

5.2 BOTSWANA

Introduction

Botswana is a land locked republic with a total area of 569 582 km² (219 916 square miles: Central Statistical Office, Gaborone). The population at the 1981 census was 1.325 million giving a mean population density of 2.33 persons/km². Botswana is bounded by Namibia in the north and west, by Zimbabwe in the northeast, and by South Africa in the south and southeast. Much of the country is situated in the Kalahari, a semi-desert region, and the only reliable water supply is from the Okavango, Chobe and Limpopo Rivers. Most of the country consists of an elevated, flat or undulating plain, at a little less than 1000 m asl. The plain is covered by Kalahari sands overlying Precambrian rock and supports open *Acacia* savanna. There is little surface drainage in the west and south, and in these regions true sand desert is found.

Climate

There are two main seasons. A hot wet 'summer' occurs from November through to March, when much of the rain falls during violent thunderstorms, while cooler dry 'winter' conditions prevail from April to September. Mean annual rainfall ranges from nearly 700 mm at Kasane in the extreme northeast to 250 mm in the extreme southwest. Temperatures can reach 44°C in central districts in March, but can fall to as low as -11°C during a winter night. Insolation is very high; the entire country receives between 3200-3600 hrs sunshine/yr.

Wetlands

In the southeast and east a few ephemeral streams may at times find their way to the Limpopo River, which forms part of the border between Botswana and South Africa. The main drainage system of the country is that of the Okavango River, which rises in Angola as the Cubango, crosses the Caprivi Strip, and flows into the northwest of Botswana, where it forms a delta and drains into a vast endorheic swamp. Evaporation from this swamp is high, and in most years floodwaters do not proceed beyond the southeastern fringes of the delta. However, in years of high floods, water overflows it and forms two continuation rivers, the Nhabe (Lake) River, which drains into Lake Ngami in the southwest, and the Boteti (Botletle) River, which drains first into Lake Xau (Dow) in central Botswana, but may finally spill into the Makgadikgadi (Makarikari) Pans, over 250 km from the delta. Occasionally excess water reaches the Zambezi River via the Selinda Spillway to the north, or the Mababe Depression via the Selinda Spillway and the Savuti Channel. In the north the swamps along the Chobe/Linyanti River extend into the Caprivi Strip region of Namibia.

Wetland Flora

Perennial Swamps: In perennial swamps subject to large seasonal fluctuations in water level, *Cyperus papyrus* is dominant, reaching 4 m in height. This species forms enormous mats, comprising culms, rhizomes and debris, which spread out from steep channel or lagoon banks over deep water for distances of 15-20 m. Although *C. papyrus* frequently grows in pure stands, many papyrus swamps contain other species. *Vossia cuspidata* is common among papyrus bases, and along all stream sides. Other species associated with papyrus include low growing forms such as *Polygonum pulchrum*, various Commelinaceae, e.g. *Floscopa glomerata*, and the swamp-fern *Cyclosorus interruptus*. *Miscanthidium junceum*, *Phragmites mauritianus* and *Typha capensis* are also associates of papyrus. These latter species may also grow in pure stands and become dominant locally. *Phragmites mauritianus* grows best in sluggish waters of medium depth and is prominent at channel sides away from the papyrus areas. *Miscanthidium* is widely distributed and usually occurs in pure stands in still less deeply inundated sites. It often occurs behind papyrus, where the channel banks slope comparatively gently, and also on levees. In the Okavango Delta populations of this plant form long 'ribbons' in the swamps, growing on submerged levees. *Typha* flourishes around pools and at channel bends and backwaters, in the shallowest permanent swamps.

On the outer margins of the tall communities, mats of short sedges such as *Cyperus nudicaulis*, *Pycnus nitidus* and *Scirpus cubensis*, or the grass *Leersia hexandra*, often float free on the surface of permanent ponds. Small floating mats are usually monospecific, but large ones generally contain several species. Both floating mats and low emergent mounds of peat tend to be colonised by the insectivorous plants *Drosera madagascariensis* and *Utricularia* spp., and by a species of *Xyris*. Rooted, floating-leaved aquatics also occur around the margins of the tall communities, and may appear between the rafts of floating vegetation. *Brasenia schreberi* and *Nymphaea caerulea* are the commonest of these species. They cover large areas of water, but are almost always associated with *Caldesia reniformis*, *Nymphaea lotus*, *Nymphoides brevipedicellata*, *N. indica*, *Potamogeton schweinfurthii* and *Trapa natans*. In deeper water, or water kept clear of floating species by wind and wave action, submerged aquatics form dense beds. Among these, *Ceratophyllum demersum*, *Lagarosiphon ilicifolius* and *Najas pectinata* are the commonest. Where areas of shallow water occur in permanent ponds there may be a sparse cover of emergent species, including *Eleocharis* spp., *Eriochrysis pallida*, *Phragmites mauritianus*, *Sacciolepis* spp. and *Typha capensis*.

Semi-permanent Ponds: Other rooted emergent species occur on the margins of shallow ponds. They grow in belts up to 50 m wide and also cover shallow patches in the ponds. Perhaps the most important species in these situations are *Leersia hexandra* and *Panicum repens*, together with species of *Eleocharis*, *Fimbristylis*, *Fuirena* and *Rhynchospora*. However, a spectrum of other species also occurs in these sites, but they seldom become dominant. These other herbaceous emergents include *Adenostemna caffrum*, *Alternanthera nodiflora*, *A. sessilis*, *Ammannia baccifera*, *A. priuriana*, *Cyperonon serrata*, *Centella asiatica*, *Commelina diffusa*, *C. fluviatilis*, *C. macrospatha*, *C. zambesica*, *Crassocephalum picridifolium*, *Ethulia conyzoides*, *Eulophia latilabris*, *Floscopa glomerata*, *Hygrophila prunelloides*, *Kosteletzkya buettneri*, *Limnophyton angolense*, *Ludwigia abyssinica*, *L. erecta*, *L. palustris*, *L. stolonifera*, *Melanthera*

scandens, *Microlepia spelunca* (a fern), *Oldenlandia lancifolia*, *Pentodon pentander*, *Polygonum limbatum*, *P. salicifolium*, *Pycnostachys coerulea*, *Senecio strictifolius*, *Torenia thouarsii*, *Thelypteris confluens* (a fern), *Xyris capensis*, *X. rehmannii* and *X. straminea*. Creepers in this vegetation include the parasitic forms *Cassytha filiformis*, *Cuscuta campestris* and *C. australis*, together with *Cissampelos mucronata*, *Cyclosorus interruptus* (a fern), *Ipomoea rubens*, *Mikania cordata* and *Vigna luteola*.

The surfaces of small ponds, which may not dry every year, tend to be totally occluded by a waterlily, *Nymphaea caerulea*, with a small admixture of *Caldesia reniformis*, *Nymphoides indica* and *Potamogeton thunbergii*. In other ponds in the same zone the floating fern *Azolla pinnata* is locally common, together with the duckweeds *Lemna perpusilla* and *Spirodela polyrhiza*. However, in the largest depressions, which are often centred on sections of abandoned river channel where wave motion inhibits the growth of floating-leaved forms, and water is perennial if not permanent, clear surfaces again occupy the centres of the lakes. In these places waterlilies grow around the peripheries inside the tall fringing vegetation. A submerged flora similar to that of the permanent swamps also prevails in these sites, but is possibly more diverse. In addition to the species mentioned previously, *Limnophila ceratophylloides*, *L. indica*, *Najas pectinata*, *Nesaea crassicaulis*, *Ottelia kunenensis*, *O. muricata*, *O. ulvifolia*, *Rotala myriophylloides*, *Vallisneria aethiopica* and *Wiesneria schweinfurthii* are prominent. A fern, *Ceratopteris thalictroides*, grows in shallow water in seasonal ponds, often tolerating total submergence. Under the open water, in mid-lake, small free-floating, but totally submerged species occur, the most important being *Aldrovanda vesiculosa*, *Utricularia benjaminiana*, *U. foliosa*, *U. reflexa* and *U. stellaris*.

