Gardenia volkensii*	1
176	*Grewia flavescens*	1
	Plot 36 = VEG36	
4	*Cyperus papyrus*	75
6	*Miscanthus junceus*	3
15	*Ceratophyllum demersum*	1
17	*Ipomoea rubens*	3
21	*Ludwigia leptocarpa*	1
30	*Cyperus denudatus*	3
40	*Thelypteris interrupta*	8
47	*Floscopa glomerata*	1
49	*Lemna* sp.	1
117	*Utricularia* sp. 1	1
120	*Vigna luteola*	1
127	*Crassocephalum picridifolium*	1
169	*Hibiscus diversifolius*	1
	Plot 37 = VEG37	
4	*Cyperus papyrus*	18
15	*Ceratophyllum demersum*	18
18	*Pycreus mundii*	75
21	*Ludwigia leptocarpa*	3
25	*Cyperus pectinatus*	3
40	*Thelypteris interrupta*	8
41	*Trapa natans*	18
50	*Nymphaea lotus*	3
55	*Azolla* sp.	1
117	*Utricularia* sp. 1	18
154	*Utricularia* sp. 2	3
	Plot 38 = VEG38	
4	*Cyperus papyrus*	75
18	*Pycreus mundii*	3
21	*Ludwigia leptocarpa*	3
62	*Thelypteris confluens*	3
154	*Utricularia* sp. 2	1
169	*Hibiscus diversifolius*	1

TWINSPAN No.	Plot/Species	Cover %
	Plot 39 = VEG39	
15	*Ceratophyllum demersum*	3
41	*Trapa natans*	38
50	*Nymphaea lotus*	3
117	*Utricularia* sp. 1	3
	Plot 40 = VEG40	
4	*Cyperus papyrus*	75
6	*Miscanthus junceus*	1
15	*Ceratophyllum demersum*	1
18	*Pycreus mundii*	1
21	*Ludwigia leptocarpa*	8
25	*Cyperus pectinatus*	3
40	*Thelypteris interrupta*	3
42	*Typha capensis*	3
47	*Floscopa glomerata*	1
62	*Thelypteris confluens*	1
120	*Vigna luteola*	1
169	*Hibiscus diversifolius*	3
	Plot 41 = VEG41	
4	*Cyperus papyrus*	8
17	*Ipomoea rubens*	3
18	*Pycreus mundii*	75
21	*Ludwigia leptocarpa*	3
25	*Cyperus pectinatus*	8
38	*Scirpus cubensis*	8
41	*Trapa natans*	18
49	*Lemna* sp.	1
154	*Utricularia* sp. 2	1
	Plot 42 = VEG42	
4	*Cyperus papyrus*	75
15	*Ceratophyllum demersum*	3
17	*Ipomoea rubens*	1
18	*Pycreus mundii*	1
21	*Ludwigia leptocarpa*	1
42	*Typha capensis*	1
49	*Lemna* sp.	1
62	*Thelypteris confluens*	3
120	*Vigna luteola*	1
169	*Hibiscus diversifolius*	1
	Plot 43 = VEG43	
1	*Nymphaea nouchali*	3

continued

TWINSPAN No.	Plot/Species	Cover %
	Plot 44 = VEG44	
3	*Cynodon dactylon*	18
9	*Panicum repens*	18
19	*Achyranthes aspera*	1
26	*Lantana angolensis*	1
33	*Seteria sphacelata*	1
34	*Imperata cylindrica*	3
57	*Eragrostis inamoena*	8
59	*Maytenus heterophylla*	1
61	*Syzygium cordatum*	1
69	*Cyperus longus*	3
72	*Jasminium fluminense*	1
89	*Ficus sycomorus*	3
93	*Rhus quartiniana*	1
99	*Andropogon eucomus*	3
144	*Phoenix reclinata*	3
177	*Kyllinga alba*	18
	Plot 45 = VEG45	
1	*Nymphaea nouchali*	3
51	*Ottelia ulvifolia*	1
	Plot 46 = VEG46	
4	*Cyperus papyrus*	75
32	*Persicaria senegalensis*	1
40	*Thelypteris interrupta*	1
112	*Polygonum meisnerianum*	1
120	*Vigna luteola*	1
	Plot 47 = VEG47	
4	*Cyperus papyrus*	8
6	*Miscanthus junceus*	38
16	*Pycreus nitidus*	18
20	*Fuirena pubescens*	3
38	*Scirpus cubensis*	18
40	*Thelypteris interrupta*	3
62	*Thelypteris confluens*	1
127	*Crassocephalum picridifolium*	3
136	*Fimbristylis complanata*	18
142	*Oldenlandia* sp.	1
178	*Pycnostachys coerula*	1
	Plot 48 = VEG48	
4	*Cyperus papyrus*	38
6	*Miscanthus junceus*	3
16	*Pycreus nitidus*	3
18	*Pycreus mundii*	3
20	*Fuirena pubescens*	3
21	*Ludwigia leptocarpa*	8
25	*Cyperus pectinatus*	3
30	*Cyperus denudatus*	3
42	*Typha capensis*	8
41	*Trapa natans*	3
40	*Thelypteris interrupta*	8
55	*Azolla* sp.	1
169	*Hibiscus diversifolius*	1
179	*Cladium mariscus*	1
	Plot 49 = VEG49	
15	*Ceratophyllum demersum*	8
41	*Trapa natans*	18
50	*Nymphaea lotus*	3
	Plot 50 = VEG50	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	8
5	*Cyperus articulatus*	1
8	*Eleocharis dulcis*	3
11	*Oryza longistaminata*	8
12	*Vossia cuspidata*	1
18	*Pycreus mundii*	3
20	*Fuirena pubescens*	8
30	*Cyperus denudatus*	3
38	*Scirpus cubensis*	1
40	*Thelypteris interrupta*	3
42	*Typha capensis*	18
53	*Phragmities mauritianus*	8
85	*Commelina* sp. 1	3
86	*Cycnium tubulosum*	3
87	*Cyperus dives*	3
152	*Brachiaria humidicola*	8
180	*Hydrocotyle verticillata*	1
	Plot 51 = VEG51	
4	*Cyperus papyrus*	3
6	*Miscanthus junceus*	75
17	*Ipomoea rubens*	3
30	*Cyperus denudatus*	3
40	*Thelypteris interrupta*	8
87	*Cyperus dives*	1
110	*Mikania sagittifera*	3

continued

TWINSPAN No.	Plot/Species	Cover %
181	*Senecio strictifolius*	18
182	*Ficus capreifolia*	1
	Plot 52 = VEG52	
1	*Nymphaea nouchali*	3
7	*Schoenoplectus corymbosus*	1
9	*Panicum repens*	8
14	*Potamogeton thunbergii*	3
22	*Nymphoides indica*	1
57	*Eragrostis inamoena*	18
78	*Utricularia* sp. 3	3
102	*Crinum* sp.	1
158	*Nesaea crassicaulis*	1
183	*Cyperus dives*	3
	Plot 53 = VEG53	
7	*Schoenoplectus corymbosus*	1
9	*Panicum repens*	38
11	*Oryza longistaminata*	3
21	*Ludwigia leptocarpa*	3
22	*Nymphoides indica*	1
30	*Cyperus denudatus*	3
33	*Seteria sphacelata*	1
57	*Eragrostis inamoena*	18
86	*Cycnium tubulosum*	1
87	*Cyperus dives*	3
152	*Brachiaria humidicola*	3
184	*Cyperus* sp. 2	3
	Plot 54 = VEG54	
3	*Cynodon dactylon*	3
19	*Achyranthes aspera*	1
28	*Diospyrus mespiliformis*	8
33	*Seteria sphacelata*	3
46	*Euclea divinorium*	8
48	*Garcinia livingstonei*	8
52	*Panicum maximum*	1
57	*Eragrostis inamoena*	3
59	*Maytenus heterophylla*	1
61	*Syzygium cordatum*	38
64	*Abutilon angulatum*	3
69	*Cyperus longus*	1
72	*Jasminium fluminense*	1
77	*Sporobolus spicatus*	3
86	*Cycnium tubulosum*	1

TWINSPAN No.	Plot/Species	Cover %
89	*Ficus sycomorus*	8
90	*Hibiscus calyphyllus*	1
93	*Rhus quartiniana*	3
97	*Vernonia amygdalina*	3
99	*Andropogon eucomus*	1
113	*Pechuel-loeschea leubnitziae*	1
121	*Acacia tortilis*	8
124	*Boerhavia diffusa*	1
125	*Carissa edulis*	8
144	*Phoenix reclinata*	18
153	*Sporobolus ioclados*	3
156	*Ximenia americana*	3
174	*Protasparagus africanus*	1
176	*Grewia flavescens*	1
184	*Cyperus* sp. 2	1
185	*Rhyncosia minima*	1
186	*Gossypium herbaceum*	3
187	*Securinega virosa*	1
188	*Capparis tomentosa*	3
189	*Chloris gayana*	1
190	*Hermannia* sp.	1
	Plot 55 = VEG55	
1	*Nymphaea nouchali*	1
8	*Eleocharis dulcis*	1
14	*Potamogeton thunbergii*	3
16	*Pycreus nitidus*	1
23	*Lagarosiphon muscoides*	1
40	*Thelypteris interrupta*	3
42	*Typha capensis*	3
75	*Rotala myriophylloides*	3
111	*Ottelia muricata*	1
147	*Potamogeton pectinatus*	1
148	*Salvinia molesta*	1
191	*Eichhornia natans*	3
	Plot 56 = VEG56	
4	*Cyperus papyrus*	8
5	*Cyperus articulatus*	1
10	*Ludwigia stolonifera*	1
13	*Najas horrida*	1
15	*Ceratophyllum demersum*	1
18	*Pycreus mundii*	38
23	*Lagarosiphon muscoides*	1

continued

TWINSPAN No.	Plot/Species	Cover %
31	*Ficus verriculosa*	3
38	*Scirpus cubensis*	38
40	*Thelypteris interrupta*	8
41	*Trapa natans*	1
42	*Typha capensis*	3
62	*Thelypteris confluens*	3
75	*Rotala myriophylloides*	1
111	*Ottelia muricata*	1
117	*Utricularia* sp. 1	1
191	*Eichhornia natans*	1
	Plot 57 = VEG57	
4	*Cyperus papyrus*	8
31	*Ficus verriculosa*	75
61	*Syzygium cordatum*	3
	Plot 58 = VEG58	
15	*Ceratophyllum demersum*	1
	Plot 59 = VEG59	
3	*Cynodon dactylon*	38
9	*Panicum repens*	8
19	*Achyranthes aspera*	3
24	*Acacia nigrescens*	18
28	*Diospyrus mespiliformis*	3
46	*Euclea divinorium*	3
54	*Seteria verticillata*	18
58	*Lonchocarpus capassa*	1
59	*Maytenus heterophylla*	3
64	*Abutilon angulatum*	1
68	*Combretum mossambicense*	1
72	*Jasminium fluminense*	3
90	*Hibiscus calyphyllus*	1
98	*Aerva leucura*	3
100	*Berchemia discolor*	3
114	*Rhus tenuineruis*	1
125	*Carissa edulis*	8
126	*Combretum imberebe*	1
174	*Protasparagus africanus*	1
192	*Hyphaene petersiana*	3
193	*Ledelele*	1
194	*Ficus thonningii*	1
196	*Acrotome inflata*	1
	Plot 60 = VEG60	
1	*Nymphaea nouchali*	8
2	*Leersia hexandra*	1
5	*Cyperus articulatus*	8
8	*Eleocharis dulcis*	3
21	*Ludwigia leptocarpa*	1
40	*Thelypteris interrupta*	1
44	*Brasenia schreberi*	8
	Plot 61 = VEG61	
2	*Leersia hexandra*	3
4	*Cyperus papyrus*	1
6	*Miscanthus junceus*	18
9	*Panicum repens*	8
11	*Oryza longistaminata*	8
16	*Pycreus nitidus*	1
18	*Pycreus mundii*	3
20	*Fuirena pubescens*	18
21	*Ludwigia leptocarpa*	3
31	*Ficus verriculosa*	18
40	*Thelypteris interrupta*	8
47	*Floscopa glomerata*	3
61	*Syzygium cordatum*	18
62	*Thelypteris confluens*	3
94	*Sacchiolepis typhura*	1
97	*Vernonia amygdalina*	3
110	*Mikania sagittifera*	3
112	*Polygonum meisnerianum*	1
120	*Vigna luteola*	3
	Plot 62 = VEG62	
8	*Eleocharis dulcis*	1
14	*Potamogeton thunbergii*	3
22	*Nymphoides indica*	1
27	*Vallisneria aethiopica*	3
158	*Nesaea crassicaulis*	38
	Plot 63 = VEG63	
6	*Miscanthus junceus*	75
20	*Fuirena pubescens*	3
21	*Ludwigia leptocarpa*	3
31	*Ficus verriculosa*	8
34	*Imperata cylindrica*	8
40	*Thelypteris interrupta*	3
110	*Mikania sagittifera*	3
120	*Vigna luteola*	1
127	*Crassocephalum picridifolium*	1
181	*Senecio strictifolius*	1

continued

TWINSPAN No.	Plot/Species	Cover %
	Plot 64 = VEG64	
6	*Miscanthus junceus*	38
8	*Eleocharis dulcis*	3
21	*Ludwigia leptocarpa*	8
31	*Ficus verriculosa*	3
40	*Thelypteris interrupta*	8
42	*Typha capensis*	18
61	*Syzygium cordatum*	3
120	*Vigna luteola*	3
	Plot 65 = VEG65	
14	*Potamogeton thunbergii*	1
22	*Nymphoides indica*	3
51	*Ottelia ulvifolia*	1
75	*Rotala myriophylloides*	38
147	*Potamogeton pectinatus*	8
158	*Nesaea crassicaulis*	18
	Plot 66 = VEG66	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	8
6	*Miscanthus junceus*	18
8	*Eleocharis dulcis*	3
16	*Pycreus nitidus*	3
18	*Pycreus mundii*	8
20	*Fuirena pubescens*	8
31	*Ficus verriculosa*	8
34	*Imperata cylindrica*	18
40	*Thelypteris interrupta*	8
42	*Typha capensis*	8
61	*Syzygium cordatum*	3
120	*Vigna luteola*	3
	Plot 67 = VEG67	
1	*Nymphaea nouchali*	1
	Plot 68 = VEG68	
9	*Panicum repens*	3
16	*Pycreus nitidus*	18
25	*Cyperus pectinatus*	1
44	*Brasenia schreberi*	8
84	*Chara* sp.	18
99	*Andropogon eucomus*	1
117	*Utricularia* sp. 1	1
132	*Eleocharis small*	18

TWINSPAN No.	Plot/Species	Cover %
	Plot 69 = VEG69	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	1
6	*Miscanthus junceus*	75
7	*Schoenoplectus corymbosus*	1
8	*Eleocharis dulcis*	1
16	*Pycreus nitidus*	3
20	*Fuirena pubescens*	3
22	*Nymphoides indica*	3
25	*Cyperus pectinatus*	3
44	*Brasenia schreberi*	8
45	*Eleocharis acutangula*	1
62	*Thelypteris confluens*	3
117	*Utricularia* sp. 1	1
131	*Eleocharis large*	3
	Plot 70 = VEG70	
1	*Nymphaea nouchali*	3
6	*Miscanthus junceus*	3
8	*Eleocharis dulcis*	18
44	*Brasenia schreberi*	18
45	*Eleocharis acutangula*	18
117	*Utricularia* sp. 1	3
	Plot 71 = VEG71	
13	*Najas horrida*	1
23	*Lagarosiphon muscoides*	1
	Plot 72 = VEG72	
1	*Nymphaea nouchali*	8
5	*Cyperus articulatus*	3
6	*Miscanthus junceus*	1
7	*Schoenoplectus corymbosus*	1
8	*Eleocharis dulcis*	3
44	*Brasenia schreberi*	18
45	*Eleocharis acutangula*	3
	Plot 73 = VEG73	
2	*Leersia hexandra*	3
6	*Miscanthus junceus*	75
8	*Eleocharis dulcis*	1
16	*Pycreus nitidus*	8
21	*Ludwigia leptocarpa*	1
25	*Cyperus pectinatus*	1
44	*Brasenia schreberi*	3
62	*Thelypteris confluens*	3

continued

TWINSPAN No.	Plot/Species	Cover %
94	*Sacchiolepis typhura*	1
132	*Eleocharis small*	3
	Plot 74 = VEG74	
2	*Leersia hexandra*	1
6	*Miscanthus junceus*	18
9	*Panicum repens*	3
16	*Pycreus nitidus*	18
25	*Cyperus pectinatus*	8
84	*Chara* sp.	8
94	*Sacchiolepis typhura*	1
131	*Eleocharis large*	18
	Plot 75 = VEG75	
1	*Nymphaea nouchali*	1
5	*Cyperus articulatus*	3
7	*Schoenoplectus corymbosus*	8
8	*Eleocharis dulcis*	3
13	*Najas horrida*	3
44	*Brasenia schreberi*	1
	Plot 76 = VEG76	
6	*Miscanthus junceus*	8
9	*Panicum repens*	3
14	*Potamogeton thunbergii*	8
16	*Pycreus nitidus*	8
22	*Nymphoides indica*	3
25	*Cyperus pectinatus*	8
45	*Eleocharis acutangula*	3
84	*Chara* sp.	18
94	*Sacchiolepis typhura*	8
132	*Eleocharis small*	3
	Plot 77 = VEG77	
1	*Nymphaea nouchali*	1
2	*Leersia hexandra*	1
6	*Miscanthus junceus*	75
16	*Pycreus nitidus*	3
20	*Fuirena pubescens*	1
22	*Nymphoides indica*	3
25	*Cyperus pectinatus*	8
31	*Ficus verriculosa*	3
62	*Thelypteris confluens*	3
84	*Chara* sp.	3
117	*Utricularia* sp. 1	1
132	*Eleocharis small*	3
150	*Scleria* sp.	1
195	*Pycreus flavescens*	1
	Plot 78 = VEG78	
5	*Cyperus articulatus*	8
7	*Schoenoplectus corymbosus*	8
8	*Eleocharis dulcis*	8
13	*Najas horrida*	18
23	*Lagarosiphon muscoides*	1
44	*Brasenia schreberi*	8
111	*Ottelia muricata*	1
	Plot 79 = VEG79	
2	*Leersia hexandra*	3
3	*Cynodon dactylon*	1
5	*Cyperus articulatus*	3
6	*Miscanthus junceus*	18
10	*Ludwigia stolonifera*	3
11	*Oryza longistaminata*	18
16	*Pycreus nitidus*	18
20	*Fuirena pubescens*	3
25	*Cyperus pectinatus*	8
39	*Caldesia reniformis*	1
42	*Typha capensis*	3
47	*Floscopa glomerata*	3
49	*Lemna* sp.	3
63	*Ammania* sp. 1	1
71	*Diospyros lyciodes*	8
81	*Alternanthera sessilis*	1
112	*Polygonum meisnerianum*	3
148	*Salvinia molesta*	8
178	*Pycnostachys coerula*	1
180	*Hydrocotyle verticillata*	3
	Plot 80 = VEG80	
2	*Leersia hexandra*	18
5	*Cyperus articulatus*	1
6	*Miscanthus junceus*	75
11	*Oryza longistaminata*	8
16	*Pycreus nitidus*	3
20	*Fuirena pubescens*	1
21	*Ludwigia leptocarpa*	3
38	*Scirpus cubensis*	1
42	*Typha capensis*	1
47	*Floscopa glomerata*	8

