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The status of freshwater resources in Namibia

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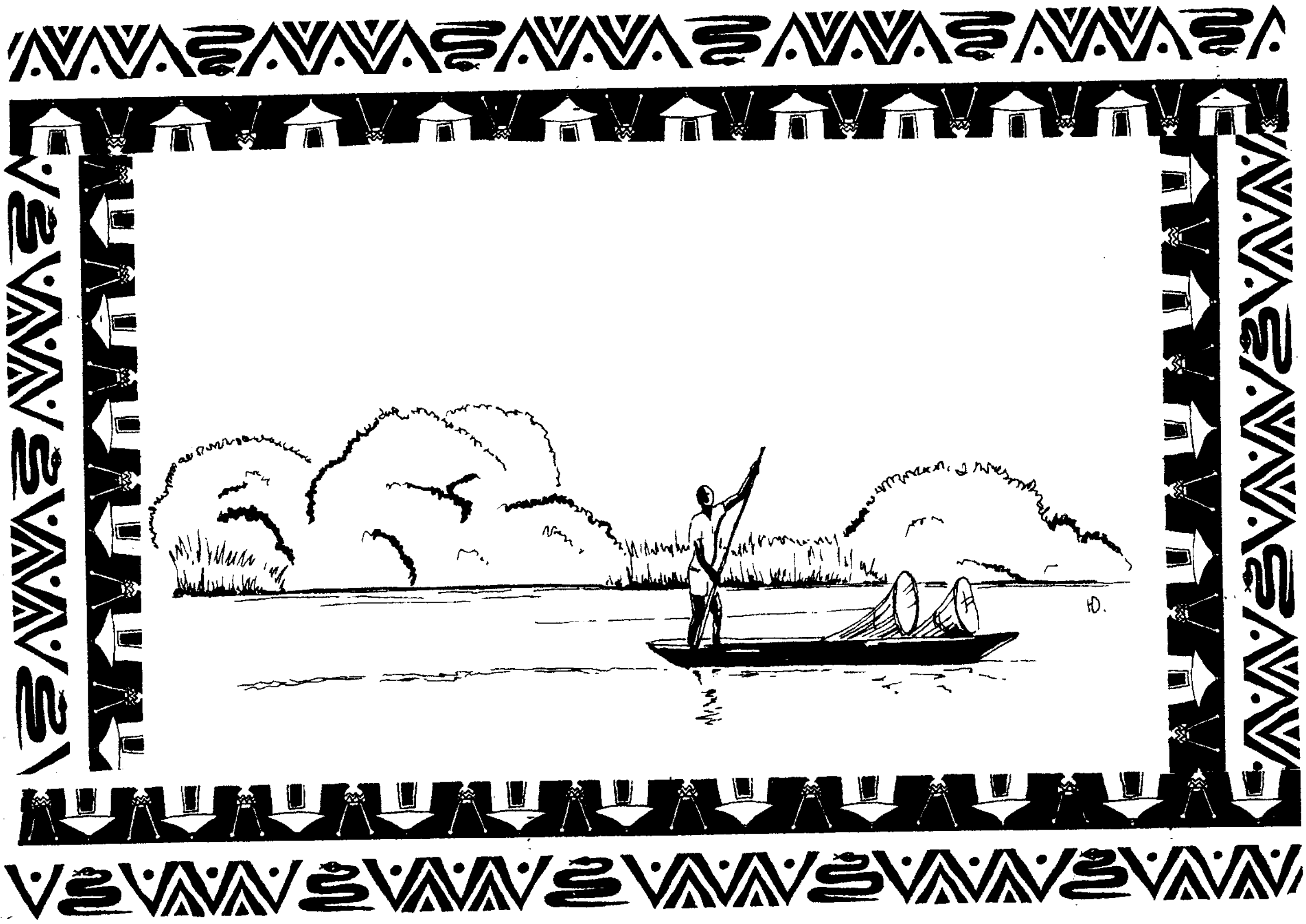

Directorate of Environmental Affairs, Ministry of Environment and Tourism, Namibia

This report is one of a series of specialist assessments of environmental threats, and potential opportunities for development assistance, in Namibia. It was prepared by Namibia Resource Consultants, Windhoek, for the United States Agency for International Development (USAID) in association with the Namibian Directorate of Environmental Affairs, Ministry of Environment and Tourism. This research discussion paper is closely adapted from the USAID report in order to bring the results to a wider audience. -- Editor.

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Table of contents

Preface

All wetland ecosystems in Namibia are under pressure of one sort or another because of the large and increasing demand for water in an extremely arid country. The key to the conservation status of aquatic ecosystems lies in the distribution and availability of water itself as a human resource and as the basis of aquatic ecosystems. Although it had been agreed by the assessment team that this paper should not address the issue of water as a resource (rather than simply as a component of aquatic ecosystems), I have found this very difficult to avoid. Because water is *the* limiting resource in Namibia, major conflicts have frequently arisen, and will no doubt continue to arise, between the "consumptive" users of water (agriculture, industries, mines and domestic users) and the maintenance of aquatic ecosystems, either as providers of resources such as water, fish and wetland plants for rural populations, or for conservation purposes. Section 1 thus provides the backdrop to all of Namibia's major environmental issues.

Acknowledgements and list of persons contacted

I am most grateful to Mr Piet Heyns of DWA for his careful scrutiny of the manuscript. He made many helpful corrections and I have attempted to correct all the errors of fact that he pointed out to me. He and I differ in matters of interpretation, and I have not altered the text except where my original interpretation was based on faulty information. I should also like to thank Phoebe Barnard for her editorial assistance; an anonymous referee for comments; Chris Brown and his staff at DEA for providing us with working facilities; Jan Glazewski, Holger Kolberg, Mike Griffin, Shirley Bethune, Mary Seely and Ben van Zyl for documents, information and valuable discussions; and Rod Davis of Namibia Resource Consultants for help and encouragement.

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List of acronyms and abbreviations

DEA	Directorate of Environmental Affairs
DDT	dichlorodiphenyltrichloroethane
DRFN	Desert Research Foundation of Namibia
DRM	Directorate of Resource Management
DTA	Democratic Turnhalle Alliance (Namibian political party)
DWA	Department of Water Affairs
EIA	environmental impact assessment
EEU	Environmental Evaluation Unit, Department of Environmental and Geographical Sciences, University of Cape Town
ENWC	Eastern National Water Carrier
MAR	mean annual runoff
MET	Ministry of Environment and Tourism (formerly Ministry of Wildlife Conservation and Tourism)
MFMR	Ministry of Fisheries and Marine Resources
NAMPOWER	Namibian electricity supply utility
NPC	National Planning Commission
PNA	protected natural areas
SADC	Southern African Development Community
SWAPO	South West Africa Peoples' Organisation (Namibian governing party)
UDF	United Democratic Front (Namibian political party)
USAID	United States Agency for International Development
UNITA	Angolan political party and faction in the civil war

Executive summary

This document was written primarily for members of the Namibian Civil Service, and also for environmental planners, economists and policymakers both nationally and internationally.

The terms of reference were to assess

* the extent and types of freshwater resources;
* the effectiveness of conserved areas for sustainable use of these resources and human development;
* the "health" of aquatic ecosystems and the pressures on them;
* the effectiveness of management and monitoring of the more "valuable" systems;
* situations where human activities are undermining the biodiversity and functioning of ecosystems that support resources usable by disadvantaged peoples;
* the extent to which government ministries and other organisations co-operate in management of these systems; and
* the extent of community participation in policymaking and management of these ecosystems.

The original proposal required more specifically that the following should be addressed, and I have also attempted to do so:

* the flow régimes of ephemeral "sand" rivers and their effects on riparian vegetation, wildlife and stock animals;
* the status of key wetlands, particularly in the oshanas, on the Kunene and Okavango Rivers, and in the Linyati swamps, including
    - what they are used for
    - their socio-economic importance
    - changes that have occurred over time
    - the driving forces behind these changes
    - the impacts of these changes on landscape-level processes
    - the potential for the sustainable use of these systems
    - the economic importance of fish, and trends in inland fisheries
    - conflicts in the use of "riparian habitats".

Namibia's water resources

Namibia is one of the most arid countries in the world. Most rain falls in short, intense episodes so that infiltration of water into the soil is low. Inter-annual variability in rainfall means that the amount of standing vegetation varies extremely from year to year, and so does the carrying capacity of terrestrial ecosystems. As a result, virtually all humans and livestock are now dependent on the "engineered" provision of water, especially for irrigating crops and watering stock animals.

About 57% of the water used in Namibia comes from underground sources, 23% from the northern border rivers and 20% from local reservoirs. A massive karst formation underlying the Grootfontein/Tsumeb district contains very large quantities of groundwater.

The population of Namibia is approximately 1.7 million people. While most people live in the oshanas of the Cuvelai drainage system, urbanisation has been a marked recent trend. The average population growth rate is estimated to be at least 3%, suggesting that the total population will reach about 4 million by 2020. This means that the demand for water will at least double over the next 25 years.

The assured annual yield of water for Namibia is about $500 \times 10^6\ m^3\ y^{-1}$ excluding water in the perennial border rivers. Water demand is expected to exceed $300 \times 10^6\ m^3\ y^{-1}$ in 2005, and Namibia will not be self-sufficient in water by 2015.

Since both the Kuriene and the Okavango Rivers rise in Angola, a good deal less water may arrive at the Namibian border as Angola's infrastructure improves. Groundwater already supplies more than half of total water demand although, except in specific areas, the supply of groundwater is already fully committed, if not over-used.

Wherever access to water has become easier, and standards of living have improved, the rate of consumption of water has increased. Additional boreholes and standpipes attract more people and livestock, leading to overgrazing, particularly in years of low carrying capacity.

Water law and DWA policies regarding water supply

Until recently, the Department of Water Affairs made every effort to provide water on demand, rather than attempting to limit demand. As a result, water tables have sunk, wells have dried up or become salty, rivers have silted up and "fossil" water has been (and continues to be) mined. Because lack of water will constrain development on a national scale, major investments are being made in a variety of water schemes, some of which will have wide-ranging economic and environmental impacts on ecosystems, on energy use, on household budgets, on competitiveness and, ultimately, on the national economy. Degradation of water resources, especially by pollution, will have the same effect.

DWA will have to adopt three parallel strategies: development of new sources where possible; improvement in management of water resources to protect them from over-exploitation, pollution, siltation, etc.; development of an ethic of water conservation by realistic pricing, tariff incentives, education, and planning in the national interest. In this regard, environmental aspects of the Eastern National Water Carrier and the Epupa hydro-electric scheme are discussed in some detail.

Management of water resources

It is State policy for Environmental Impact Assessments to be carried out for all new developments, and attempts are being made to examine the effects of damming on rivers below dams, and of abstraction of groundwater on terrestrial vegetation in ephemeral rivers and in the Karstveld.

Some water-related aspects of Namibia's "Green Plan" are briefly discussed. Policy requirements include those allowing the development of rights of local tenure; those that can ensure protection and management of key wetlands and watersheds; those related to water conservation measures and the strengthening of environmental management; and those aimed at improving our understanding of indigenous knowledge and skills in resource management. The value of water demand management is highlighted.

Water-related diseases and public health

Water-borne bacterial diseases seem not to be of major concern, but water-related parasitic diseases are. Malaria is a major killer, and chloroquine-resistant strains are known from Namibia. Bilharzia is endemic throughout the regions of the northern rivers and floodplains.

The status of wetland ecosystems in Namibia

The working definition of "wetland" commonly used in Namibia is *the interface[s] between aquatic and terrestrial systems, whether permanently or ephemerally inundated with fresh or salt water*. The present document generally considers only those aquatic ecosystems not affected by or related to the sea. By this definition, virtually all of Namibia's aquatic ecosystems, except perhaps for some of the bigger reservoirs, can be considered wetlands.