Seasonal Swamps: Depressions which normally dry out completely, but which are nevertheless shallowly inundated for many months of the year, tend to be dominated by *Scirpus inclinatus* and *Cyperus articulatus*. These species attain a height of about 2 m, and frequently grow in association with *Cyperus denudatus*, *C. longus* and *Panicum repens*.

Riparian and Fringing Forests: Strips of mixed forest occur along watercourses in sites subject to prolonged inundation, and also around the margins of islands in the Okavango Delta. These are characterised by the presence of *Ekebergia capensis*, *Rhus quartiniana*, *Syzygium guineense* and *Phoenix reclinata*. In seasonal swamp zones a shrubby tree, *Ficus verruculosa*, occurs on levees and forms dense thickets around the edges of many low islands, often spending several months of the year with its trunk bases submerged. Trees which occur in seasonal swamp forest, at higher levels than the foregoing species, include *Acacia galpinii*, *A. karroo*, *A. nigrescens*, *Albizia harveyi*, *A. versicolor*, *Berchemia discolor*, *Carrisa edulis*, *Cassine transvaalensis*, *Combretum hereroense*, *Croton megalobotrys*, *Diospyros mespiliformis*, *Ficus natalensis*, *Garcinia livingstonei*, *Hyphaene benguellensis* var. *ventricosa*, *Kigelia africana*, *Lonchocarpus capassa* and *Sclerocarya caffra*. In addition to these *Acacia albida*, *A. erubescens*, *A. nigrescens*, *Allophylus africanus*, *Combretum imberbe*, *C. zeyheri*, *Croton megalobotrys*, *Erythrophleum africanum*, *Homalium abdessammadii*, *Pteleopsis myrtifolia*, *Strychnos potatorunz*, *Syzygium cordatum* and *S. guineense* ssp.

guineense are found in riverine fringe forest, reaching or exceeding 10 m in height. All are flood tolerant.

Lower growing species found at the waterside or in fringing thicket vegetation are *Clerodendrum glabrunz*, *C. myricoides*, *Combretum albopunctatum*, *Cordia sinensis*, *Ehretia amoena*, *Euclea divinorum*, *Friesodielsia obovata* (syn. *Popowia obovata*), *Gardenia jovistonantis*, *G. resiniflua*, *Grewia bicolor*, *G. flavescens*, *G. schinzii*, *Hibiscus diversifolius*, *Markhamia acuminata*, *Maytenus senegalensis*, *Myrica serrata*, *Oncoba spinosa*, *Pappea capensis*, *Premna senensis*, *Rhus quartiniana*, *Salix subserrata*, *Sesbania sesban*, *Tarenna luteola*, *Vangueria randii*, *Vernonia amygdalina*, *Ziziphus abyssinica* and *Z. mucronata*.

The understory of riparian forests is quite dense, and comprises bushes, scandent shrubs and lianes. In the wettest areas there are a number of bushy species which can tolerate periods of prolonged, if not deep inundation. The most common of these are *Ficus capreifolia*, *F. pygmaea*, *Hibiscus diversifolius* ssp. *rivularius*, *Myrica serrata*, *Rubus exsuccus* and *Tacazzea apiculata*. In slightly drier situations, on the margins of islands and the banks of rivers, *Bauhinia petersiana*, *Boscia mossambicensis*, *Capparis tomentosa*, *Combretum albopunctatum*, *Commiphora africana*, *Cordia ovalis*, *Dichrostachys cinerea*, *Diospyros lyciodes*, *Ehretia amoena*, *E. coerulea*, *Flacourtia indica*, *Grewia bicolor*, *G. flava*, *G. flavescens*, *G. schinzii*, *Lantana angolensis*, *Markhamia acuminata*, *Maytenus heterophylla*, *M. senegalensis*, *Pavetta lasiopeplus*, *Phyllanthus reticulatus*, *Plumbago zeylanica*, *Rhus pyroides*, *R. tenuinervis*, *Securinega virosa*, *Tricalysia allenii*, *Vangueria infausta*, *Vernonia amygdalina*, *Ximenia caffra* and *X. americana* also grow as bushes or small trees.

Woody climbers or scandent shrubs are locally abundant in periodically flooded riparian forest, and include *Acacia schweinfurthii*, *Artobotrys brachypetalus*, *Byrsocarpus orientalis*, *Canthium huillense*, *Clematis brachiata*, *Clematopsis scabiosifolia*, *Cocculus hirsutus*, *Combretum mossambicense*, *Cynanchum schistoglossum*, *Dalbergia martinii*, *Feretia aeruginescens*, *Gongrothamnus divaricatus*, *Gyinnenza sylvestre*, *Hippocratea africana*, *Jastizinum fluminense*, *Pergularia daemia*, *Phyllanthus reticulatus*, *Rhoicissus tridentata* and *Sarcostemma vinzinalae*.

On the landward sides of the riverine vegetation, on higher grassy floodplains, and on the margins of marshes and pans, there are tall trees such as *Acacia polyacantha*, *A. sieberana*, *Combretum hereroense*, *Peltoporum africanum* and *Terminalia sericea*, all of which can exceed 15 m, and some of which grow to 20 m in height. *Ficus natalensis* and *Parinari curatellifolia* are common on elevated sandy ridges.

Seasonal Floodplains: Areas adjacent to river channels which are flooded only for comparatively short periods, albeit often very deeply, are dominated by grasses. These are zoned according to depth and duration of inundation and include *Acrocerus macrum*, *Andropogon appendiculatus*, *Echinochloa pyramidalis*, *Eulalia* sp., *Leersia hexandra*, *Oryza longistaminata* and *Paspalum polystachyum*. *Oryza* is generally dominant in the deepest water, followed by *Echinochloa* in the middle depths. The fringe areas adjacent to

dry land, which are flooded only shallowly and briefly each year, are also covered by grasses. Here *Chloris gayana* and *Setaria anceps* are widespread, but in places the vegetation is terraced, with tall species like *Cymbopogon excavates*, *Hyparrhenia rufa* and *Imperata cylindrica* occurring in bands at different levels. Sandy soils on the floodplains tend to be dominated by *Eragrostis inamoena*, *E. lappula*, *Setaria angustifolia* and *Trachypogon spicatus*, and saline areas by *Sporobolus spicatus*, *S. tenellus* and a sedge, *Cyperus laevigatus*. The driest and least frequently flooded areas of all are covered by lawns of *Cynodon dactylon*.

Wetland Fauna

Invertebrates: Little information is available concerning aquatic invertebrates. In both grasslands and woodlands, termites play an important role in the breakdown of litter, nutrient cycling and in soil formation. It is believed that the mounds of *Macrotermes* spp. play an important role in the formation of islands in the delta. *Glossina morsitans*, the vector of sleeping sickness, is present in the Okavango Delta, while two malaria carrying mosquitoes, *Anopheles funestes* and *A. gambiae* are common in all wetlands, as also are snails which carry bilharzia, *Biomphalaria* sp. and *Bulinus* sp.

Fishes: The fish faunas of the wetlands are typical of the upper Zambezi Basin and include such species as *Brycinus lateralis*, *Clarius gariepinus*, *C. ngamensis*, *Hepsetus odoe*, *Hydrocynus vittatus*, *Labeo lunatus*, *Oreochromis andersoni*, *O. macrochir*, *Schilbe intermedium*, *Serranochromis angusticeps*, *S. macrocephalus*, *Synodontis woosnanzi*, *Tilapia sparrmannii* and *Barbus* spp.

Amphibians: *Hemiscus marmoratum*, *Hyperolius nasutus*, *Ptychadena mascariensis* and *P. subpunctata* are representative amphibians in the wetlands of northern Botswana.

Reptiles: *Crocodylus niloticus* is moderately common, having been protected in the Okavango Delta since 1974. *Varanus exanthematicus albigularis* and *V. niloticus* are widespread in wetlands, as are two skinks and a gekko. Several semi-aquatic snakes are to be found in the swamps, including *Crotaphopeltis barotseensis*, *Dronzophis lineatus*, *Limnophis bicolor*, *Naje mossambica*, *Natriciteres olivacea*, *Philothamnus angolensis*, *Psanzmophis sibilans* and *Python sebae*, with *Dasypeltis scabra*, *Disphlodis typhus*, *Philothamnus sernivariiegatus* and *Thelotornis capensis oatesii* in the trees. *Bitis arietans* is found on the wetland fringes in and around the delta.