continued

TWINSPAN No.	Plot/Species	Cover %
49	*Lemna* sp.	1
71	*Diospyros lyciodes*	8
143	*Persicaria* sp.	3
148	*Salvinia molesta*	3
178	*Pycnostachys coerula*	1
195	*Pycreus flavescens*	3
	Plot 81 = VEG81	
3	*Cynodon dactylon*	18
19	*Achyranthes aspera*	3
29	*Croton megalobotrys*	18
35	*Indigofera* sp. 1	3
58	*Lonchocarpus capassa*	8
64	*Abutilon angulatum*	1
66	*Aristida congesta*	8
71	*Diospyros lyciodes*	8
77	*Sporobolus spicatus*	8
96	*Cenchrus ciliaris*	8
116	*Sphaeranthus* sp.	1
135	*Eragrostis superba*	1
137	*Amaranthus hybridus*	1
139	*Kalanchoe lanceolata*	3
151	*Lannea schweinfurthii*	1
196	*Acrotome inflata*	3
201	*Sporobolus* sp.	18
	Plot 82 = VEG82	
77	*Sporobolus spicatus*	3
149	*Cyperus laevigatus*	3
	Plot 86 = VEG86	
2	*Leersia hexandra*	3
3	*Cynodon dactylon*	3
6	*Miscanthus junceus*	1
9	*Panicum repens*	3
20	*Fuirena pubescens*	1
29	*Croton megalobotrys*	3
33	*Seteria sphacelata*	8
34	*Imperata cylindrica*	75
115	*Sesbania sesban*	1
118	*Vernonia glabra*	1
129	*Digiteria eriantha*	3
	Plot 87 = VEG87	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	18
5	*Cyperus articulatus*	8
7	*Schoenoplectus corymbosus*	8
9	*Panicum repens*	1
33	*Seteria sphacelata*	1
39	*Caldesia reniformis*	1
	Plot 88 = VEG88	
3	*Cynodon dactylon*	18
35	*Indigofera* sp. 1	1
47	*Floscopa glomerata*	1
67	*Aristida meridionalis*	3
70	*Dichrostachys cinerea*	1
80	*Acacia erioloba*	1
82	*Justicea betonica*	3
90	*Hibiscus calyphyllus*	1
92	*Lonchocarpus nelsii*	3
104	*Eragrostis pallens*	3
128	*Crotolaria sphaerocarpa*	1
141	*Nidorella resedifolia*	1
145	*Persicaria limbata*	1
149	*Cyperus laevigatus*	1
193	*Ledelele*	8
196	*Acrotome inflata*	3
197	*Urochloa mosambicensis*	3
198	*Colophospermum mopane*	3
210	*Denekia capensis*	1
211	*Zornia glochidata*	1
212	*Sida cordifolia*	3
213	*Chamaecrista mimosoides*	1
214	*Perotis patens*	1
215	*Phyllanthus* sp.	1
	Plot 89 = VEG89	
1	*Nymphaea nouchali*	1
3	*Cynodon dactylon*	3
23	*Lagarosiphon muscoides*	1
82	*Justicea betonica*	3
117	*Utricularia* sp. 1	1
198	*Colophospermum mopane*	8
	Plot 90 = VEG90	
3	*Cynodon dactylon*	38
36	Lamiaceae pink flower	3
77	*Sporobolus spicatus*	3
82	*Justicea betonica*	8

continued

TWINSPAN No.	Plot/Species	Cover %
118	*Vernonia glabra*	1
145	*Persicaria limbata*	1
149	*Cyperus laevigatus*	3
197	*Urochloa mosambicensis*	3
210	*Denekia capensis*	1
	Plot 91 = VEG91	
3	*Cynodon dactylon*	38
10	*Ludwigia stolonifera*	1
35	*Indigofera* sp. 1	1
82	*Justicea betonica*	3
121	*Acacia tortilis*	1
128	*Crotolaria sphaerocarpa*	1
141	*Nidorella resedifolia*	3
197	*Urochloa mosambicensis*	8
	Plot 92 = VEG92	
2	*Leersia hexandra*	1
3	*Cynodon dactylon*	3
9	*Panicum repens*	1
10	*Ludwigia stolonifera*	8
14	*Potamogeton thunbergii*	3
23	*Lagarosiphon muscoides*	1
32	*Persicaria senegalensis*	1
38	*Scirpus cubensis*	8
42	*Typha capensis*	3
49	*Lemna* sp.	1
101	*Brachiaria* sp. 1	3
109	*Marsilea* sp. 1	1
117	*Utricularia* sp. 1	1
118	*Vernonia glabra*	1
145	*Persicaria limbata*	1
	Plot 93 = VEG93	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	3
5	*Cyperus articulatus*	1
10	*Ludwigia stolonifera*	3
11	*Oryza longistaminata*	8
12	*Vossia cuspidata*	3
16	*Pycreus nitidus*	3
33	*Seteria sphacelata*	1
47	*Floscopa glomerata*	1
73	*Paspalidium obtusifolium*	18
81	*Alternanthera sessilis*	1
87	*Cyperus dives*	1
101	*Brachiaria* sp. 1	38
112	*Polygonum meisnerianum*	3
117	*Utricularia* sp. 1	3
	Plot 94 = VEG94	
3	*Cynodon dactylon*	8
19	*Achyranthes aspera*	1
24	*Acacia nigrescens*	1
28	*Diospyrus mespiliformis*	38
33	*Seteria sphacelata*	3
34	*Imperata cylindrica*	8
46	*Euclea divinorium*	1
48	*Garcinia livingstonei*	1
52	*Panicum maximum*	1
54	*Seteria verticillata*	1
58	*Lonchocarpus capassa*	8
59	*Maytenus heterophylla*	1
72	*Jasminium fluminense*	3
90	*Hibiscus calyphyllus*	1
97	*Vernonia amygdalina*	3
98	*Aerva leucura*	1
105	*Grewia bicolor*	1
107	*Kigelia africana*	8
174	*Protasparagus africanus*	1
185	*Rhyncosia minima*	1
186	*Gossypium herbaceum*	1
192	*Hyphaene petersiana*	1
194	*Ficus thonningii*	1
199	*Sorgastrum friesii*	1
216	*Ziziphus mucronata*	3
	Plot 95 = VEG95	
5	*Cyperus articulatus*	1
9	*Panicum repens*	3
34	*Imperata cylindrica*	75
101	*Brachiaria* sp. 1	8
115	*Sesbania sesban*	1
159	*Vetiveria nigritana*	1
165	*Digiteria debelis*	8
181	*Senecio strictifolius*	1
182	*Ficus capreifolia*	1
199	*Sorgastrum friesii*	1

continued

TWINSPAN No.	Plot/Species	Cover %
	Plot 96 = VEG96	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	18
5	*Cyperus articulatus*	8
6	*Miscanthus junceus*	3
9	*Panicum repens*	1
10	*Ludwigia stolonifera*	3
16	*Pycreus nitidus*	8
73	*Paspalidium obtusifolium*	18
81	*Alternanthera sessilis*	3
101	*Brachiaria* sp. 1	3
112	*Polygonum meisnerianum*	3
	Plot 97 = VEG97	
1	*Nymphaea nouchali*	38
2	*Leersia hexandra*	8
5	*Cyperus articulatus*	3
12	*Vossia cuspidata*	8
13	*Najas horrida*	38
22	*Nymphoides indica*	3
23	*Lagarosiphon muscoides*	8
112	*Polygonum meisnerianum*	1
	Plot 98 = VEG98	
1	*Nymphaea nouchali*	18
2	*Leersia hexandra*	8
5	*Cyperus articulatus*	1
10	*Ludwigia stolonifera*	8
13	*Najas horrida*	38
14	*Potamogeton thunbergii*	3
23	*Lagarosiphon muscoides*	8
73	*Paspalidium obtusifolium*	1
112	*Polygonum meisnerianum*	1
	Plot 99 = VEG99	
1	*Nymphaea nouchali*	18
2	*Leersia hexandra*	1
5	*Cyperus articulatus*	1
7	*Schoenoplectus corymbosus*	3
10	*Ludwigia stolonifera*	8
13	*Najas horrida*	18
23	*Lagarosiphon muscoides*	38
43	*Aeschynomene fluitans*	1
73	*Paspalidium obtusifolium*	18

TWINSPAN No.	Plot/Species	Cover %
	Plot 100 = VEG100	
2	*Leersia hexandra*	8
5	*Cyperus articulatus*	3
7	*Schoenoplectus corymbosus*	3
8	*Eleocharis dulcis*	1
10	*Ludwigia stolonifera*	18
11	*Oryza longistaminata*	1
13	*Najas horrida*	3
14	*Potamogeton thunbergii*	3
23	*Lagarosiphon muscoides*	3
45	*Eleocharis acutangula*	3
73	*Paspalidium obtusifolium*	8
78	*Utricularia* sp. 3	1
81	*Alternanthera sessilis*	1
83	*Brachiaria arrecta*	1
103	*Echinochloa stagnina*	1
108	*Ludwigia* sp.	18
112	*Polygonum meisnerianum*	1
	Plot 101 = VEG101	
1	*Nymphaea nouchali*	1
2	*Leersia hexandra*	8
5	*Cyperus articulatus*	1
6	*Miscanthus junceus*	75
10	*Ludwigia stolonifera*	1
11	*Oryza longistaminata*	1
16	*Pycreus nitidus*	1
20	*Fuirena pubescens*	1
30	*Cyperus denudatus*	1
83	*Brachiaria arrecta*	1
86	*Cycnium tubulosum*	1
94	*Sacchiolepis typhura*	1
108	*Ludwigia* sp.	1
112	*Polygonum meisnerianum*	1
117	*Utricularia* sp. 1	3
140	*Myriophyllum spicatum*	1
	Plot 102 = VEG102	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	3
5	*Cyperus articulatus*	8
7	*Schoenoplectus corymbosus*	18
8	*Eleocharis dulcis*	1
10	*Ludwigia stolonifera*	8

continued

TWINSPAN No.	Plot/Species	Cover %
11	*Oryza longistaminata*	1
14	*Potamogeton thunbergii*	8
45	*Eleocharis acutangula*	3
73	*Paspalidium obtusifolium*	1
78	*Utricularia* sp. 3	3
83	*Brachiaria arrecta*	1
217	*Alisma plantago-aquatica*	1
	Plot 103 = VEG103	
1	*Nymphaea nouchali*	8
2	*Leersia hexandra*	3
5	*Cyperus articulatus*	1
7	*Schoenoplectus corymbosus*	1
9	*Panicum repens*	18
10	*Ludwigia stolonifera*	8
13	*Najas horrida*	3
14	*Potamogeton thunbergii*	3
16	*Pycreus nitidus*	3
51	*Ottelia ulvifolia*	1
73	*Paspalidium obtusifolium*	3
81	*Alternanthera sessilis*	3
83	*Brachiaria arrecta*	3
87	*Cyperus dives*	1
94	*Sacchiolepis typhura*	1
	Plot 104 = VEG104	
1	*Nymphaea nouchali*	18
5	*Cyperus articulatus*	3
8	*Eleocharis dulcis*	1
10	*Ludwigia stolonifera*	1
13	*Najas horrida*	18
23	*Lagarosiphon muscoides*	1
51	*Ottelia ulvifolia*	3
112	*Polygonum meisnerianum*	3
117	*Utricularia* sp. 1	3
	Plot 105 = VEG105	
1	*Nymphaea nouchali*	18
2	*Leersia hexandra*	3
7	*Schoenoplectus corymbosus*	8
8	*Eleocharis dulcis*	1
11	*Oryza longistaminata*	1
13	*Najas horrida*	18
14	*Potamogeton thunbergii*	18
23	*Lagarosiphon muscoides*	3

TWINSPAN No.	Plot/Species	Cover %
51	*Ottelia ulvifolia*	8
112	*Polygonum meisnerianum*	8
	Plot 106 = VEG106	
1	*Nymphaea nouchali*	8
2	*Leersia hexandra*	8
7	*Schoenoplectus corymbosus*	18
10	*Ludwigia stolonifera*	1
11	*Oryza longistaminata*	18
14	*Potamogeton thunbergii*	8
23	*Lagarosiphon muscoides*	1
51	*Ottelia ulvifolia*	1
78	*Utricularia* sp. 3	1
112	*Polygonum meisnerianum*	1
	Plot 107 = VEG107	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	38
6	*Miscanthus junceus*	8
7	*Schoenoplectus corymbosus*	3
8	*Eleocharis dulcis*	1
9	*Panicum repens*	3
10	*Ludwigia stolonifera*	3
12	*Vossia cuspidata*	1
16	*Pycreus nitidus*	1
20	*Fuirena pubescens*	1
45	*Eleocharis acutangula*	1
73	*Paspalidium obtusifolium*	8
94	*Sacchiolepis typhura*	1
	Plot 108 = VEG108	
3	*Cynodon dactylon*	3
5	*Cyperus articulatus*	1
33	*Seteria sphacelata*	8
34	*Imperata cylindrica*	75
58	*Lonchocarpus capassa*	1
69	*Cyperus longus*	1
99	*Andropogon eucomus*	1
105	*Grewia bicolor*	1
106	*Hyparrhenia rufa*	3
115	*Sesbania sesban*	1
136	*Fimbristylis complanata*	1
138	*Hyperthelia dissoluta*	8
159	*Vetiveria nigritana*	8
192	*Hyphaene petersiana*	1
199	*Sorgastrum friesii*	8

continued

TWINSPAN No.	Plot/Species	Cover %
	Plot 109 = VEG109	
1	*Nymphaea nouchali*	3
2	*Leersia hexandra*	18
5	*Cyperus articulatus*	3
8	*Eleocharis dulcis*	18
9	*Panicum repens*	18
11	*Oryza longistaminata*	8
12	*Vossia cuspidata*	8
94	*Sacchiolepis typhura*	3
	Plot 110 = VEG110	
1	*Nymphaea nouchali*	8
2	*Leersia hexandra*	3
5	*Cyperus articulatus*	8
7	*Schoenoplectus corymbosus*	3
8	*Eleocharis dulcis*	18
9	*Panicum repens*	8
11	*Oryza longistaminata*	8
14	*Potamogeton thunbergii*	1
22	*Nymphoides indica*	8
94	*Sacchiolepis typhura*	38
	Plot 111 = VEG111	
5	*Cyperus articulatus*	1
6	*Miscanthus junceus*	3
25	*Cyperus pectinatus*	1
33	*Seteria sphacelata*	3
34	*Imperata cylindrica*	75
83	*Brachiaria arrecta*	8
86	*Cycnium tubulosum*	1
136	*Fimbristylis complanata*	3
199	*Sorgastrum friesii*	8
182	*Ficus capreifolia*	1
	Plot 112 = VEG112	
1	*Nymphaea nouchali*	38
2	*Leersia hexandra*	3
5	*Cyperus articulatus*	3
7	*Schoenoplectus corymbosus*	3
11	*Oryza longistaminata*	3
14	*Potamogeton thunbergii*	3
22	*Nymphoides indica*	8
78	*Utricularia* sp. 3	1
94	*Sacchiolepis typhura*	3

TWINSPAN No.	Plot/Species	Cover %
	Plot 113 = VEG113	
1	*Nymphaea nouchali*	8
2	*Leersia hexandra*	1
5	*Cyperus articulatus*	1
7	*Schoenoplectus corymbosus*	1
13	*Najas horrida*	8
14	*Potamogeton thunbergii*	8
117	*Utricularia* sp. 1	3
	Plot 114 = VEG114	
1	*Nymphaea nouchali*	18
2	*Leersia hexandra*	3
7	*Schoenoplectus corymbosus*	3
8	*Eleocharis dulcis*	1
12	*Vossia cuspidata*	8
14	*Potamogeton thunbergii*	8
22	*Nymphoides indica*	3
23	*Lagarosiphon muscoides*	1
51	*Ottelia ulvifolia*	3
94	*Sacchiolepis typhura*	1
117	*Utricularia* sp. 1	1
	Plot 115 = VEG114A	
1	*Nymphaea nouchali*	8
2	*Leersia hexandra*	3
7	*Schoenoplectus corymbosus*	3
8	*Eleocharis dulcis*	8
10	*Ludwigia stolonifera*	1
11	*Oryza longistaminata*	1
13	*Najas horrida*	18
14	*Potamogeton thunbergii*	3
23	*Lagarosiphon muscoides*	18
51	*Ottelia ulvifolia*	1
78	*Utricularia* sp. 3	1
	Plot 116 = VEG115	
1	*Nymphaea nouchali*	18
2	*Leersia hexandra*	3
5	*Cyperus articulatus*	1
7	*Schoenoplectus corymbosus*	18
8	*Eleocharis dulcis*	3
10	*Ludwigia stolonifera*	1
11	*Oryza longistaminata*	1
13	*Najas horrida*	1

continued

TWINSPAN No.	Plot/Species	Cover %
14	*Potamogeton thunbergii*	3
43	*Aeschynomene fluitans*	8
51	*Ottelia ulvifolia*	3
73	*Paspalidium obtusifolium*	1
78	*Utricularia* sp. 3	1
112	*Polygonum meisnerianum*	1
	Plot 117 = VEG	
1	*Nymphaea nouchali*	38
8	*Eleocharis dulcis*	1
13	*Najas horrida*	18
14	*Potamogeton thunbergii*	3
117	*Utricularia* sp. 1	8
	Plot 118 = VEG	
3	*Cynodon dactylon*	3
7	*Schoenoplectus corymbosus*	1
10	*Ludwigia stolonifera*	1
35	*Indigofera* sp. 1	1
38	*Scirpus cubensis*	1
49	*Lemna* sp.	1
87	*Cyperus dives*	8
88	*Echinochloa pyramidalis*	1
109	*Marsilea* sp. 1	3
115	*Sesbania sesban*	1
133	*Eragrostis* sp.	38
	Plot 119 = VEG118	
35	*Indigofera* sp. 1	3
67	*Aristida meridionalis*	8
113	*Pechuel-loeschea leubnitziae*	1
115	*Sesbania sesban*	1
134	*Eragrostis viscosa*	38
200	*Chloris virgata*	3
218	*Dicoma tomentosa*	3
219	*Ipomea* sp.	1
	Plot 120 = VEG119	
1	*Nymphaea nouchali*	1
3	*Cynodon dactylon*	8
57	*Eragrostis inamoena*	3
67	*Aristida meridionalis*	3
109	*Marsilea* sp. 1	3
132	*Eleocharis small*	8
134	*Eragrostis viscosa*	3
158	*Nesaea crassicaulis*	1
201	*Sporobolus* sp.	38
	Plot 121 = VEG120	
1	*Nymphaea nouchali*	1
3	*Cynodon dactylon*	8
9	*Panicum repens*	8
13	*Najas horrida*	1
20	*Fuirena pubescens*	3
23	*Lagarosiphon muscoides*	1
30	*Cyperus denudatus*	3
45	*Eleocharis acutangula*	8
57	*Eragrostis inamoena*	3
77	*Sporobolus spicatus*	1
109	*Marsilea* sp. 1	8
133	*Eragrostis* sp.	8
149	*Cyperus laevigatus*	3
154	*Utricularia* sp. 2	3
158	*Nesaea crassicaulis*	1
	Plot 122 = VEG121	
19	*Achyranthes aspera*	1
35	*Indigofera* sp. 1	1
66	*Aristida congesta*	1
67	*Aristida meridionalis*	3
77	*Sporobolus spicatus*	18
113	*Pechuel-loeschea leubnitziae*	1
116	*Sphaeranthus* sp.	1
220	*Pogonarthria squarrosa*	1
	Plot 123 = VEG122	
77	*Sporobolus spicatus*	8
	Plot 124 = VEG123	
3	*Cynodon dactylon*	1
19	*Achyranthes aspera*	1
24	*Acacia nigrescens*	18
29	*Croton megalobotrys*	1
46	*Euclea divinorium*	1
48	*Garcinia livingstonei*	18
54	*Seteria verticillata*	1
56	*Combretum hereroense*	1
58	*Lonchocarpus capassa*	3
64	*Abutilon angulatum*	1
70	*Dichrostachys cinerea*	1
116	*Sphaeranthus* sp.	3
121	*Acacia tortilis*	1
130	*Friesodielsia obovata*	3
139	*Kalanchoe lanceolata*	1

continued

TWINSPAN No.	Plot/Species	Cover %
153	*Sporobolus ioclados*	1
156	*Ximenia americana*	1
188	*Capparis tomentosa*	1
200	*Chloris virgata*	18
203	*Terminalia prunioides*	8
208	*Sansiveria aethiopica*	18
209	Acanthaceae sp. 1	1
221	*Adansonia digitata*	8
222	*Sarcostemma viminale*	3
	Plot 125 = VEG124	
19	*Achyranthes aspera*	1
24	*Acacia nigrescens*	38
28	*Diospyrus mespiliformis*	8
29	*Croton megalobotrys*	1
46	*Euclea divinorium*	1
52	*Panicum maximum*	1
54	*Seteria verticillata*	3
56	*Combretum hereroense*	1
58	*Lonchocarpus capassa*	3
59	*Maytenus heterophylla*	3
68	*Combretum mossambicense*	3
70	*Dichrostachys cinerea*	1
100	*Berchemia discolor*	1
114	*Rhus tenuineruis*	1
124	*Boerhavia diffusa*	3
130	*Friesodielsia obovata*	8
144	*Phoenix reclinata*	1
156	*Ximenia americana*	1
187	*Securinega virosa*	1
196	*Acrotome inflata*	3
209	Acanthaceae sp. 1	3
223	*Hippocratea africana*	3
224	*Enteropogon macrostachyus*	1
225	*Faidherbia albida*	1
	Plot 126 = VEG125	
24	*Acacia nigrescens*	38
28	*Diospyrus mespiliformis*	8
46	*Euclea divinorium*	1
48	*Garcinia livingstonei*	1
52	*Panicum maximum*	1
56	*Combretum hereroense*	1
59	*Maytenus heterophylla*	1