Wetlands are valued because of the variety of economically important services they offer to humans. Some of these services that are specifically associated with large wetlands, supporting substantial stands of plants like reeds, are storage of water, filtration of water, removal of nutrients, and stabilisation of shorelines. The presence of even minimal quantities of water often allows fodder plants, reeds and trees to grow. Some wetlands also support significant numbers of fish; many provide water that recharges underground aquifers; biodiversity is often very high; they are valuable recreational and tourist attractions; and they are of great scientific and educational value.

Close to 75% of the Namibian population lives in close association with the riverine and floodplain wetlands in the far north of the country.

Namibian wetland ecosystems

Although in terms of rainfall, the Namib is one of the driest deserts in the world, a number of different kinds of wetland are found throughout the region. Some near-permanent pools, streams and lakelets are relatively fresh and others are hypersaline. Ephemeral waters vary from rivers that run for short periods after rain has fallen upstream in the catchment to the pools they leave behind after flow has stopped, and pools formed as a result of rain falling in inward-draining basins.

All of these systems are of intrinsic interest and value from the point of view of biodiversity because they support highly specialised invertebrates such as crustaceans, insects and a few frogs. From a human point of view they are also valuable because they provide drinking water for edible terrestrial vertebrates such as birds and mammals, which means that the distribution ranges of these animals expand during wetter periods. Ephemeral rivers act as linear oases because their beds hold significant quantities of water. The groundwater associated with some of these rivers (e.g. the Kuiseb, the Swakop, the Omaruru) is sufficiently extensive to be tapped for human use. A major threat to these systems is lowering of the water table as a result of abstraction of water. If the roots of trees can no longer reach the water table, the trees will die. Much of the subsurface water in the river beds is replaced seasonally from upstream. When these rivers are dammed in their better-watered upper reaches, this water is no longer available downstream.

The **Kunene River** is relatively poorly known. Its flow régime is typical of highly variable tropical systems, with an average 11-fold difference in flow between wet and dry seasons. The mouth is the second most species-rich wetland along the coast of Namibia and fourth in importance as a habitat for wading birds. Several dams have been built on the main stream, but only three are presently of significance. Hydroelectric power is generated at Ruacana Falls. The daily fluctuations in water level caused by the operation of the dam are implicated in reduced breeding success of certain fish. The wall of the proposed hydroelectric dam at the Epupa Falls would be 130 m high, would flood 75 km of river length, would hold 5000 x 10^6 m^3 of water and would cover an area of approximately 200 km^2. It would also disrupt the lives of the local ovaHimba people.

The ephemeral rivers of the **oshanas** flow into Etosha Pan, the last major filling of which was in 1954. The oshanas are in the most densely populated area of Namibia, supporting about 400 000 people. The area suffers from overgrazing and deforestation, as a result of overpopulation. Etosha Pan is one of the biggest salt pans in the world. Except for the area immediately surrounding Etosha Pan, none of the oshana drainage is incorporated into a protected area.

The **Okavango River** forms about 415 km of the border between Angola and Namibia before turning south to empty into the Okavango Delta in Botswana. From the confluence with the Cuito, islands support riverine forest and backwater refuges for fish. The water of the Okavango River is generally very low in salts and nutrients. The soils are poor, but richer silts brought down with floodwaters from Angola provide some nutrients so that the floodplain supports crops and fruit trees. Close to the river, most people abstract water directly but further away they rely on the large aquifer that underlies the riverine area. A combination of deforestation and overgrazing results in increased turbidity of the water and siltation, and alteration of habitat for fish. This can ultimately affect flow patterns and floods. None of the extent of the Okavango River in Namibia per se is incorporated into a protected area, although part of its floodplain lies in the Mahango Game Reserve.

The **Caprivi** is bordered by the Kwando/ Linyati Rivers to the south and west, and the Zambezi/ Chobe Rivers to the east. Lake Liambezi, which is fed by the Linyati and Chobe Rivers, has been dry since 1985. Since the land is so flat, very small floods can inundate very large areas of land, and about 30% of the entire east Caprivi area is floodplain or another. A major threat to the wetlands is overgrazing: the present stocking rate is more than twice the carrying capacity of the land. Other threats include overpopulation, overfishing, pesticides and poor land management.

The **Orange River** forms the border between Namibia and South Africa. The Orange River is dammed upstream in South Africa, but there are no dams on the common border. Nonetheless, so little water is allowed downstream by the dams that the river may cease to flow to the sea. The Fish River, a southward-flowing tributary of the Orange, drains the south-central parts of Namibia and is dammed by the Hardap Dam. The southern border region is sparsely populated. A section of the lower Fish River, but none of the Orange, is protected.

The **Karstveld,** about 2500 km^2 in extent, is an area of calcareous rock formations that have been dissolved and eroded underground and now contain massive underground stores of water, mostly recharged directly from rainfall. Several unusual sinkhole lakes include Lakes Ojtikoto, Aigamas and Guinas, which support populations of endemic fish and other organisms. Groundwater is abstracted from these aquifers for domestic, irrigation and other purposes for the entire Tsumeb-Otavi-Grootfontein agricultural region. Some irrigated crops are produced in the Karstveld region, and in the past this area has been able to supply all the maize meal needed by Namibia.

The **Kalahari pans** in eastern Namibia and western Botswana are probably fossil landforms. As systems that fill ephemerally, they provide only seasonal sustenance to local human communities but some of them are being used to grow crops or sustain livestock. The San people have set aside land adjacent to and including some of the "Bushmanland Pans" in eastern Namibia for hunting and gathering. Various thermal waters also occur in this region.

In the east, the **Nossob and Auob Rivers** are blocked by Kalahari dunes, but subsurface waters support farms in the area. Most towns are supplied with water by their own small dams.

Preserved natural areas

Although 13.6% of the country consists of preserved natural areas, this includes <1% of the non-desert parts of the country. Virtually no parts of the Kunene River, Okavango River, or the oshanas are included in preserved natural areas, even though these regions are by far the most biodiverse aquatic systems in the country.

Biodiversity

Namibia has a wide diversity of aquatic ecosystems, some of which are very rare on a global scale. The biotic diversity of these wetlands is not well quantified, although a thematic issue of the journal *Madoqua* on Namibian wetlands was published shortly after Independence, and some additional lists of species are available. Partly due to Namibia's responsibilities to the Biodiversity Convention, biodiversity information systems are being developed by the DEA and National Biodiversity Task Force, and a book is now being written on Namibia's biological diversity. The northern rivers, and particularly their floodplains, are the richest in species.

Natural resources obtainable from wetlands include plants such as grasses that can be used for grazing; reeds for thatching; palms, reeds and dye plants for basketry; crops for food; herbs for traditional medicines; trees for fuel and construction; clay for pottery; and wildlife for eating or for attracting tourists.

From the points of view of resources usable by people, as well as biodiversity, key wetland areas are the oshanas, the land near the Okavango River, and the Caprivi. These are all communal land with communal management. Except in the Caprivi and Okavango, no conserved land is available to protect wetland biodiversity. Given the great number of people depending on this land, it is unlikely that any will be given over to conservation in the traditional sense. Monitoring, and even basic quantitative information on many stocks, is inadequate because MET and MFMR do not have sufficient funds or staff to do such jobs.

Namibian ecosystems suffer from the effects of a number of alien organisms, many of which are associated with wetlands and some of which pose severe threats to one or more aspects of the continued functioning or biodiversity of these systems.

Freshwater fish and fisheries

The Namibian freshwater fish fauna is fairly rich. About 103 species have been recorded, almost all of these in the northern and north-eastern rivers, particularly associated with the Okavango and Zambezi catchment wetlands. Three species are endemic to the interior of Namibia.

Although the quantity of freshwater fish caught and consumed, and the commercial value of the catches, is vastly less than that of the marine fishery, freshwater fish form a vital part of the diets of many people subsisting near the Okavango River, in the Caprivi and in the Cuvelai drainage. Virtually all of the inland fishery is artesanal. More than 100 000 people derive direct or indirect benefits from inland fish resources, and the fish supply *per capita* is approximately 10 kg person^{-1} y^{-1}, or about 10% of their total animal protein consumption.

Fishing is not of significance to the economy or to the subsistence of communities in the region of the **Kunene**. Research is needed on the biology of the fish in the Kunene River.

Fishing in the **oshanas** is very episodic, so people cannot rely on fish as a regular food source. When floodwaters are flowing, though, fishing is intense. Seventeen species of fish are known to have occurred naturally in the oshanas, but a further 46 exotic species have invaded the system since the water-supply canal from the Kunene was opened. Not much aquaculture is presently carried out in the oshanas, although a hatchery provides fingerlings to about 50 part-time farmers.

The **Okavango River** and the eastern **Caprivi** have extensive floodplains and many of the fish found in these rivers rely on floodplains for breeding, feeding, or both. About 80 species of fish have been recorded from the Okavango River. The human populations of these regions rely heavily on fish as a source of protein. Of the two systems, the Okavango is under greater pressure because it is smaller and has a relatively larger population. Fish stocks seem to be declining, as are the sizes of individual fish caught, and the proportion of long-lived species in catches. The favoured method of fishing is to use traps, sometimes baited, in shallow muddy areas. As well as scoop baskets, bows-and-arrows and spears, mosquito-nets and shadecloth may also be used. These very small-meshed nets trap fish of all sizes, including young fish that thus never reach breeding age. The effectiveness of traditional management is being eroded by pressure on natural resources, by increasing socio-economic stratification and commercialisation, and by the shift of political authority from traditional leaders to the central government. Furthermore, most fishermen also keep livestock as a form of wealth and most families have some money from wages earned elsewhere. Changes in ecosystems, including destruction of fish habitats and reduced and inadequate floods, are altering the fishery. Grazing on and harvesting of reeds and grasses also contributes to the degradation of the riverine environment, as does stamping by large numbers of women attempting to attract fish. Local people seem to have a good understanding of the relationships between fish and environment, but they tend not to see pollution as a problem. Many people have no toilets and use the river for the disposal of excreta. "Chemical" fertilisers for agriculture, and DDT and related insecticides to kill mosquitoes and tsetse flies, are used, the latter by the Ministry of Health and Social Services.

The annual value of the catch in the Caprivi is approximately N$9 million. After several years of inadequate floods, fish stocks are low and whole areas have become severely modified. Overfishing has resulted from a combination of environmental changes and increased fishing pressure from modern gear. Traditional fisheries management practices have disintegrated in the larger centres. Political and other disputes with Zambia and Botswana exacerbate the problem, and purely local politics also play a role.

The **Orange River** supports only 17 species of fish in the stretch that forms a common border between South Africa and Namibia. Few subsistence communities live along the Orange River, so the use of fish for anything other than recreational angling is very limited.

The four dams with greatest fish production are the von Bach, Hardap, Naute and Omatako Dams. Although it has been suggested that fish resources in these dams are under-utilised, the few concessions to commercial fishing seem to have been unsuccessful in the past. Sport fishing, an important tourist attraction, is organised by the Namibian Freshwater Angling Association.

Little aquaculture is presently practised. Most aquacultural enterprises in the past have attempted to grow "subsistence" fish, but without much success. The best bet seems to be small-scale, semi-intensive commercial fish culture, which would provide good social benefits and profits. The introduction of *any* alien species can be extremely dangerous to aquatic ecosystems and a careful environmental impact assessment must be done before any such introduction could be considered.

In summary, intensive grazing pressure, use of wetland resources, pesticide pollution, and physical damage to rivers and floodplains are all affecting fish habitats. None has yet caused major damage, but the combined effects of these pressures are cause for concern.

Fisheries policies, laws and regulations

Significant components of the policies contained in the draft Inland Fisheries Act concern the conservation and promotion of the sustainable utilization of the freshwater fisheries of Namibia; the protection and conservation of the ecosystems and habitats on which the freshwater fish depend; ensuring that the benefits deriving from the freshwater fishery resource are justly and equitably distributed; and the development of co-operative agreements with neighbouring states. The White Paper on the "Responsible Management of the Inland Fisheries of Namibia" (December 1995) aims to allow sustainable use but to protect biodiversity; to develop different management approaches for different systems; to protect the interests of subsistence households; to control fishing by gear restrictions; to police fishing activities; to allow local communities to share income generated from fish; and to support research and regional co-operation where these are needed. The White Paper suggests that foreign assistance might be valuable for infrastructure for research, for training law enforcement officers, for helping to put into practice the proposals that result from research projects, and for legal advice in negotiations with neighbouring countries.