Birds: More than 400 bird species have been recorded in wetlands in Botswana. Most of these are associated with the forests and herb swamps, but there are some sites for waders. *Aenigmatolimnas marginalis* and *Botaurus stellaris* are rare species confined to wetlands, while *Acrocephalus rufescens*, *Centropus bengalensis*, *Lagonosticta nitidula*, *Laniarius bicolor*, *Sarothrura rufa* and *Scotopelia peli* are comparatively common species more or less confined to wetlands. Other important species associated with wetlands are *Actophilornis africanus*, *Amblyospiza albifrons*, *Anhinga rufa*, *Ardea goliath*, *Asio capensis*, *Balearica regulorum*, *Bostrychia hagedash*,

Bradypterus baboecala, *Chlorophoneus sulphureopectus*, *Circaetus cinerascens*, *Cisticola galactotes*, *C. pipiens*, *C. rufilata*, *Clamator glandarius*, *Coracias naevia*, *Cuculus canorus*, *C. clamosus*, *Dendrocygna viduata*, *Egretta ardesiaca*, *E. intermedia*, *Ephippiorhynchus senegalensis*, *Euplectes axillaris*, *Falco dickinsoni*, *Gallinula angulata*, *Glaucidium capense*, *Grus carunculata*, *Haliaeetus vocifer*, *Hieraaetus spilogaster*, *Kaupifalco monogrammicus*, *Lophaetus occipitalis*, *Merops bullockoides*, *M. nubicoides*, *Microparra capensis*, *Motacilla flava*, *Mycteria ibis*, *Necrosyrtes monachus*, *Nettapus auritus*, *Pelecanus rufescens*, *Phalacrocorax africanus*, *Platalea alba*, *Plectropterus gambensis*, *Ploceus ocularis*, *P. rubiginosus*, *Pluvialis squatarola*, *Poicephalus meyeri*, *Polyboroides typhus*, *Porphyry alleni*, *Riparia riparia*, *Rynchops flavirostris*, *Thalassornis leuconotus*, *Tockus bradfieldi*, *T. erythrorhynchus*, *Upupa africana* and *Vanellus senegallus*. Several enormous permanent heronries exist, e.g. at Cakanaca, Gcobega and Gcodikwe. Here *Ardea melanocephala*, *Ardeola ralloides*, *A. rufivenris*, *Butorides striatus*, *Egretta garzetta*, *E. intermedia*, *E. vinaceigula*, *Ibis ibis*, *Leptoptilos crumeniferus*, *Nycticorax nycticorax*, *Plegadis falcinellus* and *Threskiornis aethiopicus* may be found nesting in the trees. From September onwards vast flocks of *Merops nubicus*, *M. superciliosus*, *Ploceus cucullatus*, *P. xanthops* and *P. xanthopterus* come to breed in the reed beds. The wetlands of Botswana are important conservation sites, in an international context, for *Anastomus lamelligerus*, *Botaurus stellaris*, *Butorides rufiventris*, *Caprimulgus natalensis*, *Ciconia episcopus*, *Egretta vinaceigula*, *Ephippiorhynchus senegalensis*, *Grus carunculata*, *Pelecanus onocrotalus*, *P. rufescens*, *Turdoides leucopygius* and *Vanellus crassirostris*.

Mammals: *Hippopotamus amphibius*, *Kobus leche* and *Tragelaphus spekei* are resident in the permanent swamps while *Loxodonta africana*, *Panthera pardus* and *Syncerus caffer* visit them. Large populations of small mammals live in the wetlands, including *Aonyx capensis*, *Atilax paludinosus*, *Dasymys incomtus*, *Dendrodromus mesomelas*, *Lutra maculicollis*, *Mus minutoides*, *Otomys angoniensis*, *Pelomys fallax*, *Praomys shortridgei* and *Saccostomus campestris*. *Cercopithecus pygerythrus* and *Paraxerus cepapi* live in swamp forests, and *Papio ursinus* and several fruit bats feed in riparian trees in large numbers in the dry seasons. *Aethomys chrysophilus* is common at the edges of pans.

As the floodwaters recede many species move onto the floodplains and pans, including *Aepyceros melampus*, *Alcelaphus buselaphus*, *Antidorcas marsupialis*, *Connochaetes taurinus*, *Damaliscus lunatus*, *Equus burchelli*, *Giraffa camelopardalis*, *Kobus leche*, *Manis tenzinzincki*, *Oryx gazella*, *Papio ursinus*, *Phacochoerus aethiopicus*, *Redunca arundinum*, *Rhaphiceros campestris*, *Taurotragus oryx*, *Tragelaphus scriptus* and *T. strepsiceros*. Predators which follow them include *Acinonyx jubatus*, *Canis adustus*, *C. mesonzeles*, *Crocuta crocuta*, *Felis caracal*, *Hyaena brunnea*, *Lycaon pictus*, *Panthera leo*, *P. pardus* and *Vulpes chama*.

List of Wetlands Described

1. The Okavango Delta

2. Lake Ngami
3. The Makgadikgadi Pans
4. Savuti Marsh & the Mababe Depression
5. Wetlands of the Linyanti/Chobe Rivers
6. The Nogatsau Pans
7. Lake Xau
8. Nxai and Kgama Kgama Pans
9. Artificial Impoundments

1. The Okavango Delta

Country: Botswana

Coordinates: 18°29'-20°12'S/22°12'-23°45'E

Area: c. 1 000 000 ha (wetland) + 400 000 ha (dryland in delta)

Altitude: 930-1000 m asl

Nearest Towns: Gaborone (580 km SE); Maun (at SE edge of delta)

General: The Okavango Delta has developed in a depression in the Kalahari bedrock in northwest Botswana. It comprises a panhandle (95 km long) and a typical delta section (170 km from base to apex). The system slopes from an elevation of 1000 m asl at Mohembo, at the beginning of the panhandle, to 980 m at the apex of the delta and to 930 m at Maun, at the base of the delta. There is very little suspended matter in the incoming river water, but a considerable bed load. The Okavango River bed consists of sand with a median grain diameter of 0.2-0.4 mm. Preliminary calculations by Wilson and Dincer (1976) show that sand discharge at the top of the panhandle may exceed 2 million tonnes annually, while in the lower swamps it is considerably less than this, with a smaller median grain diameter. This continued deposition has given rise to the present complex of islands, ridges, pools, and permanent and seasonal swamps.

The delta landscape is dynamic; channel switching is the result of aggradation within a channel accompanied by the new growth of new vegetation. This process can quickly close a large channel, and new channels are easily created by the feeding activities of a hippopotamus herd. But peat fires play a major part in the dynamics of the delta. Initially new channels are erosive but, with time, both channel bed and adjacent peat swamp begin to aggrade. The channel then becomes moribund, and if abandoned, the adjacent peat swamp dries. Subsequent burning of the dry peat completes a cycle of channel evolution which takes up to 100 years under present flow conditions. After a fire and the collapse of the peat, the old sandy channel beds are left elevated about a metre above the burnt out peat, and the old peat area becomes available for re-flooding (Stanistreet *et al.*, 1988).

The delta is subject to seismic shocks which are believed to have a marked effect on the general topography and the pattern of flooding, and especially upon the amount of water exiting from the base of the delta into the Boteti River. The delta is crossed by a number of faults. There are two major ones at right angles to the long axis of the delta, parallel to the base of

the delta, and these tend to favour the transverse spread of floodwaters across the delta rather than their continued progression to the base of the delta. These are the Gumare Fault which crosses the northern tip of Chief's Island, and the Kunyere Fault along the present base of the delta. Another complex fault system trends WNW-ESE across the southeast corner of the delta and continues through to the Makgadikgadi Depression.