TWINSPAN No.	Plot/Species	Cover %
64	*Abutilon angulatum*	1
68	*Combretum mossambicense*	3
70	*Dichrostachys cinerea*	1
92	*Lonchocarpus nelsii*	1
100	*Berchemia discolor*	3
126	*Combretum imberebe*	3
129	*Digiteria eriantha*	1
130	*Friesodielsia obovata*	3
174	*Protasparagus africanus*	1
176	*Grewia flavescens*	3
187	*Securinega virosa*	3
209	Acanthaceae sp. 1	3
223	*Hippocratea africana*	3
226	*Oplismenus hirtellus*	8
227	*Boscia albitrunca*	1
228	*Ximenia caffra*	1
	Plot 127 = VEG126	
3	*Cynodon dactylon*	3
19	*Achyranthes aspera*	1
24	*Acacia nigrescens*	8
28	*Diospyrus mespiliformis*	38
29	*Croton megalobotrys*	1
48	*Garcinia livingstonei*	18
54	*Seteria verticillata*	3
58	*Lonchocarpus capassa*	3
59	*Maytenus heterophylla*	1
61	*Syzygium cordatum*	38
64	*Abutilon angulatum*	3
93	*Rhus quartiniana*	3
116	*Sphaeranthus* sp.	3
122	Acanthaceae sp. 2	1
137	*Amaranthus hybridus*	1
139	*Kalanchoe lanceolata*	1
144	*Phoenix reclinata*	18
153	*Sporobolus ioclados*	3
194	*Ficus thonningii*	3
196	*Acrotome inflata*	3
223	*Hippocratea africana*	1
229	*Bidens pilosa*	1
230	*Gomphrena celosioides*	1

continued

TWINSPAN No.	Plot/Species	Cover %
	Plot 128 = VEG127	
3	*Cynodon dactylon*	8
19	*Achyranthes aspera*	1
28	*Diospyrus mespiliformis*	18
29	*Croton megalobotrys*	3
52	*Panicum maximum*	3
54	*Seteria verticillata*	3
64	*Abutilon angulatum*	1
66	*Aristida congesta*	1
80	*Acacia erioloba*	3
92	*Lonchocarpus nelsii*	1
97	*Vernonia amygdalina*	1
105	*Grewia bicolor*	1
116	*Sphaeranthus* sp.	3
118	*Vernonia glabra*	3
128	*Crotolaria sphaerocarpa*	1
135	*Eragrostis superba*	1
151	*Lannea schweinfurthii*	1
155	*Vangueria infausta*	1
174	*Protasparagus africanus*	1
185	*Rhyncosia minima*	1
192	*Hyphaene petersiana*	1
203	*Terminalia prunioides*	1
204	*Kirkia acuminata*	8
205	*Sclerocarya birrea*	8
208	*Sansiveria aethiopica*	1
209	Acanthaceae sp. 1	1
212	*Sida cordifolia*	1
	Plot 129 = VEG128	
3	*Cynodon dactylon*	3
9	*Panicum repens*	1
19	*Achyranthes aspera*	1
24	*Acacia nigrescens*	1
29	*Croton megalobotrys*	8
34	*Imperata cylindrica*	3
48	*Garcinia livingstonei*	1
56	*Combretum hereroense*	1
65	*Cyathula orthacantha*	
66	*Aristida congesta*	3
67	*Aristida meridionalis*	3
71	*Diospyros lyciodes*	1
80	*Acacia erioloba*	1

TWINSPAN No.	Plot/Species	Cover %
92	*Lonchocarpus nelsii*	1
95	*Heteropogon contortus*	1
104	*Eragrostis pallens*	18
114	*Rhus tenuineruis*	1
116	*Sphaeranthus* sp.	3
128	*Crotolaria sphaerocarpa*	1
129	*Digiteria eriantha*	1
135	*Eragrostis superba*	1
138	*Hyperthelia dissoluta*	3
151	*Lannea schweinfurthii*	1
155	*Vangueria infausta*	3
187	*Securinega virosa*	1
203	*Terminalia prunioides*	8
204	*Kirkia acuminata*	3
206	*Asclepias fruticosa*	1
207	*Eragrostis/Sporobolus*	1
209	Acanthaceae sp. 1	1
215	*Phyllanthus* sp.	1
232	*Cymbopogon excavatus*	1
233	*Euphorbia* sp.	1
	Plot 130 = VEG129	
3	*Cynodon dactylon*	3
19	*Achyranthes aspera*	3
24	*Acacia nigrescens*	1
28	*Diospyrus mespiliformis*	38
29	*Croton megalobotrys*	8
52	*Panicum maximum*	1
54	*Seteria verticillata*	3
56	*Combretum hereroense*	1
58	*Lonchocarpus capassa*	1
66	*Aristida congesta*	1
67	*Aristida meridionalis*	3
71	*Diospyros lyciodes*	1
80	*Acacia erioloba*	1
90	*Hibiscus calyphyllus*	1
92	*Lonchocarpus nelsii*	1
96	*Cenchrus ciliaris*	1
104	*Eragrostis pallens*	3
107	*Kigelia africana*	8
114	*Rhus tenuineruis*	1
126	*Combretum imberebe*	3
128	*Crotolaria* sp.	1

continued

TWINSPAN No.	Plot/Species	Cover %
129	*Digiteria eriantha*	1
151	*Lannea schweinfurthii*	3
155	*Vangueria infausta*	1
174	*Protasparagus africanus*	1
202	*Solanum panduraeforme*	1
205	*Sclerocarya birrea*	8
209	Acanthaceae sp. 1	1
212	*Sida cordifolia*	1
231	*Plumbago zeylanica*	1
	Plot 131 = VEG130	
3	*Cynodon dactylon*	8
19	*Achyranthes aspera*	8
24	*Acacia nigrescens*	18
28	*Diospyrus mespiliformis*	8
29	*Croton megalobotrys*	8
46	*Euclea divinorium*	1
48	*Garcinia livingstonei*	3
52	*Panicum maximum*	1
56	*Combretum hereroense*	8
58	*Lonchocarpus capassa*	18
59	*Maytenus heterophylla*	1
64	*Abutilon angulatum*	3
72	*Jasminium fluminense*	3
82	*Justicea betonica*	1
89	*Ficus sycomorus*	8
97	*Vernonia amygdalina*	8
98	*Aerva leucura*	3
105	*Grewia bicolor*	1
107	*Kigelia africana*	3
116	*Sphaeranthus* sp.	3
125	*Carissa edulis*	1
134	*Eragrostis viscosa*	3
189	*Chloris gayana*	1
192	*Hyphaene petersiana*	1
206	*Asclepias fruticosa*	1
209	Acanthaceae sp. 1	1
	Plot 132 = VEG131	
24	*Acacia nigrescens*	18
28	*Diospyrus mespiliformis*	3
29	*Croton megalobotrys*	3
46	*Euclea divinorium*	3
48	*Garcinia livingstonei*	3

TWINSPAN No.	Plot/Species	Cover %
52	*Panicum maximum*	8
54	*Seteria verticillata*	3
64	*Abutilon angulatum*	1
65	*Cyathula orthacantha*	1
80	*Acacia erioloba*	3
89	*Ficus sycomorus*	8
98	*Aerva leucura*	3
100	*Berchemia discolor*	1
107	*Kigelia africana*	3
116	*Sphaeranthus* sp.	3
124	*Boerhavia diffusa*	1
185	*Rhyncosia minima*	1
187	*Securinega virosa*	1
192	*Hyphaene petersiana*	8
194	*Ficus thonningii*	3
196	*Acrotome inflata*	1
206	*Asclepias fruticosa*	1
	Plot 133 = VEG132	
3	*Cynodon dactylon*	18
35	*Indigofera* sp. 1	3
66	*Aristida congesta*	3
104	*Eragrostis pallens*	18
113	*Pechuel-loeschea leubnitziae*	8
192	*Hyphaene petersiana*	1
207	*Eragrostis/Sporobolus*	3
209	Acanthaceae sp. 1	1
218	*Dicoma tomentosa*	3

Appendix 9

Plant species documented during the Okavango AquaRAP with their TWINSPAN number and abbreviation

W. N. Ellery

TWINSPAN number	TWINSPAN abbreviation	SPECIES
1	NYMPNOUC	*Nymphaea nouchali*
2	LEERHEXA	*Leersia hexandra*
3	CYNODACT	*Cynodon dactylon*
4	CYPEPAPY	*Cyperus papyrus*
5	CYPEARTI	*Cyperus articulatus*
6	MISCJUNC	*Miscanthus junceus*
7	SCHOCORY	*Schoenoplectus corymbosus*
8	ELIODULC	*Eleocharis dulcis*
9	PANIREPE	*Panicum repens*
10	LUDWSTOL	*Ludwigia stolonifera*
11	ORYZLONG	*Oryza longistaminata*
12	VOSSCUSP	*Vossia cuspidata*
13	NAJAHORR	*Najas horrida*
14	POTATHUN	*Potamogeton thunbergii*
15	CERADEME	*Ceratophyllum demersum*
16	PYCRNITI	*Pycreus nitidus*
17	IPOMRUBE	*Ipomoea rubens*
18	PYCRMUND	*Pycreus mundii*
19	ACHYASPE	*Achyranthes aspera*
20	FUIRPUBE	*Fuirena pubescens*
21	LUDWLEPT	*Ludwigia leptocarpa*
22	NYMPINDI	*Nymphoides indica*
23	LAGAMUSC	*Lagarosiphon muscoides*
24	ACACNIGR	*Acacia nigrescens*
25	CYPEPECT	*Cyperus pectinatus*
26	LANTANGO	*Lantana angolensis*
27	VALLAETH	*Vallisneria aethiopica*
28	DIOSMESP	*Diospyrus mespiliformis*
29	CROTMEGA	*Croton megalobotrys*
30	CYPEDENU	*Cyperus denudatus*
31	FICUVERR	*Ficus verriculosa*
32	PERSSENE	*Persicaria senegalensis*
33	SETASPHA	*Seteria sphacelata*

TWINSPAN number	TWINSPAN abbreviation	SPECIES
34	IMPECYLI	*Imperata cylindrica*
35	INDIGOSP	*Indigofera* sp. 1
36	LAMIPINK	Lamiaceae pink flower
38	OXYCCUBE	*Oxycarium cubense*
39	CALDRENI	*Caldesia reniformis*
40	THELINTE	*Thelypteris interrupta*
41	TRAPNATA	*Trapa natans*
42	TYPHCAPE	*Typha capensis*
43	AESCFLUI	*Aeschynomene fluitans*
44	BRASSCHR	*Brasenia schreberi*
45	ELIOACUT	*Eleocharis acutangula*
46	EUCLDIVI	*Euclea divinorium*
47	FLOSGLOM	*Floscopa glomerata*
48	GARCLIVI	*Garcinia livingstonei*
49	LEMNA SP	*Lemna* sp.
50	NYMPLOTU	*Nymphaea lotus*
51	OTTEULVI	*Ottelia ulvifolia*
52	PANIMAXI	*Panicum maximum*
53	PHRAMAUR	*Phragmities mauritianus*
54	SETAVERT	*Seteria verticillata*
55	AZOLLASP	*Azolla* sp.
56	COMBHERE	*Combretum hereroense*
57	ERAGINAM	*Eragrostis inamoena*
58	LONCCAPE	*Lonchocarpus capassa*
59	MAYTHETE	*Maytenus heterophylla*
60	SYZYGERR	*Syzygium guineense*
61	SYZYCORD	*Syzygium cordatum*
62	THELCONF	*Thelypteris confluens*
63	AMMANIA	*Ammania* sp. 1
64	ABUTANGU	*Abutilon angulatum*
65	CYATORTH	*Cyathula orthacantha*
66	ARISCONG	*Aristida congesta*
67	ARISDIFF	*Aristida meridionalis*

continued

TWINSPAN number	TWINSPAN abbreviation	SPECIES
68	COMBMOSS	*Combretum mossambicense*
69	CYPELONG	*Cyperus longus*
70	DICHCINE	*Dichrostachys cinerea*
71	DIOSLYCI	*Diospyros lyciodes*
72	JASMFLUM	*Jasminium fluminense*
73	PASPOBTU	*Paspalidium obtusifolium*
74	PENNGLAU	*Pennistem glaucocladum*
75	ROTAMYRI	*Rotala myriophylloides*
76	SACCAFRI	*Sacchiolepis africana*
77	SPORSPIC	*Sporobolus spicatus*
78	UTRI SP3	*Utricularia* sp. 3
79	ABUTSPEC	*Abutilon* sp.
80	ACACERIO	*Acacia erioloba*
81	ALTESESS	*Alternanthera sessilis*
82	JUSTBETO	*Justicea betonica*
83	BRACLAXA	*Brachiaria arrecta*
84	CHARA SP	*Chara* sp.
85	COMMELSP	*Commelina* sp. 1
86	CYCNTUBU	*Cycnium tubulosum*
87	CYPEDIVE	*Cyperus dives*
88	ECHIPYRA	*Echinochloa pyramidalis*
89	FICUSYCO	*Ficus sycomorus*
90	HIBICALY	*Hibiscus calyphyllus*
91	HIBISPEC	*Hibiscus* sp. 1
92	LONCNELS	*Lonchocarpus nelsii*
93	RHUSQUAR	*Rhus quartiniana*
94	SACCTYPH	*Sacchiolepis typhura*
95	HETECONT	*Heteropogon contortus*
96	CENCCILI	*Cenchrus ciliaris*
97	VERNAMYG	*Vernonia amygdalina*
98	AERVLEUC	*Aerva leucura*
99	ANDREUCO	*Andropogon eucomus*
100	BERCDISC	*Berchemia discolor*
101	BRACH SP	*Brachiaria* sp. 1
102	CRINUMSP	*Crinum* sp.
103	ECHISTAG	*Echinochloa stagnina*
104	ERAGPALL	*Eragrostis pallens*
105	GREWBICO	*Grewia bicolor*
106	HYPAHIRT	*Hyparrhenia rufa*
107	KIGEAFRI	*Kigelia africana*
108	LUDWI SP	*Ludwigia* sp.
109	MARSI SP	*Marsilea* sp. 1
110	MIKASAGG	*Mikania sagittifera*
111	OTTEMURI	*Ottelia muricata*
112	PERSMEIS	*Polygonum meisnerianum*
113	PECHLEUC	*Pechuel-loeschea leubnitziae*
114	RHUSTENU	*Rhus tenuineruis*
115	SESBSESB	*Sesbania sesban*
116	SPHA SP	*Sphaeranthus* sp
117	UTRI SP1	*Utricularia* sp. 1
118	VERNGLAB	*Vernonia glabra*
119	VIGNA SP	*Vigna* sp.
120	VIGNLUTE	*Vigna luteola*
121	ACACTORT	*Acacia tortilis*
122	ACAN SP2	Acanthaceae sp. 2
123	ARROLEAF	*Arrow leaf spongy*
124	BOERHASP	*Boerhavia diffusa*
125	CARIEDUL	*Carissa edulis*
126	COMBIMBE	*Combretum imberebe*
127	CRASPICR	*Crassocephalum picridifolium*
128	CROTSPHA	*Crotalaria sphaerocarpa*
129	DIGIERIA	*Digiteria eriantha*
130	FRIEOBOV	*Friesodielsia obovata*
131	ELIOCSP1	*Eleocharis large*
132	ELIOCSP2	*Eleocharis small*
133	ERAGR SP	*Eragrostis* sp.
134	ERAGVISC	*Eragrostis viscosa*
135	ERAGSUPE	*Eragrostis superba*
136	FIMBCOMP	*Fimbristylis complanata*
137	AMARHYBR	*Amaranthus hybridus*
138	HYPEDISS	*Hyperthelia dissoluta*
139	KALALANC	*Kalanchoe lanceolata*
140	MYRISPIC	*Myriophyllum spicatum*
141	NIDORESE	*Nidorella resedifolia*
142	OLDEN SP	*Oldenlandia* sp.
143	PERSI SP	*Persicaria* sp.
144	PHOERECL	*Phoenix reclinata*
145	POLYCHEV	*Schoenoplectus carymbosus*
146	POTAMOSP	*Potamogeton* sp.
147	POTAPECT	*Potamogeton pectinatus*
148	SALVMOLE	*Salvinia molesta*
149	SCIRINCL	*Cyperus laevigatus*
150	SCLENATA	*Scleria* sp.
151	LANNSCHW	*Lannea schweinfurthii*
152	BRACHUMI	*Brachiaria humidicola*
153	SPORIOCL	*Sporobolus ioclados*
154	UTRI SP2	*Utricularia* sp. 2
155	VANGINFA	*Vangueria infausta*
156	XIMEAMER	*Ximenia americana*
157	PANIPARV	*Panicum parvifolium*
158	NESACRAS	*Nesaea crassicaulis*
159	VETINIGR	*Vetiveria nigritana*

continued

TWINSPAN number	TWINSPAN abbreviation	SPECIES
160	CYANFOEC	*Cyanotis foecunda*
161	PASPALSP	*Paspalum* sp
162	SPORAFRI	*Sporobolus africanus*
163	NITELLSP	*Nitella* sp.
164	ETHUCONY	*Ethulia conyzoides*
165	DIGIDEBE	*Digiteria debelis*
166	EUPHORSP	*Euphorbia* sp.
167	CYPE SP1	*Cyperus* sp. 1
168	LYTHRAC1	Lythraceae sp. 1
169	HIBIRIVU	*Hibiscus diversifolius*
170	ACACHEBE	*Acacia hebeclada*
171	HIBICANN	*Hibiscus cannabinus*
172	CASSIASP	*Cassia* sp.
173	ANTIVENO	*Antidesma venosum*
174	PROTSETA	*Protasparagus africanus*
175	GARDVOLK	*Gardenia volkensii*
176	GREWFLAV	*Grewia flavescens*
177	KYLLALBA	*Kyllinga alba*
178	PYCNCOER	*Pycnostachys coerula*
179	CLADMARI	*Cladium mariscus*
180	HYDRVERT	*Hydrocotyle verticillata*
181	SENESTRI	*Senecio strictifolius*
182	FICUCAPR	*Ficus capreifolia*
183	CYPEIMME	*Cyperus dives*
184	CYPE SP2	*Cyperus* sp. 2
185	RHYNMINI	*Rhyncosia minima*
186	GOSSHERB	*Gossypium herbaceum*
187	SECUVIRO	*Securinega virosa*
188	CAPPTOME	*Capparis tomentosa*
189	CHLOGUYA	*Chloris gayana*
190	HERMANSP	*Hermannia* sp.
191	EICHNATA	*Eichhornia natans*
192	HYPHPETE	*Hyphaene petersiana*
193	LEDELELE	*Ledelele*
194	FICUTHON	*Ficus thonningii*
195	PYCRFLAV	*Pycreus flavescens*
196	ACROINFL	*Acrotome inflata*

TWINSPAN number	TWINSPAN abbreviation	SPECIES
197	UROCMOSA	*Urochloa mosambicensis*
198	COLOMOPA	*Colophospermum mopane*
199	SORGFREE	*Sorgastrum friesii*
200	CHLOVIRG	*Chloris virgata*
201	SPOROBSP	*Sporobolus* sp.
202	SOLAPAND	*Solanum panduraeforme*
203	TERMPRUN	*Terminalia prunioides*
204	KIRKACUM	*Kirkia acuminata*
205	SCLEBIRR	*Sclerocarya birrea*
206	ASCLFRUT	*Asclepias fruticosa*
207	ERAGSPOR	*Eragrostis/Sporobolus*
208	SANSAETH	*Sansiveria aethiopica*
209	ACAN SP1	Acanthaceae sp. 1
210	DENECAPE	*Denekia capensis*
211	ZORNGLOC	*Zornia glochidata*
212	SIDACORD	*Sida cordifolia*
213	CHAMMIMO	*Chamaecrista mimosoides*
214	PEROPATE	*Perotis patens*
215	PHYLANSP	*Phyllanthus* sp.
216	ZIZIMUCR	*Ziziphus mucronata*
217	ALISPLAN	*Alisma plantago-aquatica*
218	DICOTOME	*Dicoma tomentosa*
219	IPOMSPEC	*Ipomea* sp.
220	POGOSQUA	*Pogonarthria squarrosa*
221	ADANDIGI	*Adansonia digitata*
222	SARCVIMI	*Sarcostemma viminale*
223	HIPPAFRI	*Hippocratea africana*
224	ENTEMONO	*Enteropogon macrostachyus*
225	ENTAAREN	*Faidherbia albida*
226	OPLIHIRT	*Oplismenus hirtellus*
227	BOSCALBI	*Boscia albitrunca*
228	XIMECAFF	*Ximenia caffra*
229	BIDEPILO	*Bidens pilosa*
230	GOMPCELO	*Gomphrena celosioides*
231	PLUMZEYL	*Plumbago zeylanica*
232	CYMBDIET	*Cymbopogon excavatus*
233	EUPHORSP	*Euphorbia* sp.