Research requirements

The most important research and monitoring needs are a study of the fish of the Fish River; quantification of fish production in rivers and on floodplains, and of relationships between the hydrological cycle and fish production; the effects of livestock grazing on floodplains; and the effects of deforestation on riverine ecosystems.

Trends and threats: a summary

About 45% of Namibia, mostly in the southern and central areas, is devoted to commercial farming. About 40%, mostly in the north where more than 75% of the population lives, is communal land. Much of this communal land reflects the "tragedy of the commons", where degradation accompanies the over-exploitation of common resources. This is due partly to lack of tenure, partly to the pressure of a burgeoning human population, and partly to ignorance. Major human-induced changes taking place in Namibia are tabulated. In summary, the environmental threats to Namibian wetlands can virtually all be put down to the over-use of finite resources in sensitive ecosystems as a result of a combination of aridity over most of the country; massive population growth rapidly increasing the pressure on natural resources; loss of traditional resource management practices and a decline in traditional values and structures; new, "high-tech" techniques for exploiting resources; and poverty.

Trends in water-borne diseases

Anything that increases the area covered by shallow, slowly-flowing or still waters is likely to increase the presence of vectors of malarial parasites or intermediate hosts of bilharzia schistosomes, and therefore to encourage the spread of these diseases. In particular, bilharzia will spread if human hosts are unaware of the links between human urine and/or faeces and the disease. Water-borne bacterial diseases, particularly cholera and diarrhoea, are usually associated with faecally contaminated drinking or washing water. Overcrowded conditions, lack of sanitation, unprotected pit latrines and unhygienic habits all contribute to the likelihood of cholera epidemics.

Environmental "hotspots"

In summary, and not in order of importance, major environmental concerns are:

- species threatened with extinction
- clearing of riparian vegetation on the northern floodplains
- overgrazing by stock animals on the northern floodplains
- the settlement of people in new areas whenever water becomes available
- over-exploitation of aquifers and groundwater, causing lowered water tables
- overfishing
- the fact that >95% of the population lives below the poverty line
- the continued danger of alien plants and fish
- the increased likelihood of water-borne diseases.

1. Water as a resource

Much of the information in the following section is taken from Ashley (1995), a highly pertinent critical analysis of the issues of supply and demand of water in Namibia. Another particularly useful source of information is du Toit & Sguazzin (1995). Positions of the major place names and wetlands referred to in the text are indicated in Figure 1.

1.1 The availability of water in Namibia

Namibia is one of the most arid countries in the world. The entire western coastal zone is true desert, with a mean annual rainfall of less than 100 mm y^{-1} and mean annual evaporation about thirty times as great as this. Even in the better-watered eastern parts, rainfall is remarkably seasonal. At Katima Mulilo, for instance, where the mean *annual* discharge in the Zambezi River is 1300 cumecs (cubic meters per second, or m^3 sec^{-1}), mean discharge in the middle of the dry season in November is about 300 cumecs. In the wet season in April, it is an order of magnitude greater at about 3800 cumecs (Heyns 1993 in McCulloch 1994). As is the case in most deserts, variation in rainfall from year to year is also extreme: for instance, at the weir on the Omaruru River near Henties Bay on the central Namib coast, the mean annual discharge, measured yearly between 1943 and 1988, was 15 670 x 10^6 m^3, while the maximal annual value was 208 300 x 10^6 m^3 and the median value was zero (EEU 1990). Furthermore, most rain falls in short, intense episodes so that infiltration of water into the soil is low. On average, 83% of rainfall evaporates, 14% is evapotranspired, 1% recharges groundwater aquifers, and 2% appears as surface runoff (EEU 1990). Rainfall increases from <100 mm y^{-1} on the coast to >600 mm y^{-1} in the Caprivi strip; only 8% of the land surface receives >500 mm y^{-1}, which is the lowest average annual rainfall from which dryland cropping may be possible. Added to this, the country has no perennial rivers except for the Kunene and Okavango Rivers, which form the northern border with Angola; the Kwando, Linyati, Zambezi and Chobe Rivers, which form the borders with Botswana and Zambia in the north-east; and the Orange River, which forms the southern border with South Africa. The headwaters of all of these rivers are in other countries.

Inter-annual variability in rainfall means that the amount of standing vegetation varies extremely from year to year, and so does the carrying capacity of terrestrial ecosystems. Thus communities such as the Ovahimba traditionally practised nomadic pastoralism. Permanent settlements could be found only in the Oshana region of the north-west, as well as along the Okavango and Zambezi Rivers, and near surface springs in places such as Windhoek. In one of the many departures from tradition, present-day populations are larger and more settled, and tend neither to move, nor to suit the sizes of their herds to available vegetation. As a result, virtually all humans and livestock, except for a few of those living on the well-watered northern border, are now dependent on the "engineered" provision of water, especially for irrigating crops and watering livestock.

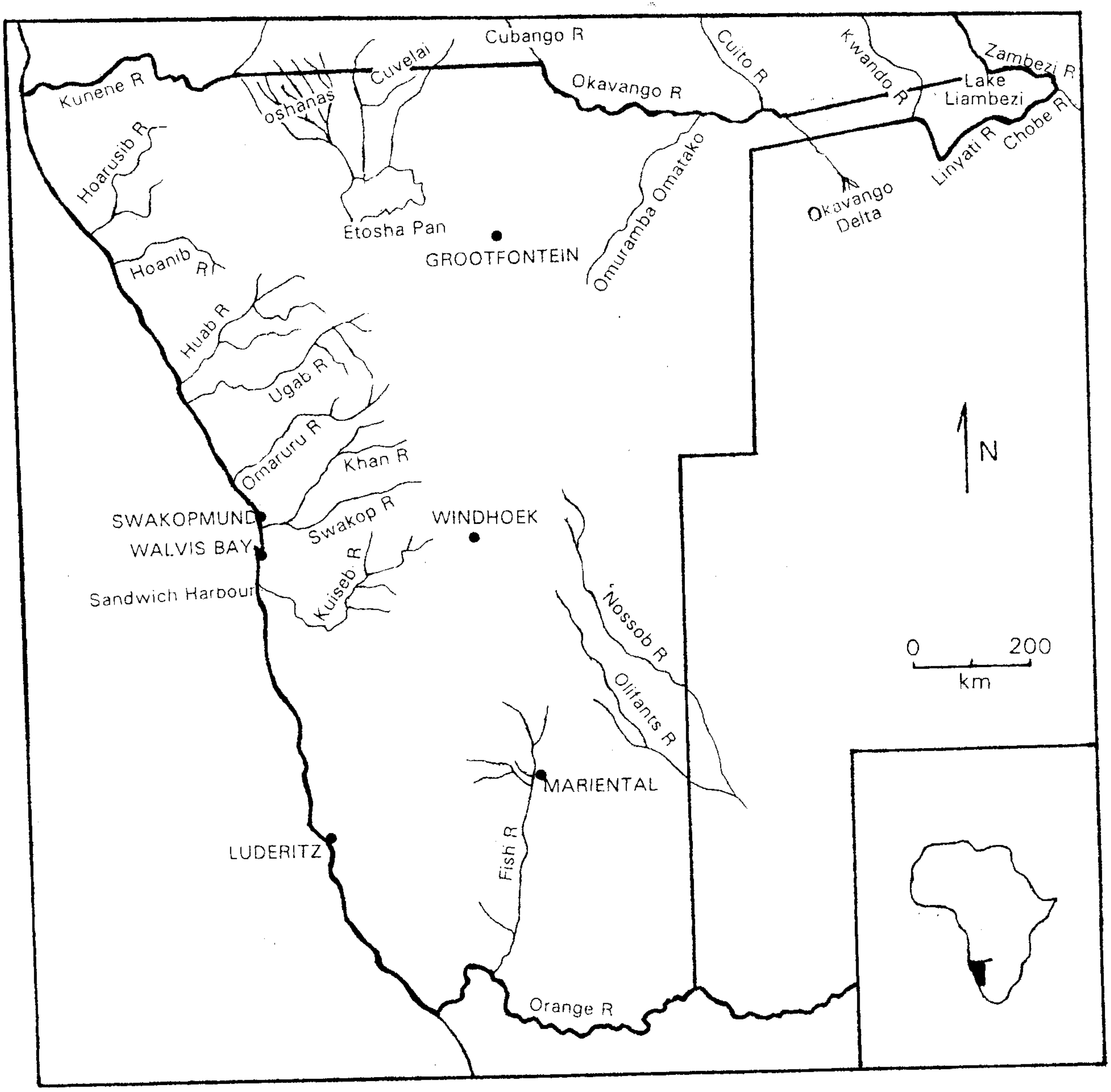

Figure 1. The major wetland ecosystems referred to in the text.

1.2 Sources of water

Presently, about 57% of the water used in Namibia comes from underground sources, 23% from the northern border rivers, and 20% from local reservoirs. A small but significant proportion of the water provided in Windhoek (about 12%) comes from the reclamation of sewage water to potable quality and the recycling of wastewater effluents for parks and sports fields. Fortunately for the existence of human populations, much of Namibia is underlain by groundwater stores of one sort or another. These are mostly alluvial aquifers, although enough water is stored in the north-eastern Stampriet Artesian Basin to supply that part of the country. A massive karst formation underlying about 2500 km^2 of land in the Grootfontein/Tsumeb district contains very large quantities of groundwater. This water is recharged fairly rapidly from rainwater (rainfall is about 500-600 mm y^{-1}) and, with care, should continue to provide a relatively large assured supply (see for instance du Toit & Sguazzin 1995, Ashley 1995).

Most of the water used in Namibia is stored locally, either under ground or in surface reservoirs. Although relatively few large reservoirs exist, thousands of small farm dams harness a significant, but unquantified, percentage of runoff. Of the 31 850 boreholes in existence in 1995 (du Toit & Sguazzin 1995), some were owned and run by national, regional or local authorities but most were private. Two important inter-basin water transfer schemes are in operation. The first provides much of the rural water supply in the Cuvelai drainage of the north-east by inter-basin transfer from the Calueque Dam on the Kunene River. The second is the Eastern National Water Carrier (ENWC). This scheme is much larger in scale and is designed to provide water, mostly from the Okavango River, for the heartland of Namibia, particularly Windhoek. It presently consists of the Swakoppoort and von Bach Dams on the Swakop River, a dam on the Omatako River in the north, a series of boreholes abstracting water from the Karstveld, and a canal linking the Omatako Dam with the Karstveld borehole field. At present, the canal is not functional and the Karstveld boreholes are used to supply water from the karst area to Okakarara and adjacent rural areas. The intention is to build a pipeline from the head of the canal northwards to the Okavango River, in order to abstract about 20 000 000 m^3 of water a year for Windhoek. Initially the quantity of water under consideration was as much as 120 000 000 m^3 per year, but the State has committed itself to abstracting no more than 20 000 000 m^3 per year (*The Namibian* newspaper, 18 October 1996). The Grootfontein-Omatako canal is a large open concrete-lined canal about 200 km long, and with a capacity of about 3m^3 sec^{-1}. It was designed as an open canal for economic reasons. Because it has acted as a longitudinal death-trap for animals both large and small, it has caused a massive outcry from the public and conservation organisations. Both for this reason, and the rate at which water evaporates from it, DWA would like the canal to be covered, but no funds are presently available for the purpose (S. Bethune, pers. comm.). The potential conflicts arising from the proposed construction of the pipeline to the Okavango River are discussed in section 1.5.1.1 below.

1.3 The human population and water demand

Unless otherwise indicated, demographic data provided in the discussion below are taken from Ashley (1994, 1995).