Estimates of the total area occupied by wetlands in the system vary widely, (between 1-2 million ha), but the most reliable figures seem to be those of Wilson & Dincer (1976), who, using satellite imagery, determined the following areas within the delta complex: panhandle 100 000 ha, central swamp 150 000 ha, Thaoghe System 70 000 ha, BoroKiri-Kunyere System 350 000 ha, Maunachira-Santantadibe System 300 000 ha, and the Magwenana (Selinda Spillway) System 30 000 ha, giving a total area of 1 000 000 ha.

Mean monthly temperatures over the delta range from 26.9°C in October to 15.6°C in June, with a mean annual figure of 22.2°C. Insolation averages 9.2 hrs/day over the year (September 10.6; December 8.3), while mean monthly humidity varies from 68.9% in February to 30.8% in September, reflecting the pattern of precipitation. Mean monthly rainfall is 120 mm in January and 0 mm in June, with a mean annual average close to 500 mm. Wind speeds are low (annual mean 4.4 km/hour) and evaporation high (class A pan 2826 mm/year, open water 1860 mm/year).

Perennial swamps cover 45 % of the total area, with the rest of the delta being subject to seasonal inundation. The permanent swamp extends from approximately half way down the panhandle to cover large areas to the northwest of the delta, penetrating further down the eastern drainage system of the Nghoka, Maunachira and Santantadibe Rivers than the others. It is characterised by deep permanent channels and lagoons containing extensive beds of *Cyperus papyrus* and *Phragmites mauritianus*. Islands occur throughout the delta with increasing frequency to the south. Channels occur between some islands, but the majority are separated by melapo, which are shallow, grass and sedge-covered floodplains up to 500 m wide. Melapo, or the lowest parts of them, which are inundated every year, are referred to as primary melapo. They are characterised by the presence of sedges, at least 75 cm high, and are flooded to depths of 50 cm or so. Secondary melapo are not flooded every year, but only when the flood is higher than average. Even then inundation may not exceed 10 cm in depth. They are characterised by the presence of grasses over 1 m tall and are often situated in strips between primary melapo and the islands. Large permanent pools are referred to as lediba, plural madiba. The largest concentrations of madiba are along the upper course of the Thaoge River in the west and along the Nqoga/Maunachira River on the eastern side. The two largest pools are Xakanaxa Lediba, 3.04 km long and 800 m wide, through which the Maunachira flows, and Jerejere Lediba, which is circular, 1 km in diameter, contains an island, and is completely isolated from any distributary stream.

Conspicuous features of the delta are the numerous small islands formed from large termite mounds, which reach elevations above maximum high water mark and have a characteristic vegetation. These mounds often occur close together in groups and provide refuges for even quite large animals during the floods. A number of long sandy ridges

form islands in the delta, oriented roughly from NW to SE along the long axis of the delta, and these tend to favour the spread of the flood down the long axis of the delta, in opposition to the influence exerted by the fault lines. The largest and highest of these long sand islands is Chief's Island in the east of the delta.

Hydrology & Water Quality: The Okavango River is derived from two rivers which rise in the highlands of Angola, the Cubango and Cuito, which both flow in an approximately southerly direction across Angola, before uniting to form the Okavango River. This then crosses the Caprivi Strip and then enters northwestern Botswana. This river then flows in a southeasterly direction for a short distance before forming a typical delta with anastomosing distributaries. The heaviest rains fall in Angola in January and February, but the floodwaters which develop do not reach the beginning of the delta, at Mohembo, before March. The delta has a comparatively gentle slope (1:3600) and the floodwaters spread slowly and thinly over it, not reaching the eastern limits, near Maun, until August. Rain falls on the delta from November to March, and therefore, except at the upper end, direct precipitation is completely out of phase with the annual flood. However, such rainfall has little impact on the principal flood wave which moves through the delta, from Mohembo to Maun, at an average speed of 3.2 cm/second (2.74 km/day). The depth of the floodwater varies from place to place, and from season to season, but the average depth, at high water, is thought to be of the order of one metre. Maximum depths of 10 m have been recorded in the distributaries. The bulk of the floodwater passes over the delta face as a widening shallow sheet of water. It is not principally carried by the river channels. Water spills out of the river in the panhandle and at the top of the delta, and where channels traverse the delta they may be perched above the level of the flood between levees. As water overtops a levee it is lost to the river forever, not being able to rejoin the channel, unless it be at a lower level in the delta miles farther on.

Wilson & Dincer (1976) have estimated the catchment area of the Cubango River to be 115 000 km² with a mean rainfall of 983 mm (range 605-1125 mm), and that of the Cuito to be 65 000 km² with a mean rainfall of 876 mm (range 476-1100 mm). They suggest that riverine inflow amounts to 11 billion m³/yr, while direct precipitation accounts for a further 5 billion m³/yr. Rain falling on land adjacent to the delta quickly penetrates the sands of the Kalahari and produces no surface run-off, but there is no information on peripheral seepage into the delta. The mean active storage capacity of the delta has been estimated at between 1 and 7 billion m³. Evapo-transpiration from the delta is colossal, amounting to some 15.4 billion m³/yr. The delta surface is warm when the floodwaters spill over it in a very thin sheet, and this exacerbates evaporation. Thus outflow to the Boteti River at the base of the delta is only a fraction of the inflow, but even then it amounts to 300 million m³/yr. Losses to ground water are considered to account for an equivalent amount. That the delta was once much wetter than at present is suggested by the fact that the Boteti River has a conveyance capacity much in excess of its present needs; it seems likely that during fairly recent pluvial phases it carried the waters of the Okavango River onwards. Further, there is good evidence that the Thaoghe System drained into Lake Ngami, only 100 years ago, but it presently runs dry long before reaching there.

Little information is available concerning the water chemistry of the delta, but salinity of the

ground water increases steadily from the panhandle to the base of the delta, and doubtless water quality varies from deep permanent swamp areas to the mainly dry, seasonal swamps. It has been estimated that approximately 370 000 tonnes of dissolved solids are left in the delta each year, equivalent to 37 g/m². Conductivity of ground water may exceed 5000 pmhos/cm locally. These extreme values are a consequence of high evapo-transpiration rates. However, flowing water in the channels seldom carries more than 250 mg/l total dissolved solids. Dissolved oxygen levels in flowing water is generally high, c. 7.5 mg/l, but in lakes and pools it declines after the flood, and many small pools become anoxic. A number of soda pools occur on the delta. Water temperatures rise to 40°C in the shallows when the waters are receding, but the temperature spectrum in flowing channels ranges from 21-27°C, and in lakes and ponds from 18-35°C.

Flora & Fauna: The delta supports a rich and varied flora since it encompasses all the vegetational types discussed in the introduction. Plant communities range from submerged aquatic, through swamp grassland, to riparian forest and seasonally inundated savanna woodland. In common with many other seasonal herb swamps, fire plays an important role in its ecology. Fires are started on the periphery by farmers during the dry season to promote the growth of new grass for their cattle, and others are started by hunters, deeper in the swamps, to flush out game. Up to 75 % of the sedge and grassland of the delta may be burnt in some years. The principal vegetational zones are the perennial and seasonal herbaceous swamps, the riparian or levee forests, the island fringes, and the pools (often called lagoons), both permanent and semi-permanent.

Although essentially floating, the papyrus mats are so dense and so deep that they often rest on the substratum and become firmly wedged in the channels in which they grow. They frequently form blockages, even in principal channels, and play a significant role in determining the morphology of the delta, diverting stream flow and producing islands. Papyrus develops best where there is little variation between minimum and maximum water levels, and is therefore a useful indicator of perennial swamplands which become progressively less common towards the lower end of the delta. A comprehensive account of the vegetation of the delta is given by Smith (1976).

More than 65 fish species have been recorded in the delta. Herbivorous species include *Tilapia rendalli*, while detritivorous ones include *Oreochromis andersoni* and *O. macrochir*. Together these contribute 18% of the total fish biomass of the delta. Species which are largely insectivorous include some Characidae, Cyprinidae and Schilbeidae. Species of Mormyridae and Mochokidae feed mainly on invertebrates, while the catfishes *Clarias gariepinus* and *C. ngamensis* have a broader diet and feed on fish, invertebrates and detritus. Purely piscivorous fish include *Hepsetus odoe* and *Hydrocynus vittatus* and various representatives of *Serranochromis*. The shallow floodplains provide breeding grounds for cichlid and clariid species at high flood. An account of the fishes of the Delta is given by Merron (1991).