Appendix 10

The output table from the TWINSPAN cluster analysis of samples in the AquaRAP study

W. N. Ellery

See next page for table.

The output table from the TWINSPAN cluster analysis of samples in the AquaRAP study.

```
                                                      11                      11111111111111       1        1      11      1    1111    1111 11111
                  12345455623345344 122344 12211  116612 1114456677778899999900000001111111 22223706677777805666890133553838998222145352223932223
               6789999871747171660847258269514341281258130263550702587923678902456790234567503680138934679010136658134232832011023949547890414562

 34 IMPE CYLI  -----------------------------------------------------------------------------------------------346666---------------2-----2-3-----  00000
 57 ERAG INAM  ----------------------------1-----------2------------------------------------------------------------34444------2---3--2----------  00000
 86 CYCN TUBU  --------------------------------------------------------------------------------------------12------1---1--------------1----------  00000
199 SORG FREE  --------------------------------------------------------------------------------------------------13------------------------1-----  00000
109 MARS I SP  ---------------------------------------23---------------1-------------------------------------------------------2-----------------  00001
  9 PANI REPE  ----------------------------22----------3-------------1-1-1--------243-------------42--22-----3--22--54353----------43----1-------  0001
115 SESB SESB  1---------------------------11-1-------1---------------------------------------------------------111---------------1--------------  0001
152 BRAC HUMI  ------------------------------------2--------------------------------------------------------3--------5-2-------------1-----------  0001
 39 CALD RENI  ------------------------------------------------------1-----------------------------------2---------------------------------------  001000
 63 AMMA NIA   ------------------------------------------------------------------------------------------1---------------------------------------  001000
 83 BRAC LAXA  --------------------------------------------------------------11-------------------2--------1-------3-----------------------------  001000
 84 CHAR A SP  ----------------------------------1-------------------------------------------------4--342----------------------------------------  001000
131 ELIO CSP1  -------------------------------------------------------------------------------------2-4------------------------------------------  001000
143 PERS I SP  -------------------------------------------------------------------------------------------2--------------------------------------  001000
148 SALV MOLE  -----------------------------------------------1------------------------------------------32--------------------------------------  001000
150 SCLE NATA  -----------------------------------------------------------------------------------------1----------------------------------------  001000
180 HYDR VERT  ------------------------------------------------------------------------------------------2--1------------------------------------  001000
195 PYCR FLAV  -----------------------------------------------------------------------------------------1-2--------------------------------------  001000
 85 COMM ELSP  ----------------------------2-----1----------------------------------------------------------2------------------------------------  001001
 87 CYPE DIVE  ---------1-----------------------------3-----------------1-------------------------1---------2----------2-------------------------  001001
 91 HIBI SPEC  ------------------------------------------------------------------------------------------------------1---------------------------  001001
102 CRIN UMSP  ------------------------------------1------1---------------------------------------------------------2-1-2------------------------  001001
106 HYPA HIRT  ---------------------------------------------------------------------------------------------------2------------------------------  001001
119 VIGN A SP  ----------------------------------------------------------------------------------------------------3-----------------------------  001001
140 MYRI SPIC  ----------------------------1---------------2-----------------------------------------------1------------4------------------------  001001
159 VETI NIGR  ------------------------------------2----1--------------------------------------------------------13------------------------------  001001
165 DIGI DEBE  ----------------------------2---------------------------------------------------------------------3-------------------------------  001001
183 CYPE IMME  -------------------------------------------------------------------------------------------------------2--------------------------  001001
 44 BRAS SCHR  ------------------------------------------------3-4413------------------------------332-------------------------------------------  001010
 81 ALTE SESS  ---------------------------------------------------------12---1--------------------2------1---------------------------------------  001010
 94 SACC TYPH  -------------------------------------------------------------------1252-1----------1--113---1-1-----------------------------------  001010
  2 LEER HEXA  -----------------------------2-22-1------3--4---1-----4-12433132-2354221222--------2-121-124332-32--------------------------------  001011
 11 ORYZ LONG  ----------------------------1-----1--------56------------3----11-14-332--11---------------43133---------2-------------------------  001011
 22 NYMP INDI  ------------------------------------112----2---------------2---------33-2------------2--22-------------11-------------------------  001011
 75 ROTA MYRI  ----------------1-----------2-------3-5--------2---------------------------------------------------------4------------------------  001011
  1 NYMP NOUC  1-2-----------------1-------------------1432-22131231-21-22544-2443223534345123----3-2---1--12--2------2--------1-----------------  001100
  5 CYPE ARTI  ----------------1-------------------------------3--2233--13211232---2321--1--------1------2111----111-----------------------------  001100
  7 SCHO CORY  ------------------------------------2--1---2-------1333------224-342-221224--------1-1---------------1-112------------------------  001100
  8 ELIO DULC  -----------2-------------------------1---------12-4223--------1111-144--1321---------11------2--2---------------------------------  001100
 10 LUDW STOL  1------------2--1--------------12------1----------------322-33431-12-----11-1-2----3------2-1-----------------1-------------------  001100
 13 NAJA HORR  ----------------1-----------------------1-----------24-----5542-44-----3-414-4-33312----------------------------------------------  001100
 14 POTA THUN  -------------------------------------21--------2--------2---2-23-43--1233222-------2----3--------------2--------------------------  001100
 23 LAGA MUSC  1-1---------1---1----------------1------1-1----1-----1-11--3352-121-----14--3221421-----------------------------------------------  001100
 27 VALL AETH  -------------------------------------2--------------------------------------------------------------------------------------------  001100
 43 AESC FLUI  --1-------------------------1---1---1------------------------1------------3-1-----------------------------------------------------  001100
 45 ELIO ACUT  ----------------------------------------3---------42----------22---1-----------------1--2-----------------------------------------  001100
 51 OTTE ULVI  --------------------------------------1-------1-----------------231-----212--4-----1----------------------------------------------  001100
 73 PASP OBTU  ---------------------------------------------------------44-1431---3------1--------2----------------------------------------------  001100
 78 UTRI  SP3  --------------------------------------------------------------12--1---1--11----------------------------2--------------------------  001100
101 BRAC H SP  ----------------------------------1---------------------252---------------------------------------3-------------------------------  001100
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continued

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112 PERS MEIS  --------------------1-----1-1--4-1-------1---------------2211-1-231-------1---------------2-1-1-----------------------------------  001100
123 ARRO LEAF  -----------------------------1------3------1--------------------------------------------------------------------------------------  001100
133 ERAG R SP  ---------------------------------------53-----------------------------------------------------------------------------------------  001100
146 POTA MOSP  ----------------------------------1---------1-------------------------------------------------------------------------------------  001100
147 POTA PECT  --------------------------------------3--------1-----------------------------1-1--------------------------------------------------  001100
158 NESA CRAS  --------------------------------1-1--54-1--------------------------------------------------------------1--------1-----------------  001100
160 CYAN FOEC  ------------------------------------4---------------------------------------------------------------------------------------------  001100
161 PASP ALSP  ------------------------------------1---------------------------------------------------------------------------------------------  001100
162 SPOR AFRI  ------------------------------------2---------------------------------------------------------------------------------------------  001100
163 NITE LLSP  -------------------------------------------4--------------------------------------------------------------------------------------  001100
170 ACAC HEBE  --------------------------------------------2-------------------------------------------------------------------------------------  001100
217 ALIS PLAN  ---------------------------------------------------------------1------------------------------------------------------------------  001100
198 COLO MOPA  -------------------------------------------------------3--------------------------------------------------2-----------------------  001101
 12 VOSS CUSP  214----------1-------------64662---3---------------------2-3-------13---3--313---------------1------------------------------------  001110
 74 PENN GLAU  --3----------------------------35163----------------------------------------------------------------------------------------------  001110
 76 SACC AFRI  ----------------------------4------------1----------------------------------------------------------------------------------------  001110
 88 ECHI PYRA  ----------------------------1-1--646---1------------------------------------------------------------------------------------------  001110
157 PANI PARV  ----------------------------------1-----------------------------------------------------------------------------------------------  001110
164 ETHU CONY  -------------------------------1--------------------------------------------------------------------------------------------------  001110
166 EUPH ORSP  ----------------------------1-----------------------------------------------------------------------------------------------------  001110
167 CYPE  SP1  ----------------------------1-----------------------------------------------------------------------------------------------------  001110
168 LYTH RAC1  ----------------------------2-----------------------------------------------------------------------------------------------------  001110
171 HIBI CANN  -----------------------------3----------------------------------------------------------------------------------------------------  001110
172 CASS IASP  -----------------------------1----------------------------------------------------------------------------------------------------  001110
108 LUDW I SP  --------------------1-----------------------------------------4-----------------------------1-------------------------------------  001111
111 OTTE MURI  ----------------1------------------------------1-----1-------------------------1--------------------------------------------------  001111
 15 CERA DEME  -----231------4-111------2-------1------------------------------------------464244------------------------------------------------  010000
 50 NYMP LOTU  ----222-------2--------------------------------------------------------------1-554------------------------------------------------  010000
117 UTRI  SP1  --2--2-------34-11--1--------------------1143-----2----112------2------21--32--3----11---1--2-------------------------------------  010000
191 EICH NATA  ----------------1------------------------------2----------------------------------------------------------------------------------  010000
 53 PHRA MAUR  2-56------------------------4--34---1-------2------------------------------------------------3------------------------------------  010001
103 ECHI STAG  1------------------------------1------------------------------1-------------------------------------------------------------------  010001
  4 CYPE PAPY  3-2-----323-344336656666666--21---21-----3----------------------------------1-----------------1-----------------------------------  010010
 17 IPOM RUBE  1232-----2--1--2-2---32--1--1--42-11----------------------------------------------------------------------------------------------  010010
 18 PYCR MUND  2-----------54665-12----21--1---1------------------------------------------------------------22-3---------------------------------  010010
 21 LUDW LEPT  -----------33222-133---121----------------------1-------------------------------------1----2--22--------2-------------------------  010010
 32 PERS SENE  362------------------42---1211--1-----------------------1-------------------------------------------------------------------------  010010
 38 OXYC CUBE  --------4---55-35------3---------------1----------------3----------------------------------1-1------------------------------------  010010
 40 THEL INTE  --------23-3--3-3323---3--1--------------------21--------------------------------------------2323---------------------------------  010010
 41 TRAP NATA  -----54-------441--2----------------------------------------------------------5-1-------------------------------------------------  010010
 55 AZOL LASP  ------------111----11--1-----------------1----------------------------------------------------------------------------------------  010010
 60 SYZY GERR  ---------------------2------------------------------------------------------------------------------------------------------------  010010
120 VIGN LUTE  -----------2-1---11------11-------------------------------------------------------------------212---------------------------------  010010
127 CRAS PICR  --------2--------1-----------------------------------------------------------------------------1----------------------------------  010010
136 FIMB COMP  --------4------------------------------------------------------------------------------------------12-----------------------------  010010
154 UTRI  SP2  --------------21--------1---------------2-----------------------------------------------------------------------------------------  010010
169 HIBI RIVU  -----------------121----11--2-----------------------------------------------------------------------------------------------------  010010
179 CLAD MARI  -------------------1----------------------------------------------------------------------------------------------------------------  010010
181 SENE STRI  ---------4-------------------------------------------------------------------------------------1--1-------------------------------  010010
 30 CYPE DENU  ---------2-------2-2----------------1---2---------------------------------------------------12----------2-------------------------  010011
 49 LEMN A SP  ---------------1-1-------1---1---------1----------------1---------------------------------21--------------------------------------  010011
 62 THEL CONF  --------1-------2-1-----22-----------------------------------------------------------22--2----2-----------------------------------  010011
110 MIKA SAGG  -2-------2------------------------------------------------------------------------------------22----------------------------------  010011
182 FICU CAPR  ---------1----------------------------------------------------------------------------------------1-1-----------------------------  010011
 31 FICU VERR  ----------62----2------------------------------------------------------------------------2----433---------------------------------  010100
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continued

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  42 TYPH CAPE  -----------4----2-23-----1---------------------2--------2---------------------------------21-4--3---------------------------------  010100
 142 OLDE N SP  --------1------------1------------1-------------------------------------------------------2---------------------------------------  010100