The population of Namibia is presently nearly 1.7 million people. The only major urban centre is Windhoek, with a human population of just over 185 000 (P. Heyns, pers. comm.); fewer than ten other towns have populations in excess of 10 000. The majority of the population is rural, and subsists wholly on natural resources. Most people live in the oshanas of the Cuvelai Basin. The oshanas are a series of seasonal drainage lines emptying into Etosha Pan, and about 28% of the entire Namibian population lives here, on less than 1% of the land. Other major population centres are along the Okavango River and in the Caprivi. The average population density over the entire country is 1.7 km^{-2} (about a thirtieth of that of Turkey or Pakistan, which are of similar area), while densities reach 100 people km^{-2} in the Cuvelai. Urbanisation has been a marked recent trend: between 1981 and 1991, the population of Windhoek has increased by 46%, of Rundu by 911% and of Katima Mulilo by about 3000%.

The average population growth rate is estimated to be at least 3% (Population Planning Unit, 1994) suggesting that the total population will double to 4 million by about 2020. This means that the demand for water will at least double during that period. Increasing urbanisation, industrial development and improvements in standards of living would all result in a relatively greater increase in demand for water (and energy, and goods) over and above the doubling resulting from the growth rate alone.

1.3.1 Nation-wide water demand

The assured annual yield of water for Namibia is about 500 x 10^6 m^3 y^{-1} (Chivell 1992), excluding water in the perennial border rivers (P. Heyns, pers. comm.). Water consumption increased by 57% between 1980 and 1993, to approximately 240 x 10^6 m^3 y^{-1} (Table 1). It is expected to exceed 300 x 10^6 m^3 y^{-1} in 2005 and may even reach 400 x 10^6 m^3 y^{-1} by then if irrigation demand is allowed to grow at the same rate as other demands. In other words, by 2005, or soon thereafter, it will be necessary to use the *entire* exploitable assured yield for the whole country. After that (Ashley 1995 predicts by 2015 at the latest), Namibia will no longer be self-sufficient in water, just as it has not been self-sufficient in food since 1965, nor will be in wood by 2003 (Ashley 1995).

1.3.2 Sectoral and regional water demands

Table 1 indicates the major users of water and the changes in the proportion of total consumption by each over a 13-year period. Although the major increase in demand is from the urban sector, the greatest absolute amount is presently used for livestock watering and irrigation, so that agriculture accounts for 72% of the total water consumed per annum. This is not surprising when one considers that one hectare of irrigated land uses as much water as about 1000 cattle or 1600 rural residents. If "food independence" were to be State policy, the amount of water required for irrigation would be greater than the overall amount of water actually available for all purposes for the entire country. As far as domestic use is concerned, ease of access to water is a major determinant of use. People with access only to standpipes use about 14-25 litres per person per day, while in Windhoek, those in low-income urban areas use about 70, in middle-income suburbia about 200, and in upper-income suburbia about 610 litres per day. Ironically, this value is high in global terms even for mesic countries.

Table 2. The "Water Regions" of Namibia designated by Ward (1994), with some amendments by P. Heyns (pers. comm.).

Water Region (political regions in parentheses)	Sources of water by % of area	Main uses of water	Existing water-supply schemes	Potential developments
1: Cuvelai (Oshana, Omusati, Ohangwena, N. Otjikoto)	70% Kunene, 30% perched aquifers	small farms, domestic	Calueque Dam, pipelines, canals	irrigation
2: Kunene (northern Kunene)	scarce groundwater (except along Kunene River)	few subsistence farms	dams in Angola, groundwater	Epupa Falls Dam (hydro-electric)
3: Okavango (Okavango)	90% river, 10% alluvial aquifer	small-scale farming, domestic	pipelines from the river, groundwater	ENWC
4: Zambezi (eastern Caprivi)	70% river, 30% alluvial aquifer	small-scale farming, domestic	from the river, groundwater	irrigation
5a: Northern Namib (S. Kunene & N. Erongo)	10% dams, 90% alluvial aquifers	few people: small industry in Khorixas	small dams, groundwater	Zebraskop Dam, Ugab River
5b: Central Namib (S. Erongo, most of Khomas)	alluvial aquifers (coastal towns), dams & recycling (Windhoek and environs)	agriculture, industry, domestic, mining	von Bach, Swakkoppoort, Friedenau, Omdel Dams	desalination for coastal towns, ENWC for Windhoek
5c: Southern Namib (W.Hardap, W. Karas)	alluvial Koichab aquifer for Lüderitz	boreholes on stock farms	groundwater	irrigation
6: Orange (south-eastern Karas)	90% river, 10% alluvial aquifers	agriculture, mining	from the river, groundwater	Mining for diamonds; irrigation
7: Kalahari-Fish (most of Hardap, Karas)	90% alluvial and artesian [Stampriet] aquifers	commercial farming; domestic	Hardap, Naute, Oanob Dams	irrigation
8: Northern Kalahari (Omaheke, Otjozondjupa)	Karstveld groundwater	stock watering, crops, mining, domestic	Omatako Dam, Karstveld boreholes	ENWC

- Whenever access to water becomes easier, and standards of living improve, the rate of consumption increases. Consumption in Namibia will outstrip supply in 20 years or so.

- Cows consume 45-55 litres per animal per day. Cows are considered to be one of the most valuable forms of wealth for peasant farmers, so it is extremely difficult to discourage farmers from increasing herd sizes. Grazing beyond the carrying capacity of the land causes major degradation and soil erosion, particularly in riparian zones.

- In the Cuvelai, the Main Shallow Aquifer is a lens of fresh water lying on top of a highly saline aquifer. Residents presently complain that the deeper they have to dig for water, the saltier it is. Mining of water is also resulting in a lowering water table on the coast. The water level in the Swartbank aquifer at the mouth of the Kuiseb River had dropped from about one metre below the surface sands in 1974 (when it had been recharged after major floods) to about 8 m below the surface in 1988 (du Toit & Sguazzin 1995). McCullum (1994) indicates that more recently, the water table in the Kuiseb aquifer had fallen from 2-3 m to 13 m below the surface (and 4 m above bedrock).

- According to du Toit & Sguazzin (1995), DWA plans to double the amount of water presently piped from Calueque Dam on the Kunene River in Angola, and to develop 300 new water supply points from boreholes over next 10 years. P. Heyns (pers. comm.), by contrast, has indicated that the capacity of the pumps removing water from the dam is 3.2 $m^3 sec^{-1}$ and that DWA has no intention of increasing this capacity in the near future. Namibia has agreed with Angola to abstract up to 6 $m^3 sec^{-1}$ of water from the river.

- Additional boreholes and standpipes attract more people and livestock, leading to overgrazing, particularly in years of low carrying capacity.

- Due to the cost of fixing pipelines when local people repeatedly break into them, the Olushandja-Ogongo-Oshakati canal is an open one. Wherever water is available in this way it is considered by the consumers to be "free" and so is wasted: for instance, taps may be left running for stock to drink *ad libitum*. This in turn leads to standing pools where mosquitoes can breed, and softened cattle tracks that result in erosion. Washing of clothes, and bathing, in open canals, has detrimental effects on water quality.

- The Namibia Development Corporation aims for "food independence" in Namibia. The Caprivi region is seen by the Corporation as the "breadbasket" of Namibia which can provide sufficient food if adequate quantities of water are available for irrigation. According to B. van Zyl (pers. comm.), "high-tech" production of millet, groundnuts and maize by communal farmers is already occurring in the area, while S. Bethune (pers. comm.) has indicated that at least two previous attempts at irrigation farming in the Caprivi have come to naught. McCullum (1994) indicated that tentative plans were underway to grow sugarcane in the Caprivi, using some 250 x 10^6 $m^3 y^{-1}$ of water from the Zambezi River, but these plans seem to have been shelved.

- More than 86 GWh y^{-1} of energy are expended every year in pumping water in Namibia.

- The biological and other environmental effects of the inter-basin transfer of water within Namibia have yet to be studied.

1.5 Water law and DWA policies regarding water supply

During the period of South African jurisdiction over Namibia, all laws were South African, but only that legislation promulgated by the South West African Administrator became law. Thus water-related legislation in Namibia is still the South African Water Act 54 of 1956. None of the South African amendments (e.g. of 1984) to this Act, nor the South African Environmental Conservation Act of 1984, was promulgated. A new Water Act has been drafted, but has not yet been distributed as a White Paper (J. Glazewski, pers. comm.).

In keeping with the colonial attitude to water supply, for many years the Department of Water Affairs made every effort to provide water on demand, rather than to manage (i.e. attempt to limit) that demand. As a result, water tables have sunk, wells have dried up or become salty, rivers have silted up and "fossil" water has been (and continues to be) mined. Mining of water results in the abstraction and use of water that accumulated in the past, presumably when the land was much wetter than it is now. It is notable that no overall policies with regard to water mining seem to be in place, even though they will have fundamental effects on the availability of water in the future. Because lack of water will constrain all other developments on a national scale, major investments are being made in a variety of water schemes, some of which will have wide-ranging economic and environmental impacts: impacts on ecosystems, on energy use, on household budgets, on competitiveness and, ultimately, on the national economy. Degradation of water resources, especially by pollution, will have the same effect.

This situation had been predicted many years ago. Potten & Pintz (1976), for instance, mention interesting old proposals, including one by EHL Schwarz to divert the Kunene, Okavango and Zambezi Rivers to Etosha Pan and Lake Makgadikgadi in order to change the climate of the entire southern African region. According to Potten & Pintz, "[Schwarz's] theories, unfortunately, were based on complete ignorance of topographical levels, very unsound meteorological theory and some very dubious arithmetic." A much more practical proposition is the desalination of seawater. Although desalination could feasibly provide all the water needed by Namibia, the process is financially so expensive that it is being considered seriously by DWA only for the provision of domestic water supplies to the most arid coastal towns (but see comments in 1.5.1.1).

DWA's water quality and environmental policies are presently being developed, so are not yet available in written form. According to Ashley (1995), though, it is going to be essential for DWA to adopt three parallel strategies:

i) to develop new sources where possible (for instance desalination; water from the Okavango River for the Eastern National Water Carrier; some further exploitation of the water in the Kunene River);

ii) to improve management of water resources to protect them from over-exploitation, pollution, siltation, etc.;

iii) to develop an ethic of demand management and water conservation by realistic pricing, tariff incentives, education, and planning in the national interest (e.g. by deciding that some industries are not cost-effective, and/or might have to relocate).

These three strategies are discussed in some detail in section 1.5.1 below.

Within the compass of these strategies, Ashley (1995) recommends that the following policies be developed or that, if they have already been developed, be seen through to implementation. She notes (p. 18) that

> "Although DWA has already established [much of what follows] as policy objectives, implementation also requires development of commitment and capacity in several other ministries (including Trade & Industry, Finance, Regional Government, Works, Fisheries, the National Planning Commission, Environment and Tourism, and the Department of Agriculture), municipalities and Regional Councils, local communities, and amongst the private sector and Namibian public."

Aspects of policies that Ashley sees as imperative are as follows:

- appropriate water pricing, block tariffs and demand management
- establishment of the principle of payment for water, in rural as well as urban areas
- analysis of water-use leading to decisions about the location of industries
- reflection of "opportunity costs" in costing the price of water from new schemes
- prioritisation of water-use in planning: recognition that some uses (for instance some industries, and agriculture in some areas) are not water-efficient and should be discouraged
- recognition that water resources are finite
- investment in improving access to clean water in rural areas (the target is 80% of the population by 2000)
- that the parastatal company being developed to provide bulk water must be required to develop water-conservation measures where possible, or else the company may encourage excessive use of water to recoup costs of developing resources
- monitoring and management of resources, especially the ephemeral rivers, oshanas and river mouths, to protect against over-utilisation and disruption of essential ecosystems or ecosystem processes.

At least the first five of these have already been addressed to some extent by DWA (Heyns 1995a).