The amphibian, reptile and bird faunas include most, if not all of the species cited in the introduction. The Delta is the most diverse wetland in Botswana in terms of habitat and consequently has the most diverse faunas. Over 400 species of birds have been recorded

there including *Turdoides melanops*, an uncommon localised resident found along the western borders. The most numerous large mammal is *Syncerus caffer* which may number 20 000 at any one time. There are also populations of *Connochaetes*, *Loxodonta* and *Equus* estimated as 14 000, 12 000 and 4 000 respectively.

Human Impact: Ngamiland (essentially the delta region) has a population of 94 322 (1991 census), 28% of which lives in the town of Mann (26 569), with most of the remainder distributed along the southern and western fringes of the delta. Some villages occur on islands of high land in the delta, but these have only sparse populations which consist primarily of women and children, the menfolk being employed in larger centres further away. Some fishing occurs from these villages, but not on a commercial scale; most fish caught are consumed locally. Some trading occurs between villages, by canoe. Population density is currently 1.06 persons /km². Infant mortality is high and life expectancy short.

The majority of people in the delta area live by subsistence farming and cattle rearing. The principal arable crops, produced on the delta fringes, are sorghum, maize and millet, grown when the floodwaters have receded. There were some 300 000 head of cattle in Ngamiland in 1990. Cattle invade the fringes of the delta in increasing numbers each year, possibly as many as 70 000 each dry season. Extensive spraying campaigns, to try to eradicate tsetse fly to open up more delta land for cattle, have been in operation for some years, and pesticide residues are now present in the food chain over most of the delta. Fences have been erected to inhibit the movement of wild animals, particularly buffalo, out of the delta, with a view to preventing infection of domestic herds with foot and mouth disease. This practice interferes with the natural migrations of several mammal species, but on the positive side prevents the incursion of cattle into the Delta during drought periods.

Income is also derived from making curios, hunting, and manufacturing processed skins and other wildlife products, and from conducting hunting and photographic safaris. In the past crocodiles (*Crocodylus niloticus*) were hunted for commercial gain, no less than 50 000 being taken between 1953-1968. That the numbers had declined seriously is evident from the fact that in 1973 a concessional quota given to a game industry company for 500 crocodiles went unfulfilled. A ban on crocodile hunting was imposed in 1974. Hunting of other animals still occurs in the delta; some 8000 animals were killed in 1974, 83% by local hunters and 17% by visiting licensed hunters.

In 1977 FAO/UNDP published the findings of an exhaustive investigation into the use of the Okavango Delta as a primary water resource (Ag. Dept. Gaborone, Botswana. Bot/71/506 Tech. Rep. 2 Vols. 361 pp. 1977). This reviews the hydrology of the delta and its biota and makes proposals for the artificial manipulation of water flow through the delta. Following this a detailed feasibility study of water extraction from the delta was carried out in the early 1980s (SMEC, 1991). However, in the face of national and international concern as to the possible impact of such action, the Southern Okavango Integrated Water Development Project was suspended pending review by an independent IUCN team during 1991-92.

Conservation Status: 390 000 ha of the delta is protected in the Moremi Wildlife Reserve. This was first created by the baTswana tribe in the 1950s, and Chief's Island was added to it at a later date. Possibly this was the first time that an African people set aside part of their land to be protected. The reserve is centred about 19°30'S/23°30'E in the Ngamiland district at the eastern side of the delta. International visitors are presently encouraged (although the FAO report previously mentioned did not regard this as desirable). There are several tourist camps in the reserve, although no camps or human habitations are permitted on Chief's Island. A potential threat to the reserve arises from the possibility of the introduction of more cattle as a consequence of the tsetse fly eradication campaign. However, this is small in comparison to the possible impact of alterations to the water regime, whether through action in Angola, Botswana or Namibia. It is possible that the delta may cease to function as a wetland if demands for irrigation are met. The delta is in a natural long term dry phase, being significantly drier than it was 100 years ago.

The Department of Wildlife and National Parks issues hunting licences for defined areas, specifying quotas and species, but enforcement is difficult and poaching and illegal fishing still occurs. The education unit of the Department attempts to promote public awareness, and the Botswana Wildlife Training Institute at Maun trains game scouts in conservation and management matters.

Tinley (1973), on the ecology of the protected part of the delta, and the proceedings of a Symposium on the Okavango Delta and its Future Utilisation, published by the National Museum of Botswana, Gaborone, in 1976, are useful references.

2. Lake Ngami

Country: Botswana

Coordinates: 20°37'S/22°40'E

Area: 67 250 ha (entire system)

Altitude: 932 m asl

Nearest Towns: Gaborone (560 km SE); Toteng (on NE edge of the lake)

General: Lake Ngami is an ephemeral endorheic lake to the south of the Okavango Delta. When Livingstone, Oswell and Murray first saw it in 1849 its diameter was thought to be 170 miles (275 km). Since then the lake has become progressively smaller, and has, on several occasions, not only dried up completely, but has remained dry for years on end. It was dry in 1800 and 1865, for the decade 1900 -1910, again in 1930 and in 1973-1974. It almost dried in the 1960s, then flooded, but was dry again by December 1982. This century its water surface has varied between 0-20 000 ha. Over the past 50 years the mean flooded area has been 12 300 ha. At high water it has had a mean depth of 1 m, a maximum depth of 3.5 m, and a storage capacity of 350 000 000 m³. That part of the lake bed which is temporarily unflooded is covered by grass, providing rich pasture for domestic cattle. Swampy grasslands frequently cover as much as 55 000 ha around the lake, but principally at the southwestern end of the lake. The overall length of the basin is 59.4 km and the maximum width is 11 km.

Hydrology: Lake Ngami is fed by several rivers carrying overflow from the Okavango Delta. The Thaoge was the main outlet from the delta 100 years ago, and then fed Lake Ngami, but blockages diverted the flow and now ensure that water from this source, on the western side of the delta, no longer reaches the lake. The Thaoge, after leaving the Okavango Delta proper, passes through a series of minor swamps and finally terminates in a small depression at Setsau. Currently, water reaches Lake Ngami from the central and eastern sides of the delta via a number of ephemeral streams, the most important of which are the Kunyere and Nhabe (Lake) Rivers. The Kunyere drains the Xo Flats, a wide, almost treeless, shallowly flooded (40 cm) and island studded region of the lower central delta. Flows in the Kunyere are more reliable than those of the Nhabe River, but do not always reach the lake. The Nhabe carries overflow from the central southern delta, arising at the Thamalakane/Boteti junction. Maximum flow in this stream in recent years has been 11 m³/sec in its upper course, but even when the river does flow here, water does not necessarily reach the lake. It is said that the lake can go from 'full' to 'dry' in two years and from 'dry' to 'nearly full' in one year, but 'full' is an inappropriate term as the entire lake bed has not been fully inundated this century.

Flora & Fauna: Much of the the lake floor is covered by grasses, but thorn trees and bushes (*Acacia reficiens*) are currently spreading over the river basin and parts of the lake, with the advent of what seems to be an increasingly drier regime.