  25 CYPE PECT  --------------23--22----------------------------------------------------------------1213333---------1-----------------------------  010101
 178 PYCN COER  --------1---------------------------------------------------------------------------------11--------------------------------------  010101
   6 MISC JUNC  --------56-5-----212------------------------------21------2--------3-----------------66436466-4641--2-----------------------------  01011
  16 PYCR NITI  --------4----------2---------------------------1---------23--------1---------------2423432421-1-2---------------------------------  01011
  20 FUIR PUBE  --------2----------2--------------------2--------------------------1-----------------2---121134231--------------------------------  01011
  47 FLOS GLOM  1----------------11---------2-----12-----1---------------1--------------------------------23--2-----------1-----------------------  01011
  33 SETA SPHA  ------------------------------------------------------1--1---------------------------------------3-32-2-1-----------1-12----2-----  011
 132 ELIO CSP2  ------------------------------------1-----------------------------------------------4-2-22-----------------2----3-----------------  011
 184 CYPE  SP2  --------------------------------------------------------------------------------------------------------2--------------1----------  011
 145 POLY CHEV  --------------------------------------------------------1-------------------------------------------------1--1--------------------  100
 149 SCIR INCL  ------------------------------------4---2-----------------------------------------------------------------1-22--------------------  100
  35 INDI GOSP  ---------------------------------------1--------------------------------------------------------------1---12--12-1-2--------------  101000
 141 NIDO RESE  ------------------------------------------------------------------------------------------------------1---1---2-------------------  101000
  36 LAMI PINK  -------------------------------------------------------------------------------------------------------------2--------------------  101001
  82 JUST BETO  -------------------------------------------------------2--------------------------------------------------2--32--------------1----  101001
 197 UROC MOSA  ----------------------------------------------------------------------------------------------------------2--23-------------------  101001
 201 SPOR OBSP  ---------------------------------------------------------------------------------------------------------------45-----------------  101001
 210 DENE CAPE  ----------------------------------------------------------------------------------------------------------1--1--------------------  101001
 211 ZORN GLOC  ----------------------------------------------------------------------------------------------------------1-----------------------  101001
 213 CHAM MIMO  ----------------------------------------------------------------------------------------------------------1-----------------------  101001
 214 PERO PATE  ----------------------------------------------------------------------------------------------------------1-----------------------  101001
 218 DICO TOME  -----------------------------------------------------------------------------------------------------------2-------2--------------  101001
 219 IPOM SPEC  -------------------------------------------------------------------------------------------------------------------1--------------  101001
 220 POGO SQUA  -----------------------------------------------------------------------------------------------------------------1----------------  101001
  77 SPOR SPIC  ----------------------------------------1-------------------------------------------------------------------22-3-43----2----------  10101
 113 PECH LEUC  -----------------------------------------------------------------------------------------------------------3-----1-1---1----------  10101
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 134 ERAG VISC  ----------------------------------------------------------------------------------------------------------------2--5---------2----  1011
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  99 ANDR EUCO  ------------------------------------------------------------------------------------1--------------1----------------2--1----------  1100
 138 HYPE DISS  ---------------------------------------------------------------------------------------------------3----------------------2-------  1100
 118 VERN GLAB  ----------------------------------1---------------------1----------------------------------------1-----------1-----------2--------  11010
   3 CYNO DACT  ----------------------------31------1--23--------------22---------------------------------1------2-2-----244-5543---45-22322331---  110110
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 139 KALA LANC  ---------------------------------------------------------------------------------------------------------------2--------1-----1---  110110
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 128 CROT SPHA  ----------------------------------------------------------------------------------------------------------1---1----------111------  110111
 207 ERAG SPOR  -----------------------------------------------------------------------------------------------------------2--------------1-------  110111
 212 SIDA CORD  ----------------------------------------------------------------------------------------------------------2--------------1-1------  110111
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Appendix 11

Brief descriptions of the AquaRAP fish sampling sites

Roger Bills, Denis Tweddle, Ben van der Waal, Paul Skelton, Jeppe Kolding, and Shaft Nengu

See next page for table.

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
N1	N1	Nata River west of Gaborone main road bridge			4/6/2000	0830	RB, BV, DT	Turbid water, no flow, large pools in main river channel. *B. paludinosus, Oreochromis* spp. & *C. gariepinus.*	3m seine net, 2 pulls	Main river channel, presently a large open pool.	Mud in shallows, deeper water sand	1.2m	20
M1	M1	Thamalakane River at the new bridge in Maun	approx. 232500	approx. 200000	4/6/2000	1500	RB, BV, DT	Clear water - just starting to flow. Rain water - not the main flood.	3m seine & throw net	Main Thamalakane channel in Maun - grassy fringes	mud	50cm	20
S1	S1	Okavango River at Sepopa (Du Plessis's camp)	184439	221147	5/6/2000	1600	RB, BV, DT	Lots of juvenile *Barbus - B. multilineatus* abundant. Juvenile pike collected.	D-net	Vegetated grassy margins of main river channel	Fine sand/ mud	<1m	50m
D1	D1	Drotsky's campsite	Not recorded	Not recorded	5/6/2000	1700	RB, BV, DT	12 species - nothing dominating, variety of barbs, characins and cichlids	3m seine	Side channel running along camp site - low flow	Leaf litter over mud substrate.	50cm	<10m
OK1	OK1.1	Channel 1km upstream of Drotskys	182535	215310	7/6/2000	1230	RB, BV, DT, SN, MM, KBW, LM,	Clear water, fast flowing, overtopping levee, likely to be hippo channel	D-net	Flooded grass, 90% cover	Fine sand	0-500cm	20
OK1	OK1.2	Channel 100m upstream from OK1.1	182431.1	215310	7/6/2000	1300	RB, BV, DT, SN, MM, KBW, LM,	Clear water, fast flowing, overtopping levee, likely to be hippo channel	D-net, electro-fishing	Flooded grass, 100% cover	Fine sand	1000cm	10
OK1	OK1.3	*Vossia* fringe on west bank of main channel	182428	215306	7/6/2000	1450	RB, BV, DT, SN, MM, KBW, LM,	Inside of a bend, sampled in *Vossia* (not underneath), 100% cover	D-net	Floating grass mat	Unknown - other teams sampled here too	Unknown - other teams sampled here too	3
OK2	OK2.1	Approx 400m upstream of Drotskys on west bank of main channel	182450	215250	7/6/2000	1400	RB, BV, DT, SN, MM, KBW, LM,	Cattle water point	Large seine, 3m seine, electro-fisher	Small lagoon / channel	Sand and leaf litter	150cm	20
OK2	OK2.2	Water quality site OK2-D	182447	215256	7/6/2000	1800-0700	BV, DT, SN	*Vossia* edge, *Najas, Nymphaea, Lagorosyphom, Ceratophyllum*, negligible flow.	Gillnet	Backwater just off main river	Sand/detritus	3000cm	90m

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK2	OK2.2	Water quality site OK2-D	182447	215256	7/6/2000	1545-1555	BV, DT, RB, SN	*Vossia* edge, *Najas, Nymphaea, Lagorosyphom, Ceratophyllum*, negligible flow.	D-net	Backwater just off main river	Sand/detritus	2000cm	2
OK2	OK2.3	Nearer shore than site 2.2			7/6/2000	1600-1615	BV, DT, RB, SN	Flooded grasses, *Phragmites, Nymphaea*	3m Seine, D-net	Newly flooded grassland	Sand	400-1000cm	10
OK3	OK3.1	Upstream Mohembo pontoon site - weedy margins	181642	214720	8/6/2000		BV, RB, DT	Baits used: snails, maggots and worms. Hooks = size 3-4.	local fishermen - bought some of their catch	Weed beds on channel margins, little flow	Mud	<2m	4 fishermen's catches examined - area unknown
OK3	OK3.2	Downstream Mohembo pontoon site - river channel	181630	214742	8/6/2000		BV, DT	At the downstream ferry landing - concrete slipway	25m seine x 2 pulls	Main river channel, fast flow with some aquatic Potamogeton in margins	sand & mud	1.5m	30m
OK3	OK3.3	Downstream Mohembo pontoon site - swamp below road	181630	214742	8/6/2000		RB	In the process of draining back into the main channel - many juvenile cichlids present.	D- & throw net	Open pool and channel in marginal swamp	sand & mud	<50cm	5m
OK4	OK4.1	Island in main river channel upstream of Shakawe	181726	214837	8/6/2000	Lunchtime	BV, RB, DT		D-net & 3m seine	Island bank in mid river channel, sand substrate	Sand	1.2m	10
OK4	OK4.2	Island in main river channel upstream of Shakawe	181726	214837	8/6/2000	Lunchtime	BV, RB, DT	*Leptoglanis* in sand and *Opsaridium* in open water, DNA samples collected	D-net & 3m seine	Vegetated grassy channel in centre of a small island	Sand	80cm	10m
OK5	OK5.1	Sand bank - inner bend on east bank of river at the northern end of Shakawe town	182029	215009	8/6/2000	Afternoon	BV, RB, DT	*Opsaridium* and *Leptoglanis* present	D-net & 3m seine	Open sand channel	Sand	<50cm	10m

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK5	OK5.2	Shallow, vegetated marginal pool cut-off from the river channel	182029	215009	8/6/2000	Afternoon	BV, RB, DT	*Rhabdalestes* and *Barbus afrovernayi* dominant	D-net	Vegetated (90%) pool	Sand & mud	50cm	2m
OK5	OK5.3	west bank of river at Shakawe town	182146	215048	8/6/2000	late after-noon	RB, BV	Dominated by *Barbus thamalakanensis, B. fas-ciolatus, B. unitaeniatus* and *B. barnardi* (75% of catch)	3m seine	wooded bank at Shakawe - main channel but out o fflow, weed beds (*Potamogeton*)	mud	10-12m	50cm
OK6	OK6.1	Primary Geo-Ref point not sampled by fish team	-	-	-	-	-	-	-	-	-	-	-
OK6	OK6.2	Long lagoon off main channel at Samochima fishing project inlet	182543	215358	9/6/2000	1730-0730	BV, FU	Overnight set of gillnet fleets. Numerous DNA samples and vouchers kept from this gill net catch	gillnets	Water lily bed next to papyrus/reeds	sand/ organic detritus	2m	115 m
OK6	OK6.2	Long lagoon off main channel at Samochima fishing project inlet	182543	215358	9/6/2000	1100-1800	BV, FU	daytime set of gillnet fleets.	gillnets	Water lily bed next to papyrus/reeds	sand/ organic detritus	2m	115 m
OK6	OK6.3	Shakawe Fish-ing Lodge (Pryce's)			9-10/6/00	1600 & 0900	RB	*Labeo cylindricus* blood and DNA samples	Electro-fishing	Rocky jetty and marginal/emergant vegetation	Packed rock baskets	80cm	5m
OK6	OK6.4	Shakawe Fish-ing Lodge (Pryce's)			9/6/2000	1630	RB & FU	DNA & blood - *Barbus unitaeniatus*	3m seine	tree shadded side channel, fine sand substarte with leaf litter	sand & mud	50cm	20m
OK7	OK7	Not sampled by fish team	-	-	-	-	-	-	-	-	-	-	-
		Okavango River at Sepopa (Du Plessis's camp)	184439	221147	10/6/2000	1200	RB, PS & BV	*Pollimyrus castelnaui* and *anabantids* collected	D-net & 3m seine	Vegetated grassy margins of main river channel	Fine sand/ mud	<1m	50m

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK8	OK8.1	Flooded inlet at Randall's new Guma camp - around concrete pipe bridge - open water of pool	Not recorded	Not recorded	11/6/2000	1000	RB & PS	*Aplocheilichthys* present in high numbers - dominated by *A. johnstoni,* possibly *A. cf. moeroensis* also.	3m seine	Open surface water of pool, susbtare vegetated	fine sand-mud	40cm	40m
OK8	OK8.2	Flooded inlet at Randall's new Guma camp - around concrete pipe bridge - marginal grasses of pool	Not recorded	Not recorded	11/6/2000	1030	RB & PS	*Aplocheilichthys* present in high numbers - dominated by *A. johnstoni*	3m seine	Emergent sedges/ grasses	Fine sand-mud	30cm	30m
OK9	OK9.1	Guma Lagoon, near entrance channel	185741	22238	11/6/2000	1145	DT, FU	Waded over papyrus and fished around flooded stems. No fish movements observed.	Electric fishing	Papyrus edge of lagoon, extensive *Trapa* beds	Sand covered by ooze	3500cm	5m
OK9	OK9.2	Guma Lagoon, near entrance channel	185741	22238	11/6/2000	1145	RB, DT, BV, PS, FU	Castnet, no catch. *M. intermedium, C. theodorae, A.* sp., *P. philander, T. rendalli* in D-net under lagoon fringing vegetation.	D-net, castnet	On papyrus edge of lagoon, extensive Trapa beds	Sand covered by ooze	3500cm	5m
OK9	OK9.3	Guma Lagoon, near entrance channel	185741	22238	11/6/2000	1000-1800 (over-night setting)	DT, BV, FU	Gillnets set from OK9.1 alongside *Trapa* bed.	Gillnets	Edge of *Trappa natans* bed	Sand covered by ooze	3500cm	115m
OK10	OK10	Guma Lagoon, water inflow under papyrus fringe	185730	222312	11/6/2000	1430	RB, DT, BV, PS, FU	No fish in D-net or 3 m seine over sand bar. 25 m seine caught few *B. lateralis* and *B. thamalakensis* in two good pulls. *S. robustus* caught by angling. Water quality team recorded very low O2 levels.	D-net, 3 m seine, 20 m seine, angling	Sand ridge with strong current flowing from under papyrus fringe	sand, detritus	1000-3000cm	50

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK11	OK11.1	Guma Lagoon, Water affairs landing	185721	222239	11/6/2000	1600	RB, DT, BV, PS, FU	One haul with each seine. Small net had *B. thamalakensis, B. bifrenatus, B. poechi, B. multilineatus, B. fasciolatus, B. afrovernayi, A. hutereaui, A. johnstonii, A.* sp. Large net had cichlids: *P. acuticeps, P. philander, T. sparrmanii*, juv. *Serranochromis.*	3 m seine, 20 m seine	Sandy beach between reed/grass fringes. Washing point.	sand	500cm	10
OK12	OK12.1	Thoage channel			12/6/2000	1000-1030	RB, PS	*M. intermedium, C. theodorae juveniles, A. johnstonii, A. katangae, A. hutereaui*	D-net	Papyrus fringe root stocks			10
OK12	OK12.2	Thoage channel	185716	222421	12/6/2000	1100	RB & PS		D-net	Grassy fringe root stocks			2
OK13	13.1	Lagoon on western side of upper Thaoge channel	185134	222421	12/6/2000	1130	RB, PS	Open lagoon, deep water, difficult to sample by hand nets.	D-net	Marginal vegetation - *Trapa*, water lilies, grass fringing papyrus		4000cm	3
OK13	13.2	Island on upper Thaoge, down-stream from site 13.1. Flowing through flooded grass	185253	222330	12/6/2000	1300	RB, PS	Downstream from site 13 lagoon. Water flowing. Good variety of Barbs and characins. Dominated by *B. multilineatus.*	3m Seine, D-net	Flooded ground around the island - looking at shaded channel covered in leaf litter and flooded grass exposed to the sun	Very fine sand	Leafy area - 500, grass - 1000cm	10 each
OK14	OK14.1	Small lagoon behind Guma Camp	185705	222223	12/6/2000	1600	BV, PA, RB. PS	Lot more species identified than in site 8, took photos of *B.afrovernayi* body olive, bright orange line along length of body vs yellow extending to the end of the tail through the middle cordal rays. This is really an extension of site 8.	3m Seine	Small isolated pool / seasonally flooded	Muddy	1500cm shelved off to approx 400cm	30

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK14	OK14.2	Pool west of Guma Air-strip	185755	222206	13/6/00	1030	RB,DT, HM	No fish found, heard barbel, collected inverts and *Xenopus* tadpoles, dry bivalves on edge of pool, *Aracara/Mytela* algae	D-net	*Phragmites*? fringing muddy pool	Mud, horse manure and plant debris	400cm	5
OK14	OK14.3	Smaller pool west of Guma airstrip	185808	222155	13/6/2000	1100	RB,DT, HM	No vegetation, green froth (blue/green algae), metamorphosed *Xenopus*. *Barbus paludinosus* first record (large adults).	D-net	Shallow open turbid pool.	Very soft fine mud on edge	20cm	10
possi-bly the groups site OK14?		Maunachira channel	Not re-corded	Not re-corded	14/6/00	1030	BV, DT, PS, FU	Fish primarily in root stocks. *Salvinia* present. *Aethiomastacembelus fre-natus* and both perches.	D-net	Sand bar, root stocks of *Cyperus* and *Phragmites*	Coarse sand	0-500cm	5
OK15	OK15	Gadikwe heron colony	190945	231429	14/6/00	1200	BV, DT, PS, FE, LA	D-net caught most fish, seine caught large bivalves in ooze.	D-net, big seine	Open lagoon, *Py-creus* sedge border	Ooze	500-1500cm	15
OK16	OK16	Gadikwe HATB camp 11	191004	231442	14/6/00	1230-1300	BV, DT, FU	*Hemichromis* (photo-graphed) in heavy root cover in 300 mm in D-net, large catch of *B. lateralis* and two large *O. zambezense* (new distribu-tion record) in seine.	D-net, big seine	Landing site for camp, Lilies on left, *Cyperus articulatus* on right, *Thelypterus interrupta*.	Mud	0-1500cm	50
OK17	OK17	Maunachira channel	190920	231533	14/6/00	1500	RB, BV, DT, PS, FU	Strongly flowing channel 10-15 m wide, D-net up into *Nesaea* and mar-ginal vegetation. Juvenile *Hemichromis, Clarias* and *Pollimyrus*.	D-net	Drifts of flotsam (cut up *Nesaea* - prop damaged), marginal grass and swamp fig roots	Sand	2m	5