1.5.1 Ashley's three major strategies with regard to water supplies

1.5.1.1 Development of new sources of water

No further sites are available for constructing large conventional dams that are likely significantly to satisfy further water demand. Thus, few of the schemes that have recently been developed, or are in the planning stage, involve merely the construction of dams. For instance, the recently developed Omdel Dam on the lower reaches of the Omaruru River is not designed so much for the conventional storage of surface water as for the recharge of the underlying aquifer. Immediate recharge of the aquifer is inefficient because finely-divided silts suspended in the water block up the interstices between sand grains and prevent water from penetrating into the aquifer; instead, much of it evaporates or flows into the sea. The Omdel Dam is designed to hold the water for long enough for the suspensoids to precipitate out before the water is run over several recharge areas (EEU 1990).

Although desalination of sea water is very expensive in monetary terms (see section 1.5.1.3 below), DWA has decided that further developments in coastal towns will have to be provided with fresh water from this source (e.g. S. Bethune, pers. comm.). Several methods of desalination are available, but they all have high running costs, partly because they are very energy-expensive.

The Eastern National Water Carrier (see section 1.2), when complete, will consist of three reservoirs, 550 km of pipelines and 200 km of open canal. According to R. Fry (DWA Deputy Permanent Secretary), the final stage, which has yet to be built, will consist of 250 km of pipeline to carry 20 x 10^6 m^3 y^{-1} (about 0.5% of the MAR at Muhembo) from the Okavango River to Windhoek and other central areas of the country.

Completion of the ENWC will have significant effects on the Okavango River and, perhaps more important, on the Okavango Delta, which is downstream of the putative take-off point for water for the pipeline. The delta is unique in many respects and it is unlikely that Botswana will accept without question the abstraction of water to the point that the water balance of the delta may be affected. Although the amount of water that Namibia plans to abstract is a relatively small fraction of the *mean* annual runoff, it may represent a significant proportion in the dry season, especially in years of below-average rainfall. DWA has calculated, though, that a pipeline from the Okavango River will cost about N$1 billion, while reducing the growth in water demand in the Windhoek area by 3% per year will allow supplies to last until approximately 2003, *without* the further development of the ENWC (P. Heyns, pers. comm.). Ashley (1995) notes, too, that if the unit cost of water to Windhoek were presently N$2.7 m^{-3}, then desalinated seawater would cost N$6-8 at the coast, and Okavango water N$7-10 m^{-3}.

Another major water engineering scheme is the damming of the Kunene River at Epupa Falls, about 200 km downstream of Ruacana Falls, in order to provide hydroelectric energy for Namibia and Angola. This scheme is not designed for water supply and is being investigated not by DWA but by NAMPOWER, the Namibian electricity supply commission. This scheme, too, has met with considerable opposition from organisations such as the Wildlife Society of Namibia (Bethune undated), mostly because of the belief that such a major scheme is not necessary. Ashley (1995) has calculated that the capital cost of providing 200 000 rural households with sufficient photovoltaic ("solar energy") units to meet their electricity needs would be about N$740 million, or about half the cost of developing the Epupa Dam (N$1.5 billion). Simmons *et al.* (1993) consider that the Epupa Dam would be immensely expensive and environmentally more damaging than alternatives such as the Kudu gas field. P. Heyns (pers. comm.), on the other hand, considers that the development of the gas field would cost "billions more than Epupa".

The Wildlife Society of Namibia's commentary (Bethune undated) on the prefeasibility study of the Epupa scheme largely highlights the very "brief addressing" of the environmental aspects of the scheme. Major environmental impacts would include loss of riverine habitat which supports many endemic species, alteration of the flow regime, the change of the river into a lake, and the dynamics of the sediments in the estuary. The scheme would also have significant impacts on traditional farming settlements on the banks of the river in Angola and Namibia, as well as on tourism. The Wildlife Society also expressed concern at the lack of an evaluation of the environmental costs of the dam (and of the proposed 100 MW coal-fired power station intended to meet shortfalls in power generation in low-flow seasons) and a lack of examination of alternatives such as the Kudu gas field, power demand management, the entire policy of Namibia being power-independent, or improving and upgrading the existing Ruacana hydroelectric scheme.

Other water-supply schemes under consideration include a dam on the Ugab River at Zebraskop to provide water for the rapidly-growing town of Khorixas (an EIA has already been done: S. Bethune, pers. comm.) and the provision of more boreholes (Namibia already has about 130 000, of which about 32 000 are presently functional: McCullum 1994).

1.5.1.2 **Management of water resources**

It should be noted that it is State policy to call for Environmental Impact Assessments for all new developments, and that an attempt is being made for the first time to consider the effects of damming on that part of a river below a dam: a monitoring programme is presently under way to examine the effects of "ecological releases" of water on the Oanob River at Rehoboth (S. Bethune, pers comm). Further, DWA has been responsible for monitoring the effects of abstraction of groundwater on terrestrial vegetation in both the Kuiseb River (S. Bethune, pers. comm.) and the Karstveld near Grootfontein (Chivell 1992).

Namibia's "Green Plan" (Brown 1992) considers various aspects of the management of water resources, and indicates the need to

- extend the rainfall gauging network;
- improve the reliability and completeness of the data collected;
- participate in the responsible regional development of shared border rivers in order to satisfy the needs of all countries involved;
- promote research into reducing the siltation of reservoirs and into methods for enhancing recharge of groundwaters;
- consider the need for including compensatory releases in the Environmental Management Study for any new project;

- continue development of computer software for the optimisation of water supply management.

The Green Plan document (Brown 1992) also lists some policy requirements with regard to promoting sustainable management of water and aquatic ecosystems:

- policies allowing the development of local tenure rights & institutions necessary for local management of resources (along the lines of MET's Conservancy policies);
- policies to ensure protection and management of key wetlands and watersheds;
- policies to ensure water conservation measures and to strengthen environmental management;
- policies aimed at improving our understanding of indigenous knowledge and skills in resource management so that these can be built on.

1.5.1.3. **Water demand management**

The need for water demand management is not peculiar to Namibia, but reducing demand is likely to be particularly cost-effective in such an arid country. Consider charging the actual cost of water, for instance. The current cost of water in Windhoek is about N$1.20 m^{-3} but it would be at least N$2.77 if one were to take into account the capital costs of providing bulk supplies, while a realistic cost is between N$4 and N$5, if one includes the capital cost of necessary new developments. Water is presently supplied to rural areas free of charge, which merely encourages the profligate use of water and a lack of concern about leaking pipes, open taps, etc. In some areas where irrigation schemes operate, the real cost of crops produced is actually less than the value of the water used. Clearly, if water were to cost anything like its real value, it would be used far more sparingly (details from Ashley 1995).

Other savings can be made by

- sealing leaks in distribution systems (up to 33% of water is lost this way in some areas);
- using appropriate drip irrigation of crops;
- charging realistic prices for water (irrigation water from Hardap Dam, for instance, is supplied at 1.5c m^{-3}, although the real cost is approximately 30c m^{-3}), which would discourage the production even of high-value crops;
- reducing the evaporation of water from the surfaces of swimming pools by using plastic covers (about 40 m^3 of water is lost per swimming pool per year in Windhoek, and yet plastic covers could reduce this by nearly 95%);
- harvesting of water (for instance from roofs);
- the use of silt dams;
- the appropriate use of water (e.g. appropriate crops, water-efficient industries);
- public education.

DWA has a massive education programme under way. They have assisted in the production of some excellent publications such as Ward (1994) and du Toit & Sguazzin (1995).

1.6 **Water quality**

According to S. Bethune (pers. comm.), management policies with regard to water quality are less advanced than some other aspects of water management in Namibia. Guidelines for management of aquatic ecosystems are presently being developed, however, while World Health Organisation standards are used for drinking water and effluents. This document does not attempt a detailed analysis of water pollution. In brief, deteriorating water quality is a serious issue in some areas. It is probably not as great a problem in much of the country as are other issues, since the use of fertilisers and other agrochemicals is uncommon. In towns and in the northern border rivers, however, deteriorating water quality needs to be monitored. For instance, du Toit & Sguazzin (1995) suggest that salinisation of the soil (and thus of water) is becoming evident in the Okavango and Hardap irrigation areas, while salinisation is a major concern in the Cuvelai Basin and surrounding areas (P. Barnard, pers. comm.).

1.7 **Water-related diseases and public health**

Water-borne bacterial diseases seem not to be of major concern, although outbreaks of diseases such as cholera are always possible. According to S. Bethune (pers. comm.), DWA regularly monitors public water supplies, and water supplies to schools and clinics, in both urban and rural areas, for faecal bacteria. DWA also contributes to public health in that its rural offices provide large numbers of latrines.

Water-related parasitic diseases are of major concern, however. As in the rest of Africa, malaria is a major killer, and chloroquine-resistant strains are known from Namibia. Malaria has been found as far south as Rehoboth, as well as in Windhoek and the Erongo Region.

Bilharzia (schistosomiasis) is endemic throughout the regions of the northern rivers and floodplains. In the Kwando area, 90-95% of the population suffers from bilharzia, and some children die from the disease. As is the case elsewhere, bilharzia can be a debilitating disease that forms part of the "poverty spiral": lack of education, lack of a job, lack of hygiene, lack of energy because of a parasite load, lack of an ability to improve one's prospects ...

1.8 **DWA staff**

An analysis of the personnel in DWA by Stanley Consultants (1995) indicates that while the Division is technically very strong, the high proportion of low-level employees, the lack of well trained staff, low salaries and difficulties in recruiting and training new staff members, lead to personnel problems. Ultimately this may lead to an inability to deal adequately with the technicalities of providing clean water in the right place at the right time to cities, towns and communities. Given that the lack of water is one of the most critical issues in the future development of Namibia, the situation in relation to the DWA staff needs urgent consideration. [*In 1997, following the drafting of this report, extensive restructuring and privatisation of some functions of the DWA have taken place - Editor*.].

2. The status of wetland ecosystems in Namibia

Wetlands are variously defined in the global literature (e.g. Breen 1991), but the working definition commonly used in Namibia appears in the Introduction to a volume of papers on Namibian wetlands (Simmons *et al.* 1991). In this document, wetlands are defined as

> *the interface[s] between aquatic and terrestrial systems, whether permanently or ephemerally inundated with fresh or salt water.*

Although this definition encompasses intertidal, estuarine and other coastal systems as well as inland waters, the present document generally considers only those aquatic ecosystems not affected by or related to the sea. By this definition, too, virtually all of Namibia's aquatic ecosystems can be considered wetlands, except perhaps some of the bigger reservoirs.

Wetlands throughout the world are valued for the variety of economically important services they offer to humans. Some of these, which are specifically associated with large wetlands that support substantial stands of aquatic macrophytes (large rooted plants like reeds), are

- *storage of water*: retention of water during periods of high flow or rainfall, and slow release during drier periods, reduces the danger of flooding and provides water over relatively long periods;
- *filtration of water*: plants act as filters, removing particulate matter such as suspended silts and bacteria;
- *removal of nutrients*: plants may take up nutrients from the water that flows past them;
- *stabilisation of shorelines*: the presence of reeds and other plants reduces erosion.

These services may also be developed in artificial wetlands, for instance to cleanse sewage effluents.

Other attributes of wetlands include the following:

- the very presence of water often allows plants (and animals) to grow; these plants include grasses for animals to graze, as well as reeds, trees and food plants for humans;
- some wetlands support significant numbers of fish;
- many provide water that recharges underground aquifers;
- biodiversity is often very high;
- they are valued recreational and tourist attractions;
- they are of great scientific and educational value.

Although only about 4% of the surface area of Namibia consists of wetlands, and most are inundated only seasonally or even less frequently, close to 75% of the population lives in close association with the riverine and floodplain wetlands in the far north of the country. For this reason, MET considers the country's wetlands to be so valuable that one of the research staff of the Division of Specialist Support Services of MET is dedicated to research on these ecosystems.