The principal fish are species which are able to survive the intermittent long periods of drought, chiefly species of *Alestes*, *Barbus*, and *Clarias*. When it contains water, Lake Ngami is an important habitat for water birds. A total of 285 bird species has been recorded at the lake over the years, and numbers vary greatly from year to year with the state of the lake. Most notable are the concentrations of pelicans and flamingoes which are found there periodically. Counts of 65 000 *Phoenicopterus Tuber* and 8000 *Pelecanus onocrotalus* were made in 1971. The flamingoes do not normally breed at the lake and when seen are usually in transit between their two major breeding sites in southern Africa, Etosha Pan in Namibia, and the Makgadikgadi Pans in Botswana. Counts for the Okavango Wildlife Society in 1981 indicated greatly reduced numbers of flamingoes, with white pelicans, which do breed on the lake, then the most numerous species. When water levels are low cattle enter the nesting colonies and cause great destruction; wet years therefore tend to be good pelican years. Ducks, e.g. *Arias erythrorhyncha* and *Dendrocygna bicolor*, and geese, e.g. *Alopochen aegyptiacus*, arrive in large flocks, sometimes numbering hundreds of thousands. 500 000 *A. erythrorhyncha* were counted on the lake in 1954. Many use the lake as a staging post, particularly if numbers are high. Some migrant waders terminate their journey from the northern hemisphere here, others also stage, before going farther south. Terns, gulls and the pied kingfisher (*Ceryle rudis*) are common. The temporary grasslands support *Anthus novaeseelandiae*, *A. similis*, *A. vaalensis*, *Charadrius asiaticus*, *Eupodotis afra*, *E. ruficrista*, *Glareola nordmanni*, *Grus carunculata*, *Oena capensis*, *Streptopelia capicola*, *S. senegalensis*, *Struthio camelus* and *Vanellus coronatus*. Predatory birds include *Accipiter badius*, *A. minullus*, *A. ovampensis*, *Aquila rapax*, *Haliaeetus vocifer*, *Leptotilos crumeniferus* and *Micronisus gabar*, while *Gyps africanus*, *Necrosyrtes monachus* and *Torgos tracheliotus* are vultures found over the lake.

Human Impact: The ephemeral nature of the lake does not lend itself to large scale exploitation. Even when it is flooded the full fishing potential of the lake is not realised, partly because the people who inhabit the area consider it unacceptable to eat fish, but some small commercial operators have enjoyed a degree of success in producing dried fish for sale in Francistown. Cattle rearing is the main means of subsistence, which is reasonably successful since tsetse fly has largely been eradicated from the lake. Many thousands of cattle graze in the area permanently, and up to three times this number concentrate on the shores in the dry season to feed on the lakeside grasslands and obtain water. High water in the lake is normally attained during the dry season, so that at this time the shores are densely stocked with cattle. They leave behind substantial quantities of manure which is beneficial, contributing to the high productivity of the lake. A program has recently been undertaken to sink boreholes away from the lake to reduce the density of cattle on the lake margins. When the lake waters recede hygrophilous grasses provide excellent grazing in those areas which are not cultivated.

The lake margin is extremely fertile and villagers implement a system of rotational cultivation for a variety of crops on a rather casual basis. Villagers also hunt a variety of game, but take ducks on the lake preferentially. A quota system was implemented, and there is a closed season for duck shooting, but neither is, or was, easily enforceable. The major threat to the ecosystem is that of its drying out permanently. Only 3-5 % of the water that enters the Okavango Delta spills out at the southern end, some normally flowing into Lake Ngami and some flowing down the Boteti. With the manipulation of the water balance of the delta, for irrigation farming along the Boteti, the prospect that Lake Ngami will get drier is very real.

Conservation Status: There is no formal protection. The area is administered tribally, and the Department of Wildlife and National Parks is trying to promote concern for conservation issues.

3. The Makgadikgadi Pans

Country: Botswana

Coordinates: 20°15 ' -21°10 ' S/25°00' -26°15 ' E

Area: c. 1 000 000 ha

Altitude: 910-915 m asl

Nearest Towns: Gaborone (410 km S); Francistown (130 km SE)

General: The Makgadikgadi Pans are salt pans lying at the end of the vast depression in NE Botswana, which, some 200 km to the west, also contains the Okavango Delta. In the Makgadikgadi region the depression is flooded by sandy alkaline lacustrine soils. There are two major pans, Ntwetwe Pan (overall dimensions of 160x96 km) in the west, and Sowa (Sua) Pan (overall dimensions of 112x72 km) in the east, with several smaller pans to the south. The rim of the depression reaches elevations of 960-1000 m asl. The lowest point, 890 m asl is in Sowa Pan. A few densely vegetated islands are isolated in the large pans, and these are so far distant from the shores that they are completely undisturbed. The entire depression once held an enormous lake which probably discharged to the Chobe

River. Alluvium from this lake, over 100 m deep, is found in the Makgadikgadi region. Ntwetwe and Sowa Pans are among the largest salt pans in the world. They are partially flooded in most years, to depths of 15-25 cm, and then attract huge numbers of wading birds. The pans provide the end point of the Okavango/Boteti drainage system, with the Boteti River entering the southern tip of Ntwetwe Pan. However, since the river has been dammed at Mopipi, water from this source only reaches the pans during extremely wet years. During the rainy season water enters Sowa Pan from the Nata River which has formed a small delta in the northeastern tip of the pan. This stream rises in Zimbabwe and drains higher land to the northeast. On occasions Sowa Pan may fill from this source. Much later in the year any residual water from the Okavango system enters Ntwetwe via the Boteti River. Direct precipitation contributes very substantially to the water regime of the pans. The total area of the pans, which has often been given as in excess of 2 300 000 ha, is frequently exaggerated. Analysis of satellite images by the authors indicates an area of close to 1 000 000 ha for the two main pans. Subsidiary pans account for a further 250 000 ha.

For most of the year the pans are completely dry, and are covered by greyish salt encrusted sand. When water levels are receding fast, bubbles of oxygen rise from submerged algae and become trapped in the surface scum, giving it a grotesque warty appearance. Some alluvium is brought in by riverine floodwaters, but a proportion of this is removed during the dry season each year by strong easterly winds which produce numerous 'dust devils'. Mists form over the pans on cool nights and develop into dust hazes as the sun rises. Dew may be quite heavy on summer mornings.

The Pans are set in thorn savanna, with the Kanyu Flats immediately to the north. This latter region is an almost perfectly flat grassland covered by myriad minute pans. Almost all of the Kalahari Desert is floored by Kalahari sands, which are white, grey, black or reddish. They are of both aeolian and fluvial origin and include silicified sands, calcareous limestones and grits, surface limestones, lake limestones, diatomaceous sandy limestones, marls, conglomerates, pan tuffs, gravels, gritty sands and a full lithological range of silcretes and calcretes. Small fresh water pans and springs are found among the occasional limestone outcrops. 'Bushman' wells in the area are perennial and seldom more than 7 m deep. The Makgadikgadi region is extremely arid and any rain that falls does so during the summer months between October and March. The mean annual rainfall is 380 mm on Sowa Pan, but it is very unreliable and annual variations are great. In some years total receipts are as low as 75 mm. There is a mean of 40 rainy days/yr. Daytime temperatures may reach 44°C in the summer, but the winters are cool and dry, and there may be frosts at night when temperatures may drop as low as -6°C.

Flora & Fauna: The almost barren pans are situated in typical savanna surroundings. Islands in the pans are covered by dense woodland which includes species able to tolerate brackish soil water, e.g. *Acacia reficiens*. There are extensive saltmarshes close to the edges of the pans, but these give way to grassland, shrub savanna, and finally to tree savanna in moving away from the pan. *Odysea paucinervis* and *Sporobolus spicatus* fringe the saltmarsh, in which *Portulaca oleracea*, *Sporobolus tenellus*, *Suaeda fruticosa* and *Vernonia fastigiata* are dominant. Isolated swampy patches along pan margins, probably associated with springs, are dominated by *Phragmites australis*, with *Alternanthera nodiflora*,

Dichanthium papillosum, *Lagarosiphon muscoides*, *Najas marina*, *Potamogeton* sp. and *Scirpus maritimus* in small pools. In moist crevices at the margins of the pans *Amaranthus thunbergii*, *Cyperus aristatus*, *C. compressus*, *Glinus bainesii*, *Pentzia* sp., and *Polygonum limbatum* may be found. The edges of the pans are grass covered, with *Cynodon dactylon* dominant towards the land, yet the regular adherence of mud to the leaf blades of this species suggests that it is frequently inundated during the rains. Sand dunes on the pan margins are colonised by *Cenchrus ciliaris* and *Panicum meyerianum*. Still farther from the pans, grasses which do not suffer inundation, and which grow in the surrounding scrub savanna, include *Aristida meridionalis*, *Heteropogon contortus*, *Odyssea paucinervis* and *Rhynchelytrum* sp.