OK18	OK18	Maunachira channel	190925	231627	14/6/00	1530-1600	RB,BV,DT, PS	2 DNA *H. multifasciatus* #93,#94, varied riverine barbs and characins	D-net, 3 m seine	sandbank with *Ne-saea* bed and mar-ginal *Cyperus*	sand	<1m	10
OK19	OK19	Maunachira channel	190858	231644	14/6/00	1630	RB,BV,DT, PS	Sampled middle of chan-nel. DNA from *Opsaridi-um* #95,#96	3 m seine	open sand bank	sand	500cm	6
OK19	OK19.2	Maunachira channel, ~1/2 km down-stream of OK19	Not re-corded	Not re-corded	15/6/00	1000	RB, PS	*O. zambezense* (blood & DNA samples taken), *B. poechii, B. fasciolatus, B. thamalakanensis*	3 m seine, D-net	Large sandbank, entire width of channel	sand	up to 1m, mostly 30-40cm	40

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK20	OK20.1	Xakanaxa Lagoon, top	191031	232340	16/6/00	1630	DT, BV	Only small *Aplos* and 1 small *P. philander* behind fringe, *B. multilineatus, A. johnstonii* and 1 big P. *philander* on lagoon side .	D-net	Algal ooze on top of 40 cm water behind *Miscanthus* fringe on bank of lagoon	ooze	400cm	10
OK20	OK20.2	Xakanaxa Lagoon, top	191019	232338	16/6/00	1800-0700 (overnight setting)	DT, BV	Very large catch, crocodile attacking catfish in nets when we arrived.	gillnets	Nets set out from *Miscanthus* bank, alongside *Trapa* bed		2m	115
OK21	OK21.1	Xakanaxa Lagoon, middle	191105	232344	15/6/00	1730-0700 (overnight setting)	DT, BV		gillnets	Edge of sparse *Cyperus* in mid lagoon.		2m	115
OK21	OK21.1	Xakanaxa Lagoon, middle	191105	232344	16/6/00	1530	DT, BV	Underneath *Cyperus* roots - no fish caught.	D-net	Sparse *Cyperus* in mid lagoon.		2m	5
OK21	OK21.2	Xakanaxa Lagoon, middle	191108	232348	16/6/00	1540	DT, BV	*B. lateralis* observed in tree roots.	not fished	Swamp fig roots	sand	1200	0
OK21	OK21.3	Xakanaxa Lagoon, middle	191107	232342	16/6/00	1550	DT, BV	*Azolla* present. Edge *C. wittei* & *Bry. Lateralis.* In shallow area *T. ruweti* and *Aplo's.*	D-net	*Miscanthus* fringe and shallow flooded ground	mud	Vegetation fringe 1m depth, lagoon 20cm depth	5
OK22	OK22	Xakanaxa Lagoon, bottom	191126	232348	16/6/00	1630	DT, BV	Site 22a (Water Team) was in lagoon - our site was at vegetation fringe. No fish caught.	D-net & angling	*Miscanthus* fringe with small water lillies.	mud	1m	3
OK23	OK23.1	Paradise pools, Moremi	191215	232736	15/6/00	1530	RB, BV, DT, PS,FU	*Salvinia* pools - collected new *Aplocheilichthys* sp. in floating grass mat (11 DNA samples).	1x 3 m seine haul; 10 D-net hauls	dense marginal vegetation and floating grass mat; PS photo.	sand and mud	<1.2m	15
OK23	OK23.2	Paradise pools, Moremi	191213	232738	15/6/00	1700	RB, PS	open brackish pools with dead trees, animal water hole much polluted, juvenile *Oreochromis* and other cichlids including mouthbrooding P. *philander, B. paludinosus*	2x 3 m seine	shallow open turbid pool	soft fine organic mud with dung	30cm	60
OK		Isolated pool in Mopani woodland	191239	232524	16/6/00	1600	RB & PS	No fish present, *Xenopus* and backswimmers. Sampled by H. Masundire.	3m seine	Isolated rainwater pool in forest.	soft mud	80cm	10m
OK24	OK24	-	-	-	-	-	-	Fish team did not collect at this site	-	-	-	-	-

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK25	OK25	-	-	-	-	-	-	Fish team did not collect at this site	-	-	-	-	-
OK26	OK26	Moremi back-water	191328	232456	16/6/00	1630	RB & PS	*Barbus paludinosus* and several cichlids	3m seine	seasonally flooded pools	sand	50cm	60
OK27	OK27	Elephant pool!	Not re-corded	Not re-corded	16/6/00	1700	RB & PS	*Barbus barnardi* - unusual record, DNA and blood samples taken also DNA from juvenile S*argochro-mis* sp..	3m seine	seasonally flooded pools	soft mud	<1m	100m
OK28	OK28	Tsetse fly island	193239	230350	19/6/00	0900	RB & DT	Flowing water - varied collection of barbs, chara-cins, toppminows and cichlids	D-net	Flooded grassy margins of small channel	mud	1.2m	20m
OK29	OK29	-	-	-	-	-	-	Fish team did not collect at this site	-	-	-	-	-
OK30	OK30.1	Lunch site near Wildlife camp	193157	230452	18/6/00	1400-1440	RB & JK		D-net	Flooded grassy margins	mud	50cm	10m
OK30	OK30.2	Boro River channel near lunch site	193157	230452	18/6/00	1400-1440	DT & BV	40 mins - 9x *S. thumbergi* and 3x *S. robustus. Bry. lateralis* seen also. DNA and skeleton samples taken for *S. thumbergi.*	Angling	Open main channel	sand	2m	
OK30	OK30.3	Wildlife camp lagoon	193157	230440	19/6/00	Over night	BV & JK	Large catch dominated by predators - *Serrano-chromis*, pike, *Schilbe* and *Clarias*. DNA from *S. altus, S. angusticeps* and *Sargo. carlottae.*	Gill nets	Open water in flow-through lagoon	sand	2m	115
OK30	OK30.3	Wildlife camp lagoon	193157	230440	18/6/00	1200	DT & BV	5x *S. robustus* and 1x *S. thumbergi* (approx 20-30cm TL) - 8 casts.	Angling	Open channel and lagoon	sand	2-3m	
OK30	OK30.4	Between Oddballs and Wildlife camps - day setting of gill net	Not re-corded	Not re-corded	20/6/00	Afternoon	JK & BV	driving fish into gill net experiment	gill net - day setting	weedy margins of Boro channel	sand	3m	115

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK31	OK31.1	1/2km down-stream from Oddballs camp - side channel of Boro	193137	230548	17/6/00	1630	RB, DT & BV	Strong flow - part of net pushed over in current.	Gill nets	Vegetated side channel	sand	2m	115
OK31	OK31.2	1/2km down-stream from Odd-balls camp - margins of channel	193137	230548	17/6/00	1700	RB, DT & BV	Small barbs, *Aplos* and cichlids. Dominated by *Aplos*.	D-net	Grassy channel margins	mud	50cm	10m
OK32	OK32? Don't	~1km down from Delta camp.	193230	230615	19/6/00	1600	RB	Water was flowing, most-ly grass, some submerged *Ludwigia*. Fish fauna identical toothergrassy margin habitats.	D-net	Grassy channel margins	sand	40cm	5
OK33	OK33	-	-	-	-	-	-	Fish team did not collect at this site	-	-	-	-	-
OK34	OK34.1	Lagoon west of Oddballs camp	193157	230521	20/6/00	0830	DT & BV	Nets set in center of the lagoon.	Gill nets	Water-lily cover cut-off lagoon.	Mud	2m	115
OK34	OK34.2	Lagoon west of Oddballs camp	193157	230521	20/6/00	0830	RB & BV	GPS taken at this site - the lagoon's eastern margin.	D-net	Grassy margins of cut-off lagoon.	mud	50cm	5m
OK35	OK35.1	Isolated pool on east bank of Boro downstream of Oddballs	191239	232524	20/6/00	1030	RB & DT	No fish present, *Xenopus* tadpoles preserved.	D-net	Turbid, isolated rain pool in the process of drying up.	mud	<30cm	3m
OK35	OK35.2	Mokoro land-ing site - east side of Boro channel.	193124	230548	20/6/00	1100	RB & DT	Typical barb and aplo fauna for the area.	D-net	Flooded grassy mar-gins of Boro River.	mud	70cm	5m
OK36	OK36	Seasonally flooded grass-land & pools near Oddballs airstrip	193209	230557	20/6/00	1430	RB & DT	Small barbs, *Aplos* and cichlids.	3m seine & D-net	Shallow pools with emergent grasses.	sand & mud	20cm	30m
OK37	OK37	Pit at bottom of Oddballs airstrip	193213	230554	20/6/00	1530	RB & DT	No fish present	3m seine	Gravel pit - now open pool	Sand - mud	80cm	10m

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Time	Collectors	Remarks	Gear	Habitat type	Bottom type	Depth	Sampling area (m^2)
OK38	OK38	Oddballs camp - mo-koro landing site	193146	230524	21/6/00	0930	RB	New record for mollusc > given to CA. *Tilapia ruweti* and *Aplos.*	D-net	Grassy margins with leaf litter.	mud	<40cm	5m
S3	S3	Okavango River at Sepopa (Du Plessis's camp)	184439	221147	23/6/00	1600	RB, BV, DT	Grassy margins no longer flooded - very few *B. multilineatus.*	D-net	Vegetated grassy margins of main river channel	Fine sand/ mud	<1m	50m
M2	M2	Thamalakane River at the new bridge in Maun	approx. 232500	approx. 200000	24/6/00	1500	RB, BV, DT	Clear water flowing, flooded grassland fringes	2x 3m seines	Flooded grassy margins	fine sand & mud	30cm	10m
M3	M3	Boro River infront of Mark & Lee-Ann Nordin's house near Maun			24/6/00	1600	RB, BV, DT	Grassy margins of Boro channel	D-net & 3m seine	grassy margins and edge of open channel	fine sand & mud	1.2m	40m

Appendix 12

Checklist of the fishes caught at each site during the AquaRAP survey, June 2000

Roger Bills, Denis Tweddle, Ben van der Waal, Paul Skelton, Jeppe Kolding, and Shaft Nengu

Fishes marked with * were caught in the gillnets and were measured on site as total length (TL), i.e. to the tip of the tail. All other fishes were preserved and returned to SAIAB, where taxonomic measurements were made using standard length (SL), i.e. to the point of flexure of the caudal fin.

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
N1	N1	Nata River west of Gaborone main road bridge			4/6/2000	*Clarias gariepinus*	3	116	150.4
						Oreochromis andersonii	1	109	
						Barbus paludinosus	40	19.3	46.6
						Barbus poechii	2	52.5	65.4
M1	M1	Thamalakane River at the new bridge in Maun	approx. 232500	approx. 200000	5/6/2000	*Barbus poechii*	8	44.1	70
						Barbus paludinosus	5	45.1	68.3
						Barbus bifrenatus	4	43.3	48
						Barbus thamalakanesis	15	26	38.5
						Barbus barnardi	17	29.2	35.6
						Aplocheilichthys katangae	2	18	18.3
						Tilapia ruweti	17	15.9	62.5
						Sargochromis sp.	5	28.5	52.3
						Pseudocrenilabrus philander	12	21.2	41.6
						Aplocheilichthys johnstoni	27	26.4	34.8
						Tilapia sparrmanii	14	22.5	48.2
						Tilapia rendalli	19	18.3	39.4
						Oreochromis andersonii	1	23.7	
						Pharyngochromis acuticeps	3	23.3	30.8
S1	S1	Okavango River at Sepopa (Du Plessis's camp)	184439	221147	5/6/2000	*Pseudocrenilabrus philander*	54	11.2	45.6
						Tilapia ruweti	1	60.3	
						Tilapia rendalli	3	23	42.3

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Tilapia sparrmanii	6	21.8	38.1
						Aplocheilichthys johnstoni	19	10.5	18.3
						Aplocheilichthys hutereaui	11	10.3	26.6
						Aplocheilichthys katangae	9	11	19.5
						Hemigrammocharax machadoi	4	20.5	29.4
						Hepsetus odoe	5	33.3	122
						Marcusenius macrolepidotus	1	81.5	
						Pollimyrus castelnaui	2	37	41.4
						Clarias theodorae	2	48.6	50.6
						Barbus afrovernayi	21	13.5	31.8
						Barbus bifrenatus	4	34	39.5
						Barbus fasciolatus	5	17	21.7
						Barbus haasianus	2	16.3	16.4
						Barbus kerstenii	2	22.5	23.3
						Barbus multilineatus	16	14	35.1
						Barbus radiatus	2	37	37.5
						Barbus thamalakanesis	17	15.8	36.3
						Coptostomabarbus wittei	4	15.4	24.6
D1	D1	Drotsky's campsite			5/6/2000	*Hydrocynus vittatus*	1	113.2	
						Aplocheilichthys johnstoni	2	26.5	28.8
						Barbus eutaenia	1	48.1	
						Barbus poechii	2	46.2	47.5
						Nannocharax macropterus	1	29.7	
						Barbus radiatus	5	33.9	43.1
						Micalestes acutidens	1	20.5	
						Pseudocrenilabrus philander	4	20.9	32
						Barbus unitaeniatus	1	35.8	
						Tilapia rendalli	1	56.8	
						Pharyngochromis acuticeps	2	41.1	42.7
						Sargochromis sp.	1	50.8	
OK1	OK1.1	Channel 1km upstream of Drotsky's	182535	215310	7/6/2000	Invertebrates			
						Synodontis sp.	1	45.4	
						Pseudocrenilabrus philander	3	15.8	30.2
						Leptoglanis cf. *dorae*	1	24.6	
						Aethiomastacembelus frenatus	2	46	50.3
						Chiloglanis fasciatus	13	15.7	22.4
						Micralestes acutidens	1	36.2	
						Nannocharax macropterus	52	28.4	35.6
						Labeo cylindricus	3	42.4	58.6

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Barbus eutaenia	15	34.9	53.7
OK1	OK1.2	Channel 100m upstream from OK1.1	182431.1	215310	7/6/2000	*Nannocharax macropterus*	30	29.1	38.6
						Barbus eutaenia	3	38.1	42.7
						Chiloglanis fasciatus	17	15.7	24.5
						Barbus thamalakanensis	1	26.4	
						Synodontis sp.	1	43.5	
						Aplocheilichthys johnstoni	1	28.6	
						Clarias theodorae	1	43.5	
						Pollimyrus castelnaui	1	57.3	
						Hemigrammocharax multifasciatus	1	33.8	
OK1	OK1.3	*Vossia* fringe on west bank of main channel	182428	215306	7/6/2000	*Rhabdalestes maunensis*	3	25.9	37.1
						Micralestes acutidens	6	21.9	30.9
						Aplocheilichthys johnstoni	15	13.3	29.6
						Aplocheilichthys katangae	1	23.1	
						Barbus eutaenia	2	46	47.5
						Pollimyrus castelnaui	1	23.3	
OK2	OK2.1	Approx 400m upstream of Drotskys on west bank of main channel	182450	215250	7/6/2000	*Serranochromis robustus*	1	95.2	
						Barbus poechii	6	39.3	48.3
						Pharyngochromis acuticeps	1	49.1	
						Barbus thamalakanensis	3	22.2	27.1
						Hemigrammocharax machadoi	2	21	
						Tilapia sparrmanii	1	55.3	
						Pseudocrenilabrus philander	3	36	40.4
						Barbus bifrenatus	3	28.7	36.2
						Rhabdalestes maunensis	1	30.1	
						Sargochromis sp.	1	56.4	
OK2	OK2.2	Water quality site OK2-D	182447	215256	7/6/2000	*Marcusenius macrolepidotus**	2	100	110
						*Mormyrus lacerda**	3	310	340
						*Petrocephalus catostoma**	3	90	90
						*Barbus poechii**	47	70	80
						*Brycinus lateralis**	25	80	130
						*Micralestes acutidens**	3	80	80
						*Hydrocynus vittatus**	37	110	170
						*Hepsetus odoe**	2	300	300

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						*Parauchenoglanis ngamensis**	1		
						*Schilbe intermedius**	56	90	310
						*Clarias gariepinus**	2	460	480
						*Clarias ngamensis**	1	370	370
						*Synodontis nigromaculatus**	19	170	280
						Synodontis spp.*	11	70	220
						*Serranochromis altus**	1		
						*Serranochromis angusticeps**	1	120	120
						*Serranochromis macrocephalus**	1	280	280
						*Oreochromis andersonii**	2	200	200
OK2	OK2.2	Water quality site OK2-D	182447	215256	7/6/2000	*Sargochromis codringtonii*	1	65.1	
						Pseudocrenilabrus philander	7	18.3	34
						Barbus haasianus	24	12.2	17.9
						Rhabdalestes maunensis	1	38.4	
						Aplocheilichthys hutereaui	12	13.1	15.2
						Aplocheilichthys johnstoni	45	12.3	26.5
						Barbus afrovernayi	1	12.8	
						Coptostomabarbus wittei	4	15	17
						Barbus multilineatus	1	22.9	
						Hemigrammocharax machadoi	5	19.2	22.7
						Azolla & invertebrates			
OK2	OK2.3	Nearer shore than site 2.2			7/6/2000	*Rhabdalestes maunensis*	90	23.4	44.6
						Aplocheilichthys hutereaui	2	13.8	17
						Barbus bifrenatus	1	30.8	
						Pseudocrenilabrus philander	1	27.7	
						Barbus multilineatus	6	24.8	26.3
						Barbus radiatus	1	37.1	
						Aplocheilichthys johnstoni	185	14	26.9
						Coptostomabarbus wittei	1	16.5	
						Hemigrammocharax machadoi	5	20.8	24
						Barbus afrovernayi	8	18	27
						Barbus thamalakanensis	3	26.4	27.5
						Invertebrates			
OK3	OK3.1	Upstream Mohembo pontoon site - weedy margins	181642	214720	8/6/2000	*Serranochromis robustus*	1	114.8	
						Oreochromis macrochir	1	90.3	
						Sargochromis codringtonii	1	97.1	

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
OK3	OK3.2	Downstream Mohembo pontoon site - river channel	181630	214742	8/6/2000	*Serranochromis robustus*	4	51.8	114.8
						Hydrocynus vittatus	2	106	147.3
						Micralestes acutidens	13	24.3	38.9
						Hemigrammocharax multifasciatus	3	28.5	33.6
						Aplocheilichthys katangae	3	24.8	26.8
						Aplocheilichthys johnstoni	23	22.1	32.6
						Barbus afrovernayi	81	22.1	31
						Rhabdalestes maunensis	50	28.2	40.6
						Pharyngochromis acuticeps	1	40.4	
						Sargochromis sp.	10	30.6	53.1
						Serranochromis sp.	1	48.8	
						Nannocharax macropterus	1	30.4	
						Barbus barnardi	2	26	26.2
						Oreochromis macrochir	1	43.5	
						Barbus thamalakanensis	7	23.5	27.4
						Tilapia sparrmanii	1	42.9	
						Barbus multilineatus	2	24.2	25.8
						Pseudocrenilabrus philander	1	27.6	
						Barbus bifrenatus	6	30.7	35
						Barbus fasciolatus	7	26.4	29.8
						Sargochromis sp.	4	41.5	54.3
						Barbus radiatus	12	33.4	48.5
						Barbus kerstenii	3		
OK3	OK3.3	Downstream Mohembo pontoon site - swamp below road	181630	214742	8/6/2000	*Barbus bifrenatus*	1	33.8	
						Barbus afrovernayi	29	11.7	27.8
						Barbus haasianus	17	16.7	19.7
						Hemigrammocharax machadoi	1	21.5	
						Barbus thamalakanensis	1	23.7	
						Aplocheilichthys hutereaui	2	13.5	14.1
						Aplocheilichthys johnstoni	160	13.7	28.9
						Pseudocrenilabrus philander	2	29	29.3
						Serranochromis robustus	2	103.8	111.3
						Tilapia rendalli	2	70.7	73.4
						Tilapia sparrmanii	3	55.7	79

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Oreochromis andersonii	2	60.4	63.3
						Oreochromis macrochir	20	56.7	77.3
						Sargochromis codringtonii	2	75.7	82
						Serranochromis angusticeps	1	99	
						Serranochromis altus	2	83.5	105.2
OK4	OK4.1	Island in main river channel upstream of Shakawe - outer margin	181726	214837	8/6/2000	*Aplocheilichthys johnstoni*	5	17.4	30.5
						Barbus thamalakanensis	6	26	26.9
						Barbus unitaeniatus	16	27.8	38
						Barbus fasciolatus	1	29.1	
						Barbus eutaenia	2	36.6	42.5
						Leptoglanis cf. *dorae*	7	17.3	26.5
						Opsaridium zambezense	40	15.4	32.2
						Barbus haasianus	3	13.3	13.4
						Hemigrammocharax machadoi	2	16.8	20.1
						Pseudocrenilabrus philander	4	18.4	25.8
						Pharyngochromis acuticeps	1	38.9	
						Oreochromis andersonii	1	63.3	
						Tilapia rendalli	1	58.3	
OK4	OK4.2	Island in main river channel upstream of Shakawe - inner channel	181726	214837	8/6/2000	*Aplocheilichthys johnstoni*	289	14.5	34.5
						Barbus eutaenia	4	33.2	44.1
						Tilapia sparrmanii	1	38.3	
						Barbus radiatus	3	39.9	41
						Serranochromis altus	1	61	
						Pharyngochromis acuticeps	7	25.7	54.6
						Rhabdalestes maunensis	77	27.5	40.1
						Barbus poechii	2	43.6	43.9
						Micralestes acutidens	2	36.6	42.3
						Schilbe intermedius	1	31	
						Nannocharax macropterus	1	30.9	
						Barbus fasciolatus	1	26.2	
						Aplocheilichthys hutereaui	1	14.8	
						Barbus thamalakanensis	11	22.3	26.2
						Pseudocrenilabrus philander	2	23.3	26.7
						Barbus afrovernayi	4	22.1	26.6

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Invertebrates			