2.1 Namibian wetland ecosystems

2.1.1 Wetlands of the Namib Desert

In terms of rainfall, the Namib is one of the driest deserts in the world (see, for instance, Lancaster *et al.* 1984), and yet a number of different kinds of wetland are found throughout the region (for instance Logan 1960, Goudie 1972, Day 1990). Relatively permanent pools, streams and lakelets fed by groundwater springs may, depending on the extent of evaporation, be relatively fresh (e.g. in the Naukluft) or at the other extreme may be hypersaline (Day & Seely 1988). Ephemeral waters vary from rivers that run for short periods after rain has fallen upstream in the catchment (these include the large "sand rivers" of the Skeleton Coast, Jacobson *et al.* 1995) to the pools they leave behind after flow has stopped, and pools formed by rain falling in endorheic (inward-draining) basins. These pools may be tiny potholes less than 1 m in diameter in granite inselbergs, or large, shallow lakes like Sossusvlei, a famous clay-bottomed depression in the dunes south of the Kuiseb River.

All of these systems are of intrinsic interest and value from the point of view of biodiversity because they support highly specialised species of invertebrates such as crustaceans and insects (and a few frogs). From a human point of view they are also valuable because they provide sources of drinking water for edible terrestrial vertebrates such as birds and mammals, so that the distribution ranges of these animals expand during wetter periods.

Far more important for the people and wildlife who live in the desert are the ephemeral rivers, which act as linear oases (for a detailed description see Jacobson *et al.* 1995). Although water is not found on the surface, the beds of most of these rivers hold significant quantities of water. If the water is relatively close to the surface, then deep-rooted trees can tap directly into the water supply. The Kuiseb River, for instance, supports large numbers of very large trees (mostly *Faidherbia albida* and *Acacia erioloba*). Trees provide shelter for a variety of other organisms, so that longitudinal terrestrial ecosystems develop with complex communities that may even include lions, hyenas, gemsbok and baboons. These oases, then, act as refugia for many of the larger vertebrates beloved by tourists. The groundwater associated with some of these rivers (e.g. the Kuiseb, the Swakop, the Omaruru) is sufficiently extensive to be tapped for human use. A major threat to these systems, and to the biological (including human) communities that rely on them, is lowering of the water table as a result of abstraction of water. If the roots of trees can no longer reach the water table, the trees will die -- as, ultimately, will the rest of the associated biological communities. Much of the subsurface water in the river beds is replaced seasonally from upstream. When these rivers are dammed in their better-watered upper reaches, this water is no longer available downstream. For example, the Kuiseb is dammed by the Friedenau Dam in its headwaters not far from Windhoek and also by about 400 smaller farm dams on its tributaries (Bate & Walker 1993). Together, these reduce the amount of water flowing down the river, either on the surface or under the ground. When dams prevent replenishment from upstream, and the aquifers in the lower reaches are also being mined, the situation is clearly not sustainable: eventually supplies of water in the aquifers must become inadequate. This is seen in the case of the aquifer supplying Khorixas. The "resting" water level in the aquifer has dropped by about 50 m since 1978. The aquifer is now considered to be "exhausted" and is unable to provide any further increase in yield (Jacobsen *et al.* 1995).

At present, the safe yield from the ephemeral rivers in the west of Namibia is about 200 x $10^6 m^3 y^{-1}$, which is about 40% of the total amount of water available for the central region of the country (P. Heyns, pers. comm.). This quantity is about four times the virgin mean annual runoff of the major rivers (from Ward 1994):

Hoarusib	20 x 10^6 m^3 y^{-1}
Omaruru	12 x 10^6 m^3 y^{-1}
Ugab	8 x 10^6 m^3 y^{-1}
Swakop	6 x 10^6 m^3 y^{-1}
Kuiseb	5 x 10^6 m^3 y^{-1}

Although the estuaries of most of the sand rivers are blocked, the sand may be gouged out by occasional floods. Some, such as the Uniab Estuary, have fairly fresh and fairly permanent pools and trickles of water that support reedbeds. Sandwich Harbour, which appears to be a relictual estuary (Ward 1994), consists mostly of 5 km^2 of saline wetland. It is fed at least partly by subsurface fresh water, and supports at least 70 000 wetland birds at certain times of year (R. Simmons, pers. comm.). The wetlands at Walvis Bay, which include the Kuiseb estuary, extend over some 35-40 km^2 and support migratory birds as well as more than half of southern Africa's flamingo populations (du Toit & Sguazzin 1995).

Except for a short stretch between Mile 108 and Walvis Bay, virtually the entire coast is protected either as national parks (the Skeleton Coast Park in the north and the Namib-Naukluft Park in the south) or, in the far south, as Diamond Area no 1.

2.1.2 The rivers and oshanas of the northern border region

Almost three-quarters of the population of Namibia lives near the northern border. Although cash wages are significant in some areas, in others the people are able to survive only because of the rivers and wetlands, being sustained by natural resources alone.

2.1.2.1 The Kunene River

The Kunene River, which forms the north-western border between Namibia and Angola, is about 1050 km long and drains a catchment of about 106 000 km^2, about 14 000 km^2 of which is in Namibia. Although it is the third largest river of Namibia, it is relatively poorly known. Mean annual runoff at the mouth is 5000-5500 x 10^6 m^3 and mean annual precipitation at its source is about 2000 mm (Simmons *et al.* 1993). The upper and middle reaches are situated in Angola, the upper reaches tending to be steep, while the middle reaches support a marshy floodplain. From Ruacana, the river is narrow and fast-flowing, with small rapids. The river is typical of highly variable tropical systems, with an average 11-fold difference in flow between wet (February to April) and dry (October) seasons; in fact the river may even cease to flow in October/November. Flow also varies by as much as 14-fold from year to year.

The estuary has a freshwater lagoon about 1.25 km^2 in area and extending 2 km south of the small mouth. At high tides, salt water backs up the river. The waters of the lagoon are up to 10°C warmer than the sea, so that the river sends a plume of warm, nutrient-rich (Simmons *et al.* 1993) water 100 km out to sea. The mouth of the Kunene River is about 200 km from the mouth of the Hoarusib River, which is the nearest wetland of any significance. Seventy-two species of wetland bird, mostly non-wading residents and including 14 Red Data Book species, have been recorded from the estuary. The Kunene mouth is the second most species-rich wetland along the coast of Namibia and fourth in importance when considering the number of birds visiting (Simmons *et al.* 1993).

Several dams have been built on the main stream, but only three are presently of significance: Gové Dam, in Angola, which is apparently not fully functional (see, for instance, Heyns 1995b); Calueque Dam, in Angola, which was damaged during the civil war but still holds enough water to supply household needs in the oshanas of Namibia; and Ruacana Dam, on the border, which is used to divert water into the Ruacana power station. The irrigation scheme at Matala in Angola is presently out of order, but when operational it will abstract unknown, but presumably significant, quantities of water from the river near Ruacana.

The Kunene River flows mostly through rocky gorges in mountainous terrain, so there are no large floodplains or wetlands for most of its length. At Swartbooisdrif the river is 80-150 m wide, and the banks support dense stands of makalani palms and reed beds. Although crocodiles occur on the river in this region, elephant and rhino are no longer found here. Two species of turtle are known from the mouth (Simmons *et al.* 1993).

Hydroelectric power is generated at Ruacana Falls. The daily fluctuations in water level caused by the operation of the dam are implicated in reduced breeding success of certain fish (B. van Zyl, pers. comm.). Another dam for the generation of power is being planned at the Epupa Falls (see discussion in section 1.5.1.1). The proposed dam wall would be 130 m high, would flood 75 km of river length, would hold 5000 x 10^6 m^3 of water and would cover an area of approximately 200 km^2. It would also disrupt the lives of the local ovaHimba people.

The Kunene region, being remote and hyper-arid, has a population density of only about 0.4 people km^{-2}. The majority of the few people living in the area are Herero-speaking Ovahimba, who today are nomadic pastoralists, but were traditionally hunter-gatherers (du Toit & Sguazzin 1995).

A stretch of about 30 km from the mouth of the Kunene is protected on the Namibian side of the border as the northernmost extremity of the Skeleton Coast Park.

2.1.2.2 **The oshanas**

The northern border area west of the Okavango River and east of the Kunene River is very flat, and is traversed roughly from north to south by numerous seasonal rivers whose waters originate in Angola. These rivers include the Cuvelai (which gives its name to the area) and the Etaka. The drainages of these rivers converge south of the Namibian border near Lake Oponono, and from here the Ekuma River flows into Etosha Pan, which last filled significantly in 1954. Extraordinarily, the only publication available on the biological limnology of oshana ecosystems is that of van der Waal 1991b on fish, while the only significant information on the biological limnology of Etosha Pan is recorded incidentally in a paper (Berry 1972) on flamingo breeding. More general aspects of the oshana region and its peoples are well detailed in Marsh & Seely (1992).

The oshanas are the most densely populated area of Namibia, supporting about 400 000 people at an average population density of 11 people km^{-2}. The major natural resources upon which the people rely are grass (for grazing) and wood (for fuel and for building). The mixed subsistence economy depends on seasonal floods to regenerate grazing and replenish the water table and soil nutrients. Although fish may be abundant in the oshanas during floods, this is a highly seasonal phenomenon and so fish do not form a particularly reliable source of food. Most water is piped from the Calueque Dam on the Kunene River, and is used for small farms and household purposes. As in the Kunene region, while most people used to be nomadic, this is no longer the case. Thus the area suffers from overgrazing and deforestation, twin results of overpopulation (Ward 1994). Some of the roads and canals, such as the Ombalantu-Oshakati canal, built in 1959, run east to west across the direction of flow of the oshanas. This means that flow is disrupted, and less water is available for groundwater recharge and for replenishing the soil.

Etosha Pan, into which the oshanas ultimately flow, is one of the biggest salt pans (or saline playa lakes) in the world. It is probably best known for the thousands of flamingos that breed on it during suitable conditions (Berry 1972). Except for the area immediately surrounding Etosha Pan, though, none of the oshona drainage is incorporated into a protected area.

2.1.2.3 The Okavango River

The Okavango River, like the Kunene, rises in Angola. It is narrow and steep for the first few kilometres of its headwaters, after which the gradient is reduced and the river develops a fringing floodplain between valley walls. It forms about 415 km of the border between Angola and Namibia before turning south to empty into the Okavango Delta in Botswana. In the stretch separating Namibia and Botswana, the Okavango lies on Kalahari sands in a valley some 2-6 km wide and about 30-70 m below the general surface of the land. Mean annual rainfall varies between about 600 and 1100 mm y^{-1}. Information on this river was obtained mostly from Bethune (1991, 1992).

The major tributaries are the Cubango and the Cuito. Inflow of the Cuito nearly doubles the mean annual runoff of the main channel (from 5600 x 10^6 m^3 y^{-1} at Rundu to 10 500 x 10^6 m^3 y^{-1} at Mukwe). Because the Cuito traverses swamps in Angola, it has more constant flow and later flood peaks than does the Cubango. From the confluence with the Cuito, the floodplain is narrower and the channel is braided, forming islands supporting riverine forest (because of faults in quartzite outcrops) and backwater refuges for fish. In the dry season the surface area of the floodplain is about 119 km^2 and in the wet season it may expand to 434 km^2. As well as supporting large populations of fish, floodwaters are important for replenishing nutrients and silts. Until recently, flood waters would normally remain on the floodplain for 1-5 months of the year. In recent years, though, floods have tended to last for no more than a month or two. Whether this is due to climatic conditions or environmental degradation is not clear.

Only two streams emerge from the Okavango Delta itself. One enters the Makgadikgadi Pans and the other Lake Ngami, which has been dry since 1860. The biggest Namibian tributary is the Omuramba Omatako (an *omuramba*, pl. *omiramba*, is a vegetated riverbed). When flooding, the Okavango sometimes runs up the Omatako, forming a huge wetland. Floods coming down the Okavango from Angola reach Rundu in March or April, and the delta in June. Lowest water levels in the delta are reached in November.