In the delta of the Nata River *Sesbania mossambicense* and *Sporobolus spicatus* are common. Various algae are found in brackish pools in the river bed in the dry season, including species of *Cosmarium*, *Nostoc*, *Oscillatoria*, *Pediastrum* and *Rivularia*. *Phragmites mauritianus* fringes semi-permanent pools, and in depressions on moist sand *Ammannia priesuriana*, *Blumea caffra*, *Corchorus tridens*, *Cyperus aristatus* and *C. compressus* are present. On drier patches *Argemone mexicana*, *Ceratotheca triloba*, *Courtoisia cyperoides*, *Cucumis metuliferus* and *Ocimum americanum* occur. Typical riverine trees found along the Nata are *Acacia albida*, *A. kirkii*, *Combretum imberbe* and *Lonchocarpus capassa*.

Because the lake often dries completely, only barbels, which overwinter buried in mud, survive to breed when water returns at the start of the summer season. However, a variety of other fish enter with the floodwaters, but they all die when the water evaporates at the end of the season. The sludgy water becomes a nutrient soup which attracts thousands of migrant wading birds and the pans are one of the principal breeding sites for flamingoes in southern Africa. *Phoenicopterus ruber* has been observed in flocks so large that they cover tens of square kilometers. Other avian visitors include ducks, geese, white pelicans and ostriches. *Gypohierax angolensis* and *Terathopius ecaudatus* are notable species found over the pans.

Seasonally the pans provide water for large numbers of immigrant herbivores, as listed in the introduction, and these are then followed by their predators. Large herds of *Connochaetes taurinus* once used to occur in the area, but their numbers have been reduced in Central Botswana, possibly by as much as 90%, by the combined effects of drought and veterinary cordon fences, which cut off their migration routes. Other resident species are *Antidorcas marsupialis*, *Manis temmincki*, *Oryx gazella*, *Panthera leo*, *Taurotragus oryx*, *Vulpes charna* and *Papio ursinus*, although the latter is now uncommon. Rats, mice and gerbils live on the fringes of the pans and otters are occasionally present near inlet streams when fish are plentiful.

Human Impact: Farming occurs in the area but the pans are virtually undisturbed. Some bushmen hunt on the pans during the rainy season. Construction of a soda ash plant began at Sowa Pan in 1988. The intention is to produce 300 000 tonnes of soda ash and 650 000 tonnes of table salt per year, sufficient to meet the entire demand of southern Africa, from a resource estimated as virtually inexhaustible (Thomas & Shaw, 1991).

This development on Sowa Spit in the north of the pan is expected to have a localised impact on its surroundings.

Conservation Status: The 250 000 ha Makgadikgadi. Game Reserve was established in 1970 and includes a small portion of the western section of Ntwetwe Pan. The reserve is centred at 20°25'S/24°55'E, and is mostly savanna. Animals which visit Ntwetwe Pan in the wet season find sanctuary in the reserve during the dry season. Otherwise the pans are unprotected. There is no organised accommodation in the reserve but visitors are permitted to camp. The northern part of Sowa Pan is protected as the Nata Sanctuary, a reserve established by the Nata community to protect bird populations and provide employment for the community.

4. Savuti Marsh & the Mababe Depression

Country: Botswana

Coordinates: 18°30 ' -19°10 ' S/23°58 ' -24°20 ' E

Location: Area: c. 3000 ha (Savuti Marsh)

Altitude: c. 920 m asl

Nearest Town: Gaborone (700 km SE)

General: Savuti Marsh lies in the Mababe Depression which is an oval shaped fossil lake bed situated to the northeast of the Okavango Delta, between the delta and the Chobe/Linyanti River. The marsh occupies only a small portion of this grass depression. It lies at the western side of it, and marks the end of the 60-70 km long Savuti Channel which brings water to the Mababe Depression from the Linyanti Swamp. The grassy floor of the depression is situated 920-930 m asl, and its sides, the banks of the fossil lake, rise steeply from it. Along the western and northern boundaries of the depression there is a long wooded sand ridge, the Magikwe Ridge, which is some 200 m wide at the top. In places this ridge rises 30 m above the fossil lake floor, having summit elevations of 936-950 m asl. From October to March, high water in the Linyanti Swamp may spill over into the Mababe Depression via the Savuti Channel which breaches this sand ridge. However, flow in the Savuti Channel is irregular, probably due to adjustments along the Linyanti and Chobe fault lines. Certainly the channel ceased to carry water for long periods, decades or more, in the 1800s and early 1900s, and at these times trees grew in its bed. After a prolonged dry period of at least 50 years, flows began again in 1957, but comprised very variable annual volumes of water. Stumps of dead trees then emerged from the water all along the channel as a testament to past dry times. Flows ceased again in the early 1980s (Shaw, 1984).

The Cubango/Okavango system is usually at high water at the same time as the Cuando/Linyanti/Chobe system, since both derive their headwaters from adjacent catchments in Angola. Thus in a year of extreme high water in the Okavango Delta, water escaping via the Magwegqana (Selinda) Spillway to the Linyanti Swamps, could find its way to Savuti Marsh. In the past water may also have reached the Mababe Depression at its southern extremity via the Khwai system. This extends almost 160 km due east from the Nqoga/Maunachira system of the Okavango Delta, in a gradually tapering swampy belt, but flows in it usually peter out long before the Mababe Depression.

Flora & Fauna: The Savuti Channel is lined by an ill-defined riverine fringe comprising *Combretum imerbe*, *Lonchocarpus nelsii* and other riparian species. Savuti Marsh *per se*, is an open grassland dominated by *Cynodon dactylon*, which is highly nutritious and attracts large numbers of grazers. The marsh is fringed by *Acacia erioloba* woodland, characterised by many dead trees. Where soils are sandy, around the marsh, there are near pure stands of *Colophospermum mopane*, or open woodland dominated by *Burkea africana*. Among the most spectacular of the birds which visit the area are enormous flocks of *Quelea quelea* which sit in the surrounding bushes. *Tockus bradfieldi* and *Pterocles gutturalis*, both rare species, are seen here. Among the large mammals which visit the marsh are *Damaliscus lunatus*, *Equus burchelli*, *Hippotragus niger*, *Kobus ellipsiprymnus*, *Loxodonta africana* and *Syncerus Gaffer*. Predators, which abound on the drying marsh, include *Acinonyx jubatus*, *Leptoptilos crumeniferus*, *Lycaon pictus*, *Panthera leo* and *P. pardus*, and many buzzards, eagles and hawks. The Savuti Channel is the home of fish, frogs, toads, crocodiles, monitor lizards, snakes, swamp rats, and hippopotamuses, as indicated in the regional introduction. It is heavily utilised by elephants, and a range of large mammals visit it to drink.

Conservation Status: Part of the Savuti Channel and the entire Savuti Marsh is contained within the Chobe National Park which was established in 1967 and enjoys full protection.

5. Wetlands of the Linyanti/Chobe River

Country: Botswana

Coordinates: 17°50'-18°28'S/23°25'-25°05'E

Area: c. 120 000 ha (in Botswana)

Altitude: 850-950m asl

Nearest Towns: Gaborone (750 km SE); Kasane (at E end of swamps)

General: A wetland system exists along the Linyanti River on the national boundary between Botswana and Namibia, on the southern side of the Caprivi Strip. The wetland comprises swampy floodplains, reed swamps and meandering and anastomosing waterways, with numerous small islands and backwaters. The entire system is backed by riverine forests. The first, and major part of the system, which is generally marked as the Linyanti Swamp in atlases, is situated in Namibia, in the southern elbow of the Caprivi Strip. However, wetlands also occur to the east of this swamp, extending for 200 km along the Linyanti/Chobe River towards Kasane. The river which enters the Linyanti Swamp from Angola is called the Cuando, but its name is changed to Linyanti in the swamp, and then again to Chobe after it leaves the swamp. Wetlands extend on both sides of the Chobe River, but are less extensive on the south bank, in Botswana, except in the vicinity of Kataba where the floodplain reaches some 25 km in width. The Linyanti/ Chobe permanent wetlands occupy about 120 000 ha of Botswana at high water, of which some 60 000 ha are situated in the Kataba region, south of Lake Liambezi in the Caprivi Strip. At times of high flood the waters of the Zambezi and Chobe Rivers mingle across a common floodplain at the eastern end of the Caprivi Strip, but if the Zambezi is high and the flood on the Chobe has been delayed, flow may be reversed in the lower Chobe. Rainfall increases from west to east

along the Linyanti/Chobe River, reaching a mean annual figure of 700 mm at Kasane. Summer temperatures in the swamps may reach 40°C.