OK5	OK5.1	Sand bank - inner bend on east bank of river at the northern end of Shakawe town	182029	215009	8/6/2000	*Aplocheilichthys johnstoni*	18	14.9	21.4
						Leptoglanis cf. *dorae*	7	18	23.8
						Barbus afrovernayi	1	27.6	
						Barbus unitaeniatus	3	28.2	30.1
						Opsaridium zambezense	47	19.4	33.7
OK5	OK5.2	Shallow, vegetated marginal pool cut-off from the river channel	182029	215009	8/6/2000	*Barbus afrovernayi*	5	22.5	27
						Aplocheilichthys johnstoni	25	14	24.9
						Hemigrammocharax machadoi	1	21.9	
						Hemigrammocharax multifasciatus	1	26.1	
						Pseudocrenilabrus philander	3	16.6	21.6
						Tilapia sparrmanii	1	38.7	
						Rhabdalestes maunensis	11	25.9	35.6
OK5	OK5.3	west bank of river at Shakawe town	182146	215048	8/6/2000	*Pseudocrenilabrus philander*	1	38.7	
						Barbus unitaeniatus	26	28.8	36.4
						Tilapia rendalli	9	26.5	42.1
						Pharyngochromis acuticeps	8	22.4	56.3
						Barbus fasciolatus	12	17.8	24.1
						Opsaridium zambezense	1	19	
						Barbus radiatus	1	38.5	
						Barbus thamalakanensis	15	24	28.2
						Sargochromis sp.	1	32.8	
						Barbus barnardi	17	24.1	38.3
						Tilapia sparrmanii	2	40.1	43
						Invertebrates			
OK6	OK6.1	Primary GeoRef point not sampled by fish team	-	-	-				
OK6	OK6.2	Long lagoon off main channel at Samochima fishing project inlet	182543	215358	9/6/2000	*Marcusenius macrolepidotus**	3	120	160

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						*Petrocephalus catostoma**	3	90	100
						*Barbus poechii**	1	80	80
						*Brycinus lateralis**	104	80	130
						*Hydrocynus vittatus**	9	120	310
						*Hepsetus odoe**	20	270	380
						*Schilbe intermedius**	37	110	300
						*Clarias gariepinus**	2	500	590
						*Clarias ngamensis**	1	470	470
						*Synodontis nigromaculatus**	2	200	200
						Synodontis spp.*	8	170	210
						*Pharyngochromis acuticeps**	2	90	110
						*Serranochromis angusticeps**	1	280	280
						*Tilapia sparrmanii**	1	170	170
						*Oreochromis macrochir**	1	270	270
						*Brycinus lateralis**	11	80	120
						*Hydrocynus vittatus**	1	180	180
						*Tilapia sparrmanii**	1	140	140
OK6	OK6.3	Shakawe Fishing Lodge (Pryce's)			10/6/2000	*Labeo cylindricus*	3	42.5	65.3
						Barbus eutaenia	2	34.6	34.9
						Barbus poechii	1	53.2	
						Sargochromis sp.	1	50	
						Tilapia sparrmanii	4	39.3	54.3
						Pseudocrenilabrus philander	10	16.7	47.5
						Pollimyrus castelnaui	2	50.9	59.9
						Hemigrammocharax multifasciatus	1	31.5	
						Hemigrammocharax machadoi	1	22	
						Schilbe intermedius	1	76.8	
OK6	OK6.3 & 6.4	Shakawe Fishing Lodge (Pryce's)			9/6/2000	*Labeo cylindricus*	5	37	83.8
						Barbus barnardi	1	22	
						Barbus thamalakanensis	2	24.5	26.4
						Barbus barotseensis	1	29	
						Barbus unitaeniatus	23	27.3	38.5
						Barbus eutaenia	2	35.3	36.8
						Nannocharax macropterus	3	29	30.5
						Hemigrammocharax multifasciatus	1		
						Micralestes acutidens	2	12.8	13
						Pseudocrenilabrus philander	6	17.9	52.5

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Pharyngochromis acuticeps	3	33.1	69
						Clarias gariepinus	1	134.5	
						Oreochromis andersonii	4	17.5	43
						Barbus barotseensis	1	27.1	
						Pseudocrenilabrus philander	3	34.3	41.1
						Barbus unitaeniatus	17	11.5	31
non OK site	DC1	Donovan's camp (DC) Xaro Lodge - lunch site			9/6/2000	*Barbus eutaenia*	3	35.5	44.4
						Nannocharax macropterus	1	32.4	
						Barbus afrovernayi	4	20.7	27.5
						Barbus radiatus	1	32.6	
OK7	OK7	Not sampled by fish team	-	-	-				
non OK site	S.2	Okavango River at Sepopa (Du Plessis's camp)	184439	221147	10/6/2000	*Barbus fasciolatus*	9	15.6	22.4
						Barbus afrovernayi	2	16.2	21
						Barbus haasianus	11	14	17.4
						Barbus barnardi	1	15.7	
						Barbus kerstenii	1	18.6	
						Barbus multilineatus	31	11.3	40
						Barbus thamalakanensis	3	29.6	33.2
						Barbus bifrenatus	1	35.3	
						Coptostomabarbus wittei	9	13	15
						Hemigrammocharax machadoi	4	20.3	22.7
						Hemigrammocharax multifasciatus	2	25.5	31.2
						Aplocheilichthys katangae	40	14	33.8
						Aplocheilichthys johnstoni	132	9.5	35.9
						Aplocheilichthys hutereaui	62	11	28.7
						Aplocheilichthys n.sp.	1	13.7	
						Hepsetus odoe	1	43.8	
						Tilapia sparrmanii	4	16.4	38
						Tilapia rendalli	5	33.3	40.3
						Sargochromis codringtonii	1	60.6	
						cichlid juvenile	1	30.9	
						Pseudocrenilabrus philander	79	9.6	55
						cichlid juvenile	2	15.5	15.5
						Ctenopoma multispine	3	61.5	92.7
						Microctenopoma intermedium	1	44	

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
OK8	OK8.1	Flooded inlet at Randall's new Guma camp - around concrete pipe bridge - open water of pool			11/6/2000	*Barbus thamalakanensis*	21	25.9	36
						Aplocheilichthys johnstoni	1	31.3	
						Tilapia sp.	1	24.1	
OK8	OK8.2	Flooded inlet at Randall's new Guma camp - around concrete pipe bridge - marginal grasses of pool			11/6/2000	*Tilapia sparrmanii*	1	38.3	
						Aplocheilichthys johnstoni	91	20.2	33
						Barbus thamalakanensis	3	27.5	29
OK9	OK9.1	Guma Lagoon, near entrance channel	185741	22238	11/6/2000	no fish present			
OK9	OK9.2	Guma Lagoon, near entrance channel	185741	22238	11/6/2000	*Pseudocrenilabrus philander*	43	15.1	41.8
						Clarias theodorae	2	19.1	58.8
						Microctenopoma intermedium	11	16.5	33
						Aplocheilichthys johnstoni	1	22.5	
						Aplocheilichthys hutereaui	23	9.1	22.5
OK9	OK9.3	Guma Lagoon, near entrance channel	185741	22238	11/6/2000	*Barbus poechii**	3	-	-
						*Brycinus lateralis**	25	-	-
						*Hepsetus odoe**	6	220	410
						*Clarias ngamensis**	1	470	470
						*Oreochromis andersonii**	6	220	240
						*Oreochromis macrochir**	1	230	230
OK9	OK9.3	Guma Lagoon, near entrance channel	185741	22238	12/6/2000	*Marcusenius macrolepidotus**	16	130	210
						*Mormyrus lacerda**	1	370	370
						*Petrocephalus catostoma**	3	70	90
						*Brycinus lateralis**	7	80	110
						*Hepsetus odoe**	12	220	340
						*Schilbe intermedius**	34	130	260
						*Clarias gariepinus**	8	370	610
						*Clarias ngamensis**	1	450	450

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						*Serranochromis macrocephalus**	3	230	240
						*Serranochromis robustus**	1	240	240
						*Tilapia rendalli**	1	240	240
						*Tilapia sparrmanii**	3	70	160
OK10	OK10	Guma Lagoon, water inflow under papyrus fringe	185730	222312	11/6/2000	*Brycinus lateralis*	4	67.2	87.2
						Barbus thamalakanensis	6	27.5	33.5
						Aplocheilichthys hutereaui	2	13.8	15.5
						Serranochromis robustus	1	205	
OK11	OK11.1	Guma Lagoon, Water affairs landing.	185721	222239	11/6/2000	*Aplocheilichthys johnstoni*	160	13.9	33.2
						Barbus thamalakanensis	242	24.7	36.3
						Barbus bifrenatus	87	28.2	46.9
						Barbus poechii	4	46.1	56.4
						Barbus fasciolatus	2	45.5	46.3
						Barbus afrovernayi	21	19.7	27.5
						Barbus haasianus	1	22.4	
						Barbus multilineatus	10	22	28.9
						Rhabdalestes maunensis	25	28.5	33.9
						Hemigrammocharax machadoi	1	25.3	
						Barbus barnardi	1	34	
						Aplocheilichthys katangae	1	16.3	
						Aplocheilichthys hutereaui	7	13.1	20.7
						Pseudocrenilabrus philander	6	26	53.9
						Tilapia rendalli	23	23.8	46.3
						Pharyngochromis acuticeps	24	20.2	71.5
						Serranochromis sp.	3	33.4	43.2
OK11	OK11.2	New Guma lagoon lodge jetty			11/6/2000	*Ctenopoma multispine*	2		
						Barbus haasianus	41	16.8	20.9
						Barbus multilineatus	3	22.9	26.3
						Aplocheilichthys johnstoni	1	31.9	
						Aplocheilichthys hutereaui	1	14.3	
						Barbus afrovernayi	4	20.7	25.4
						Pseudocrenilabrus philander	3	30.8	43.1
						Tilapia sparrmanii	1	19	
OK12	OK12.1	Thoage channel	1857	2224	12/6/2000	*Microctenopoma intermedium*	3	21.2	25.7
						Clarias theodorae	7	24	43.8

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Barbus afrovernayi	2	18.2	23
						Aplocheilichthys katangae	1	20.6	
						Aplocheilichthys johnstoni	25	8.5	29.3
						Aplocheilichthys hutereaui	7	19.5	25.7
OK12	OK12.2	Thoage channel	185716	222421	12/6/2000	*Microctenopoma intermedium*	2	17.5	26.2
						Rhabdalestes maunensis	2	28.6	28.7
						Aplocheilichthys katangae	10	13	19
						Aplocheilichthys johnstoni	4	15.3	19.2
						Aplocheilichthys hutereaui	2	10.2	13.8
OK13	13.1	Lagoon on western side of upper Thaoge channel	185134	222421	12/6/2000	*Aplocheilichthys hutereaui*	13	10.8	20.9
						Aplocheilichthys johnstoni	121	6	29.5
						Barbus afrovernayi	2	21.2	23
						Hemigrammocharax machadoi	1	22.7	
						Pseudocrenilabrus philander	2	12.4	20.2
						Rhabdalestes maunensis	1	16.4	
OK13	13.2	Island on upper Thaoge, down-stream from site 13.1. Flowing through flooded grass.	185253	222330	12/6/2000	*Schilbe intermedius*	1	74.9	
						Tilapia sparrmanii	3	38.3	66.1
						Aplocheilichthys katangae	6	14.1	22.5
						Pseudocrenilabrus philander	13	15.6	48.4
						Barbus haasianus	7	18.1	22.8
						Rhabdalestes maunensis	1	36.3	
						Hemigrammocharax machadoi	2	20.4	22.2
						Aplocheilichthys johnstoni	39	8.6	38.3
						Barbus afrovernayi	1	25.3	
						Barbus multilineatus	1	19.8	
						Barbus bifrenatus	1	33.3	
						Barbus thamalakanensis	2	26.1	29.2
						Pollimyrus castelnaui	1	17.3	
						Aplocheilichthys hutereaui	1	21.4	
OK13	13.3	Island on upper Thaoge, down-stream from site 13.1. Under trees.	185253	222330	12/6/2000	*Barbus multilineatus*	37	13.7	22.7

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Barbus fasciolatus	8	17	25.9
						Barbus afrovernayi	2	19	20.3
						Barbus thamalakanensis	6	26.8	34.4
						Barbus kerstenii	2	24.1	25
						Hemigrammocharax machadoi	1	20.5	
						Pseudocrenilabrus philander	7	15.3	41
						Aplocheilichthys katangae	14	13.3	32.4
OK14	OK14.1	Small lagoon behind Guma Camp	185705	222223	12/6/2000	*Barbus barnardi*	37	21	30.7
						Coptostomabarbus wittei	3	14	25.3
						Barbus haasianus	2	17.5	18.2
						Barbus multilineatus	3	26.4	27.2
						Barbus eutaenia	6	30.4	33.6
						Barbus afrovernayi	28	19.7	32.5
						Aplocheilichthys johnstoni	241	17.2	33.8
						Barbus bifrenatus	16	25.3	45.1
						Barbus thamalakanensis	39	28.7	41
						Rhabdalestes maunensis	1	42	
OK14	OK14.2	Pool west of Guma Airstrip	185755	222206	13/6/00	no fish collected			
OK14	OK14.3	Smaller pool west of Guma airstrip	185808	222155	6/13/2000	*Pseudocrenilabrus philander*	16	13.7	51.2
						Barbus paludinosus	12	20.3	74.6
non-OK site	MC1	Maunachira channel - on the way to Gadikwe heron colony	Not recorded	Not recorded	14/6/00 (1030am)	*Marcusenius macrolepidotus*	1	92.8	
						Aplocheilichthys johnstoni	1	21	
						Pseudocrenilabrus philander	9	18	30.5
						Microctenopoma intermedium	2	22.5	23.5
						Aplocheilichthys katangae	1	16.7	
						Aethiomastacembelus frenatus	1	68.7	
						Clarias theodorae	10	24.8	57.5
						Sargochromis sp.	1	17.6	
						Pollimyrus castelnaui	13	18.5	47.3
						Tilapia ruweti	2	26.2	38.3
						Tilapia sparrmanii	2	30	39.9
						Invertebrates			
OK15	OK15	Gadikwe heron colony	190945	231429	14/6/00	*Aplocheilichthys johnstoni*	5	15.9	38.1

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Pharyngochromis acuticeps	3	26.2	52.2
						Pseudocrenilabrus philander	3	17.2	37.5
						Barbus bifrenatus	1	30.1	
OK16	OK16	Gadikwe HATB camp 11	191004	231442	14/6/00	*Hemichromis elongatus*	1	77.3	
						Pseudocrenilabrus philander	3	18.7	40.7
						Brycinus lateralis	1	51.5	
						Aplocheilichthys hutereaui	1	19.5	
						Aplocheilichthys n. sp.	1	19	
						Aplocheilichthys johnstoni	15	22.8	36.7
						Tilapia ruweti	2	37.1	46.6
						Opsaridium zambezense	1	79.5	83.7
						Sargochromis codringtonii	2	110.2	110.5
						Pharyngochromis acuticeps	9	78.5	97.7
						Brycinus lateralis	294	30	87.9
						Micralestes acutidens	28	36.7	56.2
						Barbus poechii	10	44	82.7
						Aplocheilichthys johnstoni	11	29	38.8
						Rhabdalestes maunensis	2	34.5	35.2
OK17	OK17	Maunachira channel	190920	231533	14/6/00	*Pseudocrenilabrus philander*	3	17.4	46.5
						Aplocheilichthys hutereaui	2	14.8	15.9
						Hemigrammocharax multifasciatus	1	26.1	
						Pollimyrus castelnaui	1	15.7	
						Clarias theodorae	2	16.5	50
						Ctenopoma multispine	1	44.3	
OK18	OK18	Maunachira channel	190925	231627	14/6/00	*Barbus afrovernayi*	1	39.7	
						Barbus bifrenatus	6	30.6	33.3
						Barbus thamalakanensis	2	25.2	25.3
						Barbus eutaenia	1	32.9	
						Aplocheilichthys katangae	1	17.6	
						Aplocheilichthys johnstoni	4	33.1	36.4
						Hemigrammocharax multifasciatus	7	25	38.5
						Pollimyrus castelnaui	1	47.1	
						Ctenopoma multispine	1	54.8	
						Pseudocrenilabrus philander	2	16.8	22.3
						Tilapia sparrmanii	8	37.5	46.5
OK19	OK19	Maunachira channel	190858	231644	14/6/00	*Opsaridium zambezense*	31	39.6	92.6
						Micralestes acutidens	2	46.6	57.8

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Pharyngochromis acuticeps	1	30.2	
OK19	OK19.2	Maunachira channel, ~1/2 km downstream of OK19	not taken	not taken	15/6/00	*Opsaridium zambezense*	20	25.6	90.3
						Micralestes acutidens	3	51.4	62.5
						Barbus poechii	2	47.5	48.7
						Clarias theodorae	3	33.5	88.9
						Pollimyrus castelnaui	2	32	33.3
						Barbus fasciolatus	2	25.3	31.8
						Barbus euteania	1	32.4	
						Aethiomastacembelus frenatus	1	76.8	
						Pseudocrenilabrus philander	4	14.5	30.3
						Barbus thamalakanensis	27	20.9	33.2
						Barbus bifrenatus	1	30	
						Aplocheilichthys johnstoni	2	30.8	33.7
						Tilapia sparrmanii	1	35.7	
						Hemigrammocharax machadoi	2	21	23.6
						Leptoglanis cf. *dorae*	5	18.5	23.5
OK20	OK20.1	Xakanaxa Lagoon, top	191031	232340	16/6/00	*Aplocheilichthys johnstoni*	3	18	27.6
						Aplocheilichthys hutereaui	23	11	19.1
						Aplocheilichthys n. sp.	1	17	
						Pseudocrenilabrus philander	3	16.5	51.5
						Barbus multilineatus	1	24.8	
OK20	OK20.2	Xakanaxa Lagoon, top	191019	232338	16/6/00	*Petrocephalus catostoma**	1	70	70
						*Barbus poechii**	13	70	100
						*Brycinus lateralis**	273	-	-
						*Hepsetus odoe**	28	260	380
						*Schilbe intermedius**	159	90	270
						*Clarias gariepinus**	27	330	670
						*Clarias ngamensis**	3	350	450
						*Serranochromis altus**	2	340	390
						*Serranochromis macrocephalus**	1	-	-
						*Tilapia sparrmanii**	1	80	80
						*Oreochromis andersonii**	1	300	300
OK21	OK21.1	Xakanaxa Lagoon, middle	191105	232344	15/6/00	*Mormyrus lacerda**	1	370	370
						*Barbus poechii**	14	70	90
						*Brycinus lateralis**	207	80	110

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						*Hepsetus odoe**	11	280	400
						*Schilbe intermedius**	98	100	290
						*Clarias gariepinus**	20	430	730
						*Clarias ngamensis**	2	380	490
						*Sargochromis carlottae**	1	200	200
						*Oreochromis andersonii**	3	240	340
						*Oreochromis macrochir**	4	200	270
OK21	OK21.1	Xakanaxa Lagoon, middle	191105	232344	16/6/00	no fish caught			
OK21	OK21.2	Xakanaxa Lagoon, middle	191108	232348	16/6/00	not fishable with D-net - tree roots			
OK21	OK21.3	Xakanaxa Lagoon, middle	191107	232342	16/6/00	*Rhabdalestes maunensis*	3	18.1	38.3
						Tilapia ruweti	3	28	54.9
						Aplocheilichthys johnstoni	4	24.1	34
						Aplocheilichthys hutereaui	28	10.4	20
						Aplocheilichthys n. sp.	4	13	17.3
						Pseudocrenilabrus philander	3	23.4	43.7
OK22	OK22	Xakanaxa Lagoon, bottom	191126	232348	16/6/00	no fish collected			
OK23	OK23.1	Paradise pools, Moremi	191215	232736	15/6/00	*Clarias theodorae*	2	101.2	192.7
						Aplocheilichthys n. sp.	26	11.9	19.3
						Aplocheilichthys hutereaui	14	15.8	24.4
						Pseudocrenilabrus philander	58	15.4	52.4
						Tilapia sparrmanii	1	58.5	
						Oreochromis sp.	1	30	
						Coptostomabarbus wittei	9	20.6	24.4
OK23	OK23.2	Paradise pools, Moremi	191213	232738	15/6/00	*Pseudocrenilabrus philander*	7	30	61.6
						Barbus paludinosus	2	17.6	50.2
						Oreochromis macrochir	26	24.6	43.6
						Oreochromis andersonii	7	34.6	42.8
						Tilapia sp.	17	16.3	29
OK?	OK?	Isolated pool in Mopani woodland	191239	232524	16/6/00	no fish collected			
OK24	OK24	-	-	-	-	not sampled by fish team			
OK25	OK25	-	-	-	-	not sampled by fish team			
OK26	OK26	Moremi backwater	191328	232456	16/6/00	*Barbus paludinosus*	3	41.2	58.3
						Barbus barnardi	2	33.2	22.5

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Pseudocrenilabrus philander	2	31.1	44.4
						Tilapia sparrmanii	13	21	40.2
						Tilapia rendalli	4	20.1	38.1
						Oreochromis andersonii	13	30	42.9
						Oreochromis macrochir	2	33.7	42.7
OK27	OK27	Elephant pool!	Not recorded	Not recorded	16/6/00	*Barbus barnardi*	15	23	28
						Sargochromis sp.	1	70.8	
						Tilapia sparrmanii	9	20.8	39.1
						Tilapia rendalli	9	17.7	48.6
						Pseudocrenilabrus philander	7	16.7	53
						Oreochromis andersonii	3	30.8	56.7
						Oreochromis macrochir	10	32.2	67.2
						Barbus thamalakanensis	1	26.8	
						Aplocheilichthys hutereaui	2	15.1	16.8
						Aplocheilichthys johnstoni	11	17.9	32
OK28	OK28	Tsetse fly island	193239	230350	19/6/00	*Coptostomabarbus wittei*	37	13.5	18
						Aplocheilichthys katangae	29	13.5	19.7
						Aplocheilichthys johnstoni	154	11.1	28.1
						Aplocheilichthys hutereaui	16	12.2	17.3
						Barbus paludinosus	1	22.2	
						Barbus multilineatus	18	20	28.5
						Hemigrammocharax multifasciatus	16	24.5	32.1
						Barbus bifrenatus	6	27.6	42.3
						Tilapia ruweti	6	26.5	43.8
						Barbus haasianus	19	15.3	19.8
						Tilapia sparrmanii	14	27.5	43.3
						Pseudocrenilabrus philander	24	12.1	36.5
						Rhabdalestes maunensis	1	26	
						Schilbe intermedius	1	68.6	
						Barbus thamalakanensis	39	20	34.8
						Barbus afrovernayi	45	18.8	28.1
						Invertebrates			
OK29	OK29	-	-	-	-	No collections made by the fish team here.			