The water of the Okavango River is generally very low in salts (conductivity <10 mS m^{-1}) and nutrients, although nitrate values are known to have reached 4 mg l^{-1} N and phosphate 0.2 mg l^{-1} PO_4 on occasion (Hay 1995). The soils are poor, but richer silts brought down with floodwaters from Angola provide some nutrients so that the floodplain supports crops such as millet or maize, as well as fruit trees such as custard apple, marula and monkey apple. Close to the river, most people abstract water directly but further away they rely, both for household use and for irrigation, on the large alluvial aquifer that underlies the riverine area. The floodplain is used for small-scale crop farming, hunting and grazing during the dry period, and during the whole year for harvesting reeds for building and weaving.

Traditional homes and villages often make use of a great deal of wood. Deforestation of northern alluvial terraces is taking place so that the wood can be used for fuel and for carving, as well as for building. However, according to the Forestry Act of 1952 it is illegal to remove living trees, bushes or shrubs from within 100 m of a watercourse (du Toit & Sguazzin 1995). A combination of deforestation and overgrazing results in increased turbidity of the water, siltation and alteration of habitat for aquatic organisms, including fish (van Zyl & Hay 1994), and can ultimately affect flow patterns and floods. Brown (1992) suggests that over 70% of riparian forest may already have been lost from the Namibian section of the floodplain.

A major water-resource development is likely to be the abstraction of some 20 x 10^6 m^3 y^{-1} from the Okavango at Rundu for inter-basin transfer to Windhoek (see section 1.5.1.1). Although this is a small proportion of the mean annual flow, abstraction of water from the river already causes noticeable effects in periods of low flow (B. van Zyl, pers. comm.).

Only about 15 km of the Okavango River (3% of its length in Namibia) is incorporated into a protected area, the Mahango Game Reserve, which formally extends halfway into the river along its border (Curtis *et al.* 1998).

2.1.2.4 The Caprivi

The Caprivi is bordered by the Kwando/ Linyati Rivers to the south and west, and the Zambezi/ Chobe Rivers to the east. Drainage is unusual as the land is so flat: normally water flows down the Kwando to the Linyati Swamps, and ultimately some enters Lake Liambezi. This has not happened for several years, though, and Lake Liambezi has been dry since 1985. When full, the lake reaches a depth of about 6 m and a surface area of about 10 000 ha, overflowing into the Chobe River and from there into the Zambezi. When Lake Liambezi is dry, however, the Linyati Swamps and the Chobe River are not connected, so when the Zambezi is in flood, water pushes up the Chobe to Lake Liambezi (Schlettwein *et al.* 1991). Lake Liambezi had dropped 4 m between the period of high water in 1979 and the point at which it dried up in 1985.

Because the land is so flat, very small floods can inundate very large areas of land. Indeed, about 30% of the entire Caprivi area is part of one floodplain or another. The wetlands change extensively with the seasons: people can graze cattle there or grow crops when grasses develop during dry periods, while in the wet season the land may be inundated.

One of greatest threats to the continued health of the wetlands is overgrazing. About 60% of the population is concentrated on about 30% of the land, mainly in the eastern floodplain. The carrying capacity for cattle is approximately 30 000 - 40 000, but approximately 96 000 head of cattle actually graze there (Schlettwein *et al.* 1991). Other threats include overpopulation, pesticides and poor land management, resulting in loss of habitat for native species. Large-scale poaching (mostly of elephants, hippo, lechwe and buffalo) has resulted in areas left with no large mammals, and therefore with little appeal to tourists. Overgrazing and overfishing are as much a problem here as they are in the rest of the border area.

Namibia has 620 bird species, of which 430 have been recorded in the Caprivi. At least 73 of these are endangered, mostly because of loss of habitat and the use of pesticides: dieldrin against tsetse flies on the Linyati and Kwando Rivers, and others such as DDT against malaria mosquitoes. Two seriously invasive alien aquatic plants found in the Caprivi are Kariba weed *Salvinia molesta* and Nile lettuce *Pistia stratiotes*. People living away from the immediate area of the rivers rely on groundwater, mostly reached by hand-dug wells. The water is easily polluted if these are not fenced off from stock animals and kept separate from pit latrines.

A large part of the Caprivi is protected in the Caprivi Game Park, which stretches from Andara to Kongola. Mamili National Park was proclaimed to protect the Linyati Swamps, and Mudumu National Park to protect the Kwando River floodplain. The existence of such large protected areas is a matter of some contention with the local populace, and MET is considering recommending deproclamation of part of this park (H. Kolberg, pers. comm.).

2.1.2.5 **The Orange and Fish Rivers**

The Orange River, which forms the southern border of Namibia with South Africa, is the largest river south of the Zambezi. In its lowest reaches it is allogenic, meaning that it obtains almost all of its waters from wetter areas upstream: only 1.8% of virgin runoff at the mouth is generated below the confluence with the Vaal. Although the Orange River is dammed upstream in South Africa, there are no dams on the lower river. Nonetheless, so little water is allowed downstream by the dams that on occasion the river ceases to flow to the sea. Aspects of the biology of the river can be found in, for instance, Cambray *et al.* (1986). The Fish River is a southward-flowing tributary of the Orange, draining the south-central parts of Namibia. It is dammed by the Hardap Dam.

The southern border region is poorly populated. Some irrigation presently takes place, but most inhabitants rely on groundwater or water abstracted directly from the river. Because of the wild and scenic nature of the rivers, and the lack of pollution in the area, they are major tourist attractions. In particular, canoeing, rafting, camping and hiking trails are the most valuable activities relating to tourism (du Toit & Sguazzin 1995). Several irrigation schemes are also being considered. A section of the lower Fish River is protected in the Fish River National Park but none of the Orange River is protected in this way.

2.1.3 The Karstveld, sinkhole lakes and caves

The Karstveld, about 2500 km^2 in extent, is an area of calcareous rock formations that have been dissolved and eroded underground and now contain massive underground water stores, most recharged directly from rainfall. Dragon's Breath Cave contains the largest underground lake in the world. As well as the underground lakes and caves, this region has several unusual sinkhole lakes, including Lakes Otjikoto, Aigamas (surface area 18 x 2.5 m, depth 30-50 m) and Guinas (70 m^2 in surface area and about 120 m deep), which support populations of endemic fish and other organisms. Groundwater is abstracted from the Karstveld aquifers for domestic, irrigation and other purposes for the entire Tsumeb-Otavi-Grootfontein region. The mines in the region have to be constantly "dewatered" to prevent flooding.

The river drainages include shallow sandy rivers (*omiramba*) flowing towards north and east; the largest is the Omuramba Omatako, which is dammed by the Omatako Dam as part of the ENWC. This river seldom floods but, because it is blocked by sand dunes in various stretches, develops fairly extensive wetlands at times. The north-western part of this region is sandy, with little or no surface water. Most boreholes are about 100 m deep.

Some irrigated crops are produced in the Karstveld region and in the past this area has supplied all the maize meal needed by Namibia (Ward 1994).

2.1.4 The pans and rivers of the Otjozondjupa and Omaheke regions

According to Lancaster (1974), the pans of the Kalahari in eastern Namibia and western Botswana are probably fossil landforms, having been formed by deflation under wetter and cooler climatic conditions. With the exception of a valuable paper by Hines (1993), mostly on these systems as bird habitat, practically nothing has been written about them. Their limnology is still virtually unknown. As systems that fill ephemerally, and most often seasonally, they seldom provide any direct sustenance to local human communities. Because they may retain water for some months, though, some of them are being used to grow crops or sustain livestock. The Ju' /Hoan San people of the Tsumkwe District have set aside land adjacent to and including some "Bushmanland Pans" as a conservancy for hunting and gathering (P. Barnard, pers. comm.). Various thermal waters also occur in this region.

In the east, the Nossob and Auob Rivers are blocked by Kalahari dunes but subsurface water supports farms in the area. The Otjivero Dam on the White Nossob contains a silt dam. Silt dams are built slightly upstream of main storage dams to intercept the bulk of silt washing downstream. Significant quantities of water may be retained within the sediment to provide a usable supply. Most towns are supplied with water by their own small dams. For instance, Rehoboth is supplied by a dam on the Oanob River, from which experimental releases of water are now underway in an attempt to prevent damage to *Acacia* forests downstream.

Preserved natural areas (PNAs)

Although 13.6% of the country consists of preserved natural areas, the distribution and functions of these areas were not well planned. For instance, the three desert parks, plus Etosha National Park, make up 85% of PNAs, which leaves less than 1% of the non-desert areas preserved. As far as wetland areas are concerned, it seems strange that virtually no parts of the Kunene and Okavango Rivers, and the oshanas, are included in PNAs, even though it is these regions that represent by far the most biodiverse aquatic systems in the country. The fact that consideration is being given to the deproclamation of part of the Mudumu National Park does not bode well for further protection of the northern border area.

Suitable Ramsar sites (wetlands of international importance, especially as waterfowl habitat) are either already proclaimed, in which case management plans are being developed for them, or Ramsar status is being sought for them (e.g. Hines & Kolberg 1996).

2.1.6 Summary

Except for the most arid desert areas, virtually all of the deep-water wetlands of Namibia are degraded to a greater or lesser extent, as a result of abstraction of water for human use, or of overexploitation of wetland resources, or both.

2.2 Key resources

2.2.1 Biodiversity

It is clear from section 2.1 above that Namibia is fortunate to have a wide diversity of aquatic ecosystems, some of which are very rare on a worldwide scale. The taxonomic diversity of these wetlands is less well known, although some progress has been made in providing lists of species of different kinds for various wetlands (e.g. Brain 1980, Day 1990, Bethune 1991, van der Waal 1991a, van der Waal 1991b, Curtis 1991, Holtzhausen 1991, Bethune & Roberts 1991, Griffin & Channing 1991, Channing 1991, Griffin & Grobler 1991, Hines 1991, Channing & Griffin 1993, Skelton 1993). As part of its responsibility to the Biodiversity Convention, a biodiversity information system is being developed by DEA and a book (P. Barnard, in press) is being written on the biological diversity of Namibia.

2.2.1.1 Endemics

Because of the isolated nature of many wetlands in Namibia, and of the island nature of Namibia as a centre of aridity, one might expect many taxa to have endemic representatives. This is certainly true for some groups of crustaceans such as the ostracods (e.g. Martens 1984) and branchiopods (e.g. K. H. Barnard 1924, Hamer *et al.* 1994) and frogs (see also Curtis *et al.* 1998). The taxonomy of many other groups is too poorly known at present for definitive statements to be made about levels of endemism.

.2 **Species richness**

It is very difficult to provide details of the comparative species richness of different types or areas of wetlands in Namibia, but it is generally agreed that the northern rivers, and particularly their floodplains, are the richest in species, probably by an order of magnitude or more for most taxa, certainly for most vertebrate taxa (e.g. S. Bethune, M. Griffin, H. Kolberg, R. Simmons, pers. comm., and see Curtis *et al.* 1998; P. Barnard, in press).

2.2.1.3 **Freshwater fish**

Although Namibia is an extremely arid country, and has no perennial rivers except at its borders, the Namibian freshwater fish fauna is fairly rich, about 103 species having been recorded (van Zyl & Hay 1994). Almost all of these are associated with the floodplain wetlands of the Okavango and Zambezi catchments. Although only three species are endemic to the interior of Namibia (Table 3 and Holtzhausen 1991), and a number confined to one or more of its bordering rivers. As is commonly the case with organisms exhibiting restricted distribution, many of these species are classified as "rare" (Skelton 1993). Table 3 lists the habitats, distribution and conservation status of these species. Most species with limited distribution also have populations in the Zambezi, Kafue or Zaïre (Congo) Rivers, but the 14 species listed in Table 3 have no populations outside of Namibia or its shared border rivers. Note that the issue of freshwater fisheries in Namibia is discussed in detail in section 3 below.

2.2.1.4 **Other resources**

As well as water, natural resources obtainable from wetlands include

- plants such as grasses that can be used for fodder
- reeds for thatching
- palms and reeds, and dye plants, for basketry
- crops for food
- herbs for traditional medicines
- trees for building houses and palisade fences, and for fuel
- clay for pottery
- wildlife for eating or for attracting tourists.