Flora & Fauna: True high forest in Botswana occurs along the banks of the Linyanti/Chobe River, and while the riverine forest shares many species of plants and animals with the Okavango Delta, it is nevertheless, a distinct biome. On some bends the river banks are steep and undercut, if seen at low water, while on the opposite sides, away from the current, there are broad vegetated mudflats. The water fern *Salvinia molesta* occludes many backwaters, and at times of low water, may block the main channel. The river is continuously fringed by dense stands of *Cyperus papyrus* and *Phragmites inauritianus*, behind which are groves of *Phoenix reclinata* set against a backdrop of riverine forest. In places the forest canopy is 18 m high, but it frequently gives way to patches of low riverine thicket only 5-9 m high. The floristic diversity of the riverine vegetation increases downstream, from west to east. Most of the species cited in the introduction are present.

A wealth of animal life is associated with the riverine forests, the reed beds and the river banks, and most of the species cited in the introduction are present. In addition to the resident fauna of the permanent swamps, a range of animals moves seasonally between the wetlands and the adjacent savannas, again as indicated in the introduction. The fish fauna of the Chobe River and its associated pan/swamp system is typical of the upper Zambezi Basin. Altogether 25 snake species have been collected from the wetlands of the eastern Caprivi Strip, and most of these are likely to occur on the Botswanan side of the border.

At least 200 species of birds are associated with the river and its peripheral vegetation, among which *Merops nubicoides* is the most numerous, nesting in holes in the river banks in vast numbers. Other important species are *Ardeola ralloides*, *Cisticola rufilata*, *Cossypha heuglini*, *Ephippiorhynchus senegalensis*, *Glaucidium capense*, *Haliaeetus vocifer*, *Hieraetus fasciatus*, *Necrosyrtes monachus*, *Nectarinia senegalensis*, *Nettapus auritus*, *Pelecanus onocrotalus*, *Phalacrocorax africanus*, *Scotopelia pelf* and *Rhynchopsflavirostris*. All the small mammals cited in the introduction are present and *Kobus vardonii* and *Tragelaphus spekei* occur on the floodplains.

Human Impact & Utilisation: The river is fished by local villagers, and some hunting occurs in the unprotected western end near the Linyanti Swamps. However, because of the regular high floods the area has not been developed and is little exploited by the indigenous population. Tourism is on the increase.

Conservation Status: Almost the entire stretch of this wetland, 220 km long, is protected in three contiguous reserves: the Chobe Forest Reserve which borders the river for some 130 km in the west, the Chobe National Park which borders the river for a further 60 km in the centre, and the Kasane Forest Reserve which borders it for a further 30 km in the east. There are no tourist facilities in the reserves, but there is a safari camp near Linyanti and permits may be granted for camping in the reserves.

6. The Nogatsau Pans

Country: Botswana

Coordinates: 18°19'S/25°00'E

Area: No reliable information

Altitude: c. 950 m asl

Nearest Towns: Gaborone (700 km S); Kasane (65 km N)

General: A cluster of 8 large depressions and a dam on the Ngwezumba River comprise the 'wetlands' in this area, in the northeastern part of the Chobe National Park some 60 km due south of Kasane. The depressions are essentially fossil pans and although situated on what was once the active floodplain of the river, are now surrounded by forest and mopane savanna. They do not nowadays hold water for any length of time. The largest pans, Cwikampa, Mandabuza and Mapororo, have a resident fauna of amphibians, reptiles, birds and small mammals. They are visited by a spectrum of large mammals throughout the year, but principally during the wet season as indicated in the introduction.

Conservation Status: Protected within the Chobe National Park, and the adjacent Kasane Forest Reserve Extension. There are two campsites for visitors and an airstrip.

7. Lake Xau

Country: Botswana

Coordinates: 21°14'S/24°50'E

Area: c. 30 000 ha (highly variable)

Altitude: c. 920 m asl

Nearest Towns: Gaborone (400 km SE); Francistown (270 km E)

General: Lake Xau, to the south of the Boteti River and the Makgadikgadi Pans, was once a large shallow lake fed by overspill from the Boteti River. However, since the impoundment at Mopipi, itself a former pan, the lake is usually as dry as the pans in nearby Makgadikgadi Depression. There are still reeds on the lake shore, but they are less extensive and less luxuriant than in former times. Bird life is still abundant on the lake floor, but this is now flooded only sporadically, and to depths of a few centimetres, mainly following local rain. The present lake bed is some 15 km long and 8 km wide, covering some 12 000 ha. It is known to have dried up naturally during past drought periods, e.g. in 1800, when Lake Ngami was also dry. However, in the pluvial past, Lake Xau supported a substantial fish fauna, together with crocodiles and hippopotamuses, waterlilies and submerged aquatic vegetation.

Conservation Status: Unprotected.

8. Nxai and Kgama Kgama Pans

Country: Botswana

Coordinates: 19°50'-19°59' S/24°45 '-24°47 'E

Area: c. 23 000 ha (both pans)

Altitude: c. 930 m asl

Nearest Towns: Gaborone (530 km SSE); Francistown (320 km SE)

General: These two large pans are situated in the Nxai Pan National Park. Nxai Pan, the

larger of the two, is a fossil lake bed with a total area of some 15 400 ha. During the rainy season depressions in the pan may fill with water, but the whole pan is never flooded. Kgama Kgama Pan is smaller, but of similar origin and nature. Both pans are set in savanna woodland or open forest which supports large herds of game. Nxai Pan is usually covered by short grass, except for the depressions, and contains many little tree-studded islands which are emergent even if the entire pan is flooded. Common trees on these islands are *Acacia erubescens*, *A. nigrescens*, *A. reficiens*, *Colophospermum mopane*, *Syzygium cordatum*, and *Terminalia sericea*. Many of these species also occur on the pan margins, together with an occasional *Adansonia digitata*.

There are many snakes in the pans, including *Bills arietans*, *Dasypeltis scabra*, *Dendroaspis polylepis* and various cobras. Birds of interest are *Accipiter badius*, *Gyps africanus*, *Micronisus gabar*, *Necrosyrtes monachus*, *Terathopius eadatus* and *Tringoides occipitalis*, while noteworthy mammals include *Acinonyx jubatus*, *Connochaetes taurinus*, *Equus burchelli*, *Felis caracal*, *Giraffa camelopardalis*, *Otocyon nzealotis*, *Panthera leo* and *Proteles cristatus*.

Human Impact & Utilisation: Virtually none.

Conservation Status: The pans are fully protected in the Nxai National Park. Visitors may enter the park by permit and are permitted to camp at specified campsites.

9. Artificial Impoundments

The largest impoundment is the Shashe Dam (21°20'S/27°22'E) on the Shashe River at an altitude of 1000 m near Francistown. This artificial lake is 15 km long and up to 4.2 km wide in places, with an open water surface close to 3200 ha at capacity. Some way to the south is the Slime Dam (21°57'S/27°50'E) at an altitude of c. 900 m, near the settlement of Selebi-Phikwe. This is much smaller, with maximum dimensions of 1.7 and 0.8 km. In this locality there are a further 18 dams on the Ramokgwebana, Sansukwe and Simukwe Rivers, all tributaries of the Shashe. While these dams are comparatively small they each have more than 60 ha of open water surface. The Gaborone Dam, serving the capital, is one of the largest artificial waterbodies in the country.

The Marico and Limpopo Rivers form the border between Botswana and South Africa over a riverine distance of about 500 km, and in this area there are 55 weirs on the rivers and their tributaries. In this area there are also 4 major impoundments on the tributaries, one at Gaborone serving the capital, and several thousand small farm dams in the country, mostly in the wetter eastern part.