OK30	OK30.1	Lunch site near Wildlife camp	193157	230452	18/6/00	*Aplocheilichthys hutereaui*	28	12.6	18
						Aplocheilichthys johnstoni	10	16.2	20.9
						Barbus haasianus	1	20	
						Pseudocrenilabrus philander	12	11.7	35.8
						Barbus afrovernayi	11	23	27.2

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Aplocheilichthys katangae	3	12.7	18.3
						Barbus thamalakanensis	3	22.7	26.1
						Tilapia sparrmanii	4	21.3	46.4
						invertebrates			
OK30	OK30.2	Boro River channel near lunch site	193157	230452	18/6/00	*Serranochromis thumbergi*	2	210	260
						Aplocheilichthys johnstoni	54	14.7	34.8
						Aplocheilichthys hutereaui	2	17.3	18.4
						Pseudocrenilabrus philander	2	21.9	23.4
OK30	OK30.3	Wildlife camp lagoon	193157	230440	19/6/00	*Marcusenius macrolepidotus**	5	130	270
						*Mormyrus lacerda**	1	290	290
						*Barbus poechii**	15	90	120
						*Barbus unitaeniatus**	3	100	100
						*Brycinus lateralis**	129	90	140
						*Hepsetus odoe**	32	180	420
						*Schilbe intermedius**	718	90	370
						*Clarias gariepinus**	14	370	820
						*Clarias ngamensis**	4	380	490
						*Synodontis nigromaculatus**	1	210	210
						Synodontis spp. *	6	170	210
						*Pharyngochromis acuticeps**	2	100	120
						*Sargochromis carlottae**	1	200	200
						*Sargochromis codringtoniii**	6	150	260
						*Serranochromis altus**	10	230	350
						*Serranochromis angusticeps**	6	220	290
						*Serranochromis macrocephalus**	15	180	300
						*Serranochromis robustus**	7	220	350
						*Serranochromis thumbergi**	10	230	300
						*Tilapia sparrmanii**	9	60	160
						*Oreochromis andersonii**	2	250	310
						*Oreochromis macrochir**	3	220	300
OK30	OK30.3	Wildlife camp lagoon	193157	230440	18/6/00	*Serranochromis thumbergi**	9	250	320
						*Serranochromis robustus**	3	250	32
OK30	OK30.4	Between Oddballs camp and Wildlife camp - day setting of gill net	Not recorded	Not recorded	20/6/00	*Hepsetus odoe**	15	180	330
						*Schilbe intermedius**	2	160	180
						*Pseudocrenilabrus philander**	1	60	60

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						*Serranochromis macrocephalus**	1	360	360
						*Serranochromis thumbergi**	4	210	260
						*Tilapia rendalli**	1	50	50
						*Tilapia sparrmanii**	5	50	150
						*Oreochromis andersonii**	1	260	260
						*Ctenopoma multispine**	1	80	80
OK31	OK31.1	1/2km down-stream from Oddballs camp - side channel of Boro	193137	230548	17/6/00	*Marcusenius macrolepidotus**	23	110	250
						*Mormyrus lacerda**	5	280	310
						*Petrocephalus catostoma**	4	80	100
						*Barbus paludinosus**	3	70	80
						*Brycinus lateralis**	65	80	130
						*Hepsetus odoe**	19	140	290
						*Schilbe intermedius**	175	90	210
						*Clarias gariepinus**	3	370	480
						*Clarias ngamensis**	1	280	280
						Synodontis spp. *	11	110	180
						*Pseudocrenilabrus philander**	1	70	70
						*Sargochromis codringtonii**	8	150	230
						*Sargochromis giardi**	1	190	190
						*Serranochromis macrocephalus**	2	240	280
						*Tilapia rendalli**	1	150	150
						*Tilapia sparrmanii**	44	80	190
						*Oreochromis andersonii**	4	220	260
						*Oreochromis macrochir**	3	180	280
OK31	OK31.2	1/2km down-stream from Oddballs camp - margins of channel	193137	230548	17/6/00	*Barbus haasianus*	22	15.8	19.7
						Aplocheilichthys hutereaui	240	13.2	17.5
						Barbus thamalakanensis	11	21.2	25
						Tilapia ruweti	2	33	38.2
						Pseudocrenilabrus philander	17	10	30.5
						Aplocheilichthys katangae	14	14.7	20.5
						Coptostomabarbus wittei	27	13.8	16.8
						Barbus multilineatus	1	22.4	
						Aplocheilichthys johnstoni	35	14	35.2

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Invertebrates			
		~1km down from Delta camp.	193230	230615	19/6/00	*Aplocheilichthys katangae*	1	11.8	
						Aplocheilichthys hutereaui	10	17.2	17.3
						Aplocheilichthys johnstoni	39	10.3	30.8
						Coptostomabarbus wittei	15	15.8	17
						Barbus haasianus	1	17.4	
						Barbus afrovernayi	34	14.9	23.5
						Hemigrammocharax multifasciatus	1	22.5	
						Pseudocrenilabrus philander	3	21	26.3
						Tilapia sparrmanii	2	19.5	20.3
OK33	OK33	-	-	-	-	Not sampled by fish team			
OK34	OK34.1	Lagoon west of Oddball's camp	193157	230521	20/6/00	*Marcusenius macrolepidotus**	25	110	230
						*Petrocephalus catostoma**	25	80	100
						*Barbus paludinosus**	4	70	90
						*Barbus poechii**	15	90	120
						*Brycinus lateralis**	184	70	140
						*Hepsetus odoe**	29	260	400
						*Schilbe intermedius**	136	80	320
						*Clarias gariepinus**	5	360	720
						*Clarias ngamensis**	1	370	370
						Synodontis spp. *	7	110	200
						*Sargochromis carlottae**	3	190	220
						*Sargochromis codringtonii**	2	150	150
						*Serranochromis angusticeps**	3	240	300
						*Serranochromis thumbergi**	1	230	230
						*Tilapia rendalli**	2	220	280
						Tilapia sparrmanii	4	130	150
OK34	OK34.2	Lagoon west of Oddball's camp	193157	230521	20/6/00	*Tilapia sparrmanii*	4	20	25.5
						Coptostomabarbus wittei	28	12.7	19
						Barbus haasianus	1	15.8	
						Aplocheilichthys hutereaui	70	11.5	22.3
						Aplocheilichthys katangae	4	14.7	21.4
						Pseudocrenilabrus philander	27	8.5	42.9
						Tilapia ruweti	4	25.6	34
						Barbus paludinosus	1	23.5	
						Barbus thamalakanensis	1	23.5	
						Aplocheilichthys johnstoni	52	14.6	28.9

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						invertebrates			
OK35	OK35.1	Isolated pool on east bank of Boro downstream of Oddball's	191239	232524	20/6/00	no fish collected			
OK35	OK35.2	Mokoro landing site - east side of Boro channel.	193124	230548	20/6/00	*Barbus multilieatus*	1	24.3	
						Barbus haasianus	10	15	18.3
						Coptostomabarbus wittei	9	15.3	17.3
						Pseudocrenilabrus philander	2	16.3	22.4
						Tilapia sparrmanii	2	31	35.2
						Aplocheilichthys hutereaui	5	13.7	16
						Aplocheilichthys johnstoni	5	11.8	18.2
OK36	OK36	Seasonally flooded grassland & pools near Oddballs airstrip	193209	230557	20/6/00	*Clarias theodorae*	3	30.3	35.7
						Barbus thamalakanensis	2	16	18.6
						Barbus haasianus	1	12.8	
						Coptostomabarbus wittei	5	11.1	14.4
						Barbus paludinosus	5	18	25
						Pseudocrenilabrus philander	11	12.9	20
						Tilapia sparrmanii	12	19.2	27.1
						Aplocheilichthys hutereaui	13	10	15
						invertebrates and tadpoles			
OK37	OK37	Pit at bottom of Oddball's airstrip	193213	230554	20/6/00	no fish collected			
OK38	OK38	Oddballs camp - mokoro landing site	193146	230524	21/6/00	*Barbus thamalakanensis*	4	22.7	25.6
						Aplocheilichthys johnstoni	20	15.9	19.3
						Aplocheilichthys hutereaui	85	10.5	23.7
						Aplocheilichthys katangae	29	10.5	23.2
						Pseudocrenilabrus philander	30	8.8	33.2
						Tilapia ruweti	6	28.4	37.6
S3	S3	Okavango River at Sepopa (Du Plessis's camp)	184439	221147	23/6/00	*Marcusenius macrolepidotus*	5	70.1	87.1
						Rhabdalestes maunensis	11	19.5	46.5
						Barbus thamalakanensis	30	24.9	35.1

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Pseudocrenilabrus philander	17	11.8	58.3
						Barbus bifrenatus	16	26.8	43.9
						Barbus radiatus	6	31.3	40.6
						Aplocheilichthys katangae	4	12	35.3
						Aplocheilichthys hutereaui	20	11.6	26
						Barbus afrovernayi	13	11.7	16.9
						Coptostomabarbus wittei	2	14.8	22
						Barbus haasianus	8	15.4	23.4
						Hemigrammocharax machadoi	11	21.2	24.2
						Barbus fasciolatus	21	19	24
						Barbus barnardi	2	19.6	28.5
						Aplocheilichthys johnstoni	43	10	24.2
						Barbus kerstenii	4	17	22.5
						Pollimyrus castelnaui	1	24.3	
						cichlid sp. (juvenile)	1	16.7	
						Invertebrates			
M2	M2	Thamalakane River at the new bridge in Maun	approx. 232500	approx. 200000	24/6/00	*Tilapia ruweti*	1	24	
						Oreochromis andersonii	7	16.4	25.7
						Tilapia rendalli	5	16.5	29.5
						Barbus bifrenatus	1	44	
						Barbus thamalakanensis	1	31	
						Barbus barnardi	6	29	39.2
						Barbus afrovernayi	1	28.6	
						Aplocheilichthys johnstoni	37	17.2	34.8
						Sargochromis sp.	2	48.6	52.2
						Tilapia sparrmanii	7	24	62.4
						Sargochromis sp.	13	13.2	22.6
						Pharyngochromis acuticeps	5	22.4	25.2
						Sargochromis sp.	3	23.2	28.9
						Serranochromis robustus	4	13.8	22.4
						invertebrates			
M3	M3	Boro River in front of Mark & Lee-Ann Nordin's house near Maun (Maun 3)			24/6/00	*Barbus afrovernayi*	197	19.3	32.4
						Barbus haasianus	188	17.2	23.9
						Barbus bifrenatus	1	35.4	
						Barbus thamalakanensis	13	29.3	40.7
						Schilbe intermedius	1	66.2	

continued

Geo Ref #	Field #	Locality	Latitude (UTM)	Longitude (UTM)	Date	Fish species	Numbers	SL Min (mm)	SL Max (mm)
						Rhabdalestes maunensis	9	20	51.2
						Coptostomabarbus wittei	116	14.8	27
						Tilapia ruweti	6	46.3	48.8
						Hepsetus odoe	1	80	
						Barbus barnardi	9	25.7	41.1
						Barbus multilineatus	57	19.3	24.3
						Aplocheilichthys katangae	1	23.8	
						Brycinus lateralis	7	45.3	87.4
						Tilapia sparrmanii	10	25.6	53.9
						Pseudocrenilabrus philander	21	31.2	51
						Barbus paludinosus	9	37	44.4
						Hemigrammocharax multifasciatus	14	26.5	38.4
						Aplocheilichthys hutereaui	1	14.3	
						Hemigrammocharax machadoi	31	20.3	27.7
						Aplocheilichthys johnstoni	171	14.7	37.1
						Invertebrates			
						Total number of fishes	**11261**		

Appendix 13

List of fish species collected during the AquaRAP Expedition

Roger Bills, Denis Tweddle, Ben van der Waal, Paul Skelton, Jeppe Kolding, and Shaft Nengu

Sampling area:	Shakawe		Guma		Moremi		Chief's Island	
No. of sites visited:	(19)		(14)		(19)		(16)	
Species	**No. fishes**	**No. sites**	**No. fishes**	**No. sites**	**No. fishes**	**No. sites**	**No. fishes**	**No. sites**
Marcusenius macrolepidotus (Peters)	5	2	16	1	1	1	53	3
Mormyrus lacerda Castelnau	3	1	1	1	1	1	6	2
Petrocephalus catostoma (Günther)	6	2	3	1	1	1	29	2
Pollimyrus castelnaui (Boulenger)	4	3	1	1	17	4	0	0
Barbus afrovernayi Nichols & Boulton	133	8	60	7	1	1	90	3
Barbus barnardi Jubb	20	3	38	2	17	2	0	0
Barbus barotseensis Pellegrin	2	2	0	0	0	0	0	0
Barbus bifrenatus Fowler	11	4	104	3	8	3	6	1
Barbus eutaenia Boulenger	33	8	6	1	2	2	0	0
Barbus fasciolatus Günther	21	4	10	2	2	1	0	0
Barbus haasianus David	44	3	51	4	0	0	55	7
Barbus kerstenii Peters	3	1	2	1	0	0	0	0
Barbus multilineatus Worthington	9	3	54	5	1	1	20	3
Barbus paludinosus Peters	0	0	12	1	5	2	14	2
Barbus poechii Steindachner	57	5	7	2	39	4	30	2
Barbus radiatus Peters	18	5	0	0	0	0	0	0
Barbus thamalakanensis Fowler	49	9	319	7	30	3	60	6
Barbus unitaeniatus Günther	85	5	0	0	0	0	3	1
Coptostomabarbus wittei David & Poll	5	2	3	1	9	1	121	6
Labeo cylindricus Peters	11	3	0	0	0	0	0	0
Opsaridium zambezense (Peters)	88	3	0	0	52	3	0	0
Hemigrammocharax machadoi Poll	17	7	5	4	2	1	0	0
Hemigrammocharax multifasciatus Boulenger	7	5	0	0	8	2	17	2
Nannocharax macropterus Pellegrin	88	6	0	0	0	0	0	0
Brycinus lateralis (Boulenger)	140	3	36	3	775	4	378	3
Hydrocynus vittatus Castelnau	49	4	0	0	0	0	0	0
Micralestes acutidens (Peters)	27	6	0	0	33	3	0	0
Rhabdalestes maunensis (Fowler)	233	7	30	5	5	2	1	1
Hepsetus odoe (Bloch)	22	2	18	2	39	2	95	4

continued

	Sampling area:	Shakawe		Guma		Moremi		Chief's Island	
	No. of sites visited:	(19)		(14)		(19)		(16)	
Species		No. fishes	No. sites	No. fishes	No. sites	No. fishes	No. sites	No. fishes	No. sites
Parauchenoglanis ngamensis (Boulenger)		1	1	0	0	0	0	0	0
Leptoglanis cf. *dorae* (non Poll)		15	3	0	0	5	1	0	0
Schilbe intermedius (Rüppell)		95	4	35	2	257	2	1032	5
Clarias gariepinus (Burchell)		5	3	8	1	47	2	22	3
Clarias ngamensis Castelnau		2	2	2	2	5	2	6	3
Clarias theodorae Weber		1	1	9	2	17	4	3	1
Chiloglanis fasciatus Pellegrin		30	2	0	0	0	0	0	0
Synodontis nigromaculatus Boulenger		21	2	0	0	0	0	1	1
Synodontis spp.		21	4	0	0	0	0	24	3
Aplocheilichthys hutereaui (Boulenger)		17	4	0	8	70	6	469	9
Aplocheilichthys johnstoni Günther		766	10	0	10	56	9	369	8
Aplocheilichthys katangae (Boulenger)		4	2	0	5	2	2	80	6
Aplocheilichthys n. sp.		0	0	0	0	32	4	0	0
Hemichromis elongatus (Guichenot)		0	0	0	0	1	1	0	0
Oreochromis andersonii (Castelnau)		9	4	6	1	27	5	7	3
Oreochromis macrochir (Boulenger)		23	4	1	1	42	4	6	2
Oreochromis spp.		0	0	0	0	1	1	0	0
Pharyngochromis acuticeps (Steindachner)		23	7	24	1	13	3	2	1
Pseudocrenilabrus philander (Weber)		46	13	90	7	104	12	130	11
Sargochromis carlottae (Boulenger)		0	0	0	0	1	1	4	2
Sargochromis codringtonii (Boulenger)		4	3	0	0	2	1	16	3
Sargochromis giardi (Pellegrin)		0	0	0	0	0	0	1	1
Sargochromis spp.		17	5	0	0	2	2	0	0
Serranochromis altus Winemiller & Kelso-Winemiller		4	3	0	0	2	1	10	1
Serranochromis angusticeps (Boulenger)		3	3	0	0	0	0	9	2
Serranochromis macrocephalus (Boulenger)		1	1	3	1	1	1	18	3
Serranochromis robustus (Günther)		8	4	2	2	0	0	10	2
Serranochromis thumbergi (Castelnau)		0	0	0	0	1	1	26	5
Serranochromis spp.		1	1	3	1	0	0	0	0
Tilapia rendalli (Boulenger)		12	3	24	2	13	2	4	3
Tilapia ruweti (Poll & Thys van den Audenaerde)		0	0	0	0	7	3	18	4
Tilapia sparrmanii A. Smith		15	9	8	4	35	7	100	10
Tilapia spp.		0	0	1	1	17	1	0	0
Ctenopoma multispine Peters		0	0	2	1	2	2	1	1
Microctenopoma intermedium (Pellegrin)		0	0	16	3	2	1	0	0
Aethiomastacembelus frenatus (Boulenger)		2	1	0	0	2	2	0	0
Total		**2336**	**54**	**1782**	**39**	**1813**	**48**	**3346**	**41**

Appendix 14

Summary datasheet for aquatic monitoring

COMMUNITY MONITORING PROJECT - SUMMARY OF FINDINGS

DATE:

NAME:

LOCATION:

DESCRIPTION OF SITE:

TEST TYPE	DETAILS	RESULTS	NOTES
Water depth	Distance from top of marker to water		cm (note if it has dropped or risen)
Water flow	Number of seconds to flow from 1 marker to the other		seconds
Water quality	Litter in water		yes/no (if yes, give details)
	Smell		yes/no (if yes, give details)
	Visibility		cm
	Temperature		°C
	pH		
	Colour		clear/brown/green etc.
	Nitrates		yes/no
	Phosphates		yes/no
	Bacteria		yes/no
Invertebrates	Shrimps		How many?
	Waterbugs		How many?
	Ramshorn snail		How many?
Aquatic weeds	Kariba weed		yes/no (if yes, note how large an area is covered)
	Water hyacinth		yes/no (if yes, note how large an area is covered)
	Water lettuce		yes/no (if yes, note how large an area is covered)
Aquatic plants	Plant species		increased or decreased
	Plant numbers		increased or decreased
Birds	Crane sightings		yes/no
	Skimmer sightings		To be addressed later
	Breeding sites		increased or decreased
Channels	New channels forming / old channels blocked		yes/no
Fish	Number of fish caught in 1 month		
Climate	Average monthly rainfall		mm
	Average monthly temperature		°C
Other natural resources	Status of natural resources in area		Increased / decreased

Appendix 15

List of aquatic bird species observed during the AquaRAP Expedition in the Okavango Delta, Botswana June 2000

Common name	Scientific name	Upper Panhandle	Lower Panhandle	Moremi/ Xakanaxa	Chief's Island
African Crake	*Crex egregia*			x	x
African Fish Eagle	*Haliaeetus vocifer*	x	x	x	x
African Jacana	*Actophilornis africanus*	x	x	x	x
African Marsh Harrier	*Circus ranivorous*	x	x	x	x
African Skimmer	*Rynchops flavirostris*	x	x	x	x
African Spoonbill	*Platalea alba*			x	
Bateleur	*Terathopius ecaudatus*				x
Bittern	*Botaurus stellaris*	x			x
Black Crake	*Amaurornis flavirostris*	x	x	x	x
Black Egret	*Egretta ardesiaca*	x		x	x
Blackcrowned Night Heron	*Nycticorax nycticorax*			x	x
Blacksmith Plover	*Vanellus armatus*	x	x	x	x
Burchell's Coucal	*Centropus burchelli*	x	x	x	x
Cape Reed Warbler	*Acrocephalus gracilirostris*	x	x	x	x
Cattle Egret	*Bubulcus ibis*	x	x	x	x
Dabchick	*Tachybaptus ruficollis*	x			
Darter	*Anhinga melanogaster*	x	x	x	x
Egyptian Goose	*Alopochen aegyptiacus*		x	x	x
Falcon	*Falco* sp.	x	x	x	x
Giant Kingfisher	*Megaceryle maxima*	x			
Glossy Ibis	*Plegadis falcinellus*			x	
Goliath Heron	*Ardea goliath*			x	x
Great White Egret	*Egretta alba*	x		x	x
Greenbacked Heron	*Butorides striatus*	x	x	x	x
Grey Heron	*Ardea cinerea*	x		x	x
Grey Lourie	*Corythaixaides concolor*	x	x	x	x
Hadeda Ibis	*Bostrychia hagedash*		x	x	x
Hamerkop	*Scopus umbretta*			x	

continued

Common name	Scientific name	Upper Panhandle	Lower Panhandle	Moremi/ Xakanaxa	Chief's Island
Knobbilled Duck	*Sarkidiornis melanotos*			x	
Lesser Jacana	*Microparra capensis*		x	x	x
Lesser Moorhen	*Gallinula angulata*				x
Little Egret	*Egretta garzetta*	x	x	x	x
Longtoed Plover	*Vanellus crassirostris*				x
Maccoa Duck	*Oxyura maccoa*				x
Malachite Kingfisher	*Alcedo cristata*	x	x	x	x
Marabou Stork	*Leptoptilos crumeniferus*			x	
Myer's Parrot	*Poicephalus meyeri*	x	x	x	x
Openbilled Stork	*Anastomus lamelligerus*	x	x	x	x
Osprey	*Pandion haliaetus*	x	x	x	x
Pied Kingfisher	*Ceryle rudis*	x	x	x	x
Pratincole	*Glareole* sp.	x	x	x	x
Purple Gallinule	*Porphyrio porphyrio*	x			x
Purple Heron	*Ardea purpurea*			x	x
Pygmy Goose	*Nettapus auritus*	x	x	x	x
Redbilled Teal	*Anas erythrorhyncha*				x
Reed Cormorant	*Phalacrocorax africanus*	x	x	x	x
Roufusbellied Heron	*Butorides rufiventris*	x	x	x	x
Sacred Ibis	*Threskiornis aethiopicus*			x	
Saddlebilled Stork	*Ephippiorhynchus senegalensis*			x	x
Slaty Egret	*Egretta vinaceigula*			x	x
Spurwinged Goose	*Plectropterus gambensis*	x	x	x	x
Squacco Heron	*Ardeola ralloides*	x	x	x	x
Swamp Boubou	*Laniarius bicolor*	x	x	x	x
Water Dikkop	*Burhinus vermiculatus*	x	x	x	x
Wattled Crane	*Grus carunculatus*			x	
Whiskered Tern	*Chlidonias hybridus*			x	x
Whitebacked Duck	*Thalassornis leuconotus*			x	x
Whitebacked Night Heron	*Gorsachius leuconotus*		x	x	x
Whitebreasted Cormorant	*Phalacrocorax carbo*	x		x	x
Whitefaced Duck	*Dendrocygna viduata*	x	x	x	x
Whitefronted Bee-eater	*Merops bullockoides*	x	x	x	x
Yellowbilled Duck	*Anas undulata*		x	x	x
Yellowbilled Stork	*Mycteria ibis*			x	x
Number of Species	**63 (total)**	**37**	**34**	**54**	**54**