Some data are available on these resources (e.g. Marsh & Seely 1992, Jacobson *et al.* 1995, le Roux 1996) and their economic value (reviews in Richardson 1998; P. Barnard, in press).

2.2.1.5 **Uniqueness**

Namibia has some unusual and interesting wetlands and wetland biotas, particularly in the arid Namib Desert and Karstveld system where there are numerous endemic species and genera (Curtis *et al.* 1998). There are apparently no endemic families. Several types of ecosystems, such as the hypersaline springs, are found only rarely, and only in arid environments. They are particularly conservation-worthy, although they are not strictly speaking unique.

ıe 3. Fish endemic to Namibia, or those with distributions limited to Namibia and its ɟering rivers (data from Skelton 1992).

	distribution	habitat	conservation status
neria maydelli Kunene kneria	Kunene River	silt-free rocky streams	rare: distribution very limited
Barbus breviceps shorthead barb	Kunene & Okavango Rivers	no data	rare
Barbus hospes Namaqua barb	lower Orange River	open water and backwaters	rare (may benefit from regulation of flow)
Labeo ansorgi Kunene labeo	Kunene & Quanza Rivers	flowing water on rocky bed	limited distribution
Clarias cavernicola cave catfish	Aigamas cave near Otavi	clear, open water	endangered: depletion of groundwater
Clariallabes platyprosopos broadhead catfish	Okavango and upper Zambezi Rivers	rocky rapids of large rivers	rare
Chiloglanis fasciatus Okavango sucker-mouth	Okavango & Kwando Rivers	rocky rapids, fringing vegetation, in currents	limited distribution
Nothobranchius sp Caprivi killifish	Caprivi	temporary pans (aestivate as eggs)	rare; endangered by roadbuilding, pollution
Orthochromis machadoi Kunene dwarf happy	Kunene River	poorly known	limited distribution
Chetia welwitschi Angolan happy	Kunene, one tributary of the Zaire River	no data	rare
Thoracochromis albolabris thick-lipped happy	Kunene River	rocky habitats	limited distribution
Sargochromis coulteri Kunene happy	Kunene River	no data	limited distribution
Sargochromis gracilis slender happy	Kunene River & Cutato trib.	no data	limited distribution
Tilapia guinasana Otjikoto tilapia	L Guinas (introduced to L Otjikoto)	vertical "shores"	endangered: loss of groundwater

2.2.1.6 **Alien organisms**

Namibian ecosystems suffer from the effects of numerous alien species, many of which are associated with wetlands (Table 4). Some pose severe threats to ecosystem functioning or biodiversity. In the west, almost all invasive plants occur in riverbeds and/or at waterholes, where permanent water occurs below the surface. In less arid regions, some invasives may also occur on other disturbed ground. The oshanas represent an ecosystem where major invasions of fish have taken place as a result of inter-basin water transfers.

Table 4. The more important invasive alien organisms in aquatic and riparian ecosystems in Namibia (mostly from Brown *et al.* 1985).

Taxon	**common name**	**biotope**	**distribution**
PLANTS			
Argemone ochroleuca (Papaveraceae)	Mexican poppy	wastelands, dry riverbeds	widespread, including Caprivi
Bambusa balcooa (Poaceae)	bamboo	riparian	Zambezi River at Katima Mulilo
Chenopodium ambrosoides (Chenopodiaceae)	goosefoot	rivercourses and around dams	scattered
Datura spp. (Solanaceae)	thorn apples	widespread in dry riverbeds	central Namibia
Mangifera indica (Anacardiaceae)	mango	rivercourses	Caprivi
Melia azedarach (Meliaceae)	syringa	riparian and elsewhere	north-central and Caprivi
Myriophyllum aquaticum (Halogoraceae)	parrot's feather	floating aquatic	Ovamboland
Nicotiana glauca (Solanaceae)	wild tobacco	riverbeds, road verges	most of central and southern Namibia
Opuntia spp (Cactaceae)	prickly pear	widespread, including riverbeds	northern parts, including Caprivi
Pistia stratiotes (Araceae)	Nile lettuce	floating aquatic	Calueque, Caprivi
Prosopis glandulosa (Fabaceae)	mesquite	widespread, including rivercourses	a noxious invader in all drier areas
Psidium guajava (Myrtaceae)	guava	riparian bush	Caprivi
Ricinus communis (Euphorbiaceae)	castor-oil plant	riverbanks, floodplains	north & central coast; Okavango, Caprivi
Sacchurum sacher (Poaceae)	sugarcane	riparian, floodplain	Caprivi
Salvinia molesta (Pteridophyta)	Kariba weed	floating aquatic	Caprivi rivers, Lake Liambezi
Tagetes minuta (Asteraceae)	khaki weed	riverbeds and disturbed areas	north-central
Pistia stratiotes (Araceae)	Nile lettuce	aquatic	

Table 4 (continued)

FISH			
Cyprinus carpio (Cyprinidae)	common carp	prefers standing waters	in Omatako drainage, so might enter Okavango
Micropterus salmoides (Centrarchidae)	largemouth bass	prefers slow-flowing or still waters	widespread, including Swakop and Omatako
Oreochromis mossambicus (Cichlidae)	Mozambique tilapia	tolerant of most conditions	widespread, L Otjikoto
Poecilia reticulata (Poeciliidae)	guppy	still waters	L Otjikoto[1]
Tilapia guinasana (Cichlidae)	Otjikoto tilapia	L Guinas	L. Otjikoto[1]
Xyphophorus helleri (Poeciliidae)	swordtail		L Otjikoto[1]

[1]de Moor & Bruton (1988)

2.2.2 Summary

Although specific areas elsewhere are conservation-worthy, there is no doubt that the *key localities* with regard to valuable wetlands, biodiversity and human use are the northern border areas: the oshanas, the land near the Okavango River, and the Caprivi.

A major conflict arises in the fact that these areas are all on extremely valuable communal land and so what management there is, is communal. Except in the Caprivi, no conserved land is available to preserve biodiversity or wetland communities. It is unlikely, given the number of people depending on this land, that any will be given over to conservation in the traditional sense, although there is excellent potential for community conservation management.

Monitoring, and even basic quantitative information on many stocks, is inadequate, simply because MET and MFMR do not have sufficient funds or staff to do such jobs. USAID might consider funding one or more of DEA's planned Environmental Profiles (on areas other than the Caprivi, for which a profile is already being done).

3 The freshwater fisheries of Namibia

Most of the information quoted here is from Dr Ben van Zyl (pers. comm.), van der Waal (1991a, 1991b), Tvedten *et al.* (1994), Hay (1995) and the White Paper on Inland Fisheries. In particular, Tvedten *et al.* provide a valuable assessment of the socioeconomic aspects of the subsistence fisheries of Namibia.

Although the quantity of freshwater fish caught and consumed, and the commercial value of the catches, is vastly less than that of the marine fishery, freshwater fish form a vital part of the diets of many people subsisting near the Okavango River, in the Caprivi and, to a lesser extent, in the oshana region of the Cuvelai drainage. Virtually all of the inland fishery is artesanal. It has been estimated that approximately 50% of the Namibian population relies on fish for half of their protein needs, but this figure does not distinguish between the consumption of marine and freshwater fish.

According to the draft White Paper (December 1995), approximately 2800 tons of freshwater fish are caught in Namibia each year. Although the UN Institute for Namibia (1986, cited in Tvedten *et al.* 1994) estimated that this could be increased to 15 000 tons per year, it is widely considered (e.g. Hay 1995) that the maximal sustainable yield has already been reached, or even surpassed, in most regions. The figures of 150 and 350 tons *per annum* given by McCullum (1994) are incorrect; see for instance van Zyl & Hay (1994). About 750 people are permanently employed in fishing, and some 64 000 people take part in fishing at least now and then. More than 100 000 people derive direct or indirect benefits from inland fish resources and the fish supply *per capita* is approximately 10 kg person^{-1} y^{-1}, which is about 10% of their total consumption of animal protein.

3.1 Fish populations and fishing in the major rivers

3.1.1 The Kunene River

Although 68 species have been recorded from the Kunene River (Holtzhausen 1991), fishing is not of any significance to the economy or to the subsistence of communities in the area, partly because the region, being extremely arid, is very sparsely populated, and partly because the Himba and Herero peoples of the region are not traditionally fisherfolk (B. van Zyl, pers. comm.). van Zyl comments that local communities even reject gifts of fish that have been caught for research purposes.

Very little information is available on the biology of the fish in the Kunene River, and so a good deal of research needs to be done in this regard. It has been noticed, however (van Zyl & Hay 1994) that breeding of *Tilapia rendalli* has been affected by the large (>1 m) daily fluctuations in water level resulting from operation of the hydroelectric scheme at Ruacana.

The Kunene represents the southernmost distribution of the freshwater prawn *Macrobrachium vollenhovenii*, which might be developed as a subject of aquaculture.

According to Tvedten *et al.* (1994), traditional laws in this region of the country were designed to protect water resources, not fish. Local communities are generally opposed to the use of modern fishing gear, which tends to reduce the value of river water for watering their stock animals, and wish to have State regulations to assist in the proper management of fisheries in their area.

3.1.2 The oshanas of the Cuvelai drainage

Oshanas temporarily fill with water only after sufficient rain has fallen in their headwaters in Angola, and so most of the time there is no water, and thus no fish, in the dry drainage lines. During floods, though, fish move southwards from their normal habitats in the perennial rivers of Angola. Enormous numbers may move southwards during reasonably large floods, which may, however, occur on average only once in every four to five years. Thus fishing is very episodic and the population cannot rely on fish as a regular source of food. When the fish reach the oshanas, they are essentially "genetically dead", in that neither they nor their offspring will survive the forthcoming drought. So although catches can be very high (van der Waal 1991*b* has recorded 4200 kg of fish being caught at the culverts of seven oshanas in a single day), even massive exploitation will have no effect on the parent population. Thus there is no need to conserve these fish in the oshanas, although it is essential to do so in Angola (Marsh & Seely 1992). A more significant factor locally is that, when floodwaters are flowing, intensive fishing in the upper parts of the oshanas may prevent fish from reaching fishermen further downstream.

Marsh & Seely (1992) note that the most important fish caught in the oshanas are *Clarias* spp. (barbels), *Barbus paludinosus* (the straight-fin barb), and *Oreochromis andersonii* (the three-spot tilapia). Catches may be as much as 150 kg per person per day, especially using funnel nets (van der Waal 1991*b*). Most of the catch is dried and sold, or stored for the long period between floods. An informal trade in dried fish is carried on with Angola (especially of *Clarias* and *Labeo* spp.) and with the eastern Caprivi (mostly large catfish and cichlids). Local trading in dried fish consists mostly of catfish and cichlids from Lake Olushandja, and catfish from Lake Oponono.

Seventeen species of fish are known to have occurred naturally in the oshanas, but a further forty-six exotic species have invaded the drainage system since the water-supply canal from the Kunene River was opened. The connection was initiated as a canal linking most of the more eastern oshanas so that floodwaters could be directed to deep reservoirs. From 1972, water was pumped from the Caluque Dam on the Kunene River via Lake Olushandja to Oshakati. Presently a lined canal takes water from the Calueque Dam to Ogongo and the Olushandja Dam for distribution to local communities. Of the 46 species that have on occasion been translocated from the Kunene to the oshanas, only three, all cichlids, have been seen to breed in the oshana system. Nonetheless, the genetic identity of the other species may well have been lost (Marsh & Seely 1992).

Only a small number of people engage in oshana fishing. This fishing is nonetheless important, not least because local people prefer freshwater to marine fish (they will eat marine fish, but will pay less for them than for freshwater fish). The value of fishing is also considered secondary to using water for washing, cooking and stock watering.

Traditionally, local headmen had jurisdiction over fishing rights (Tvetden *et al.* 1994). This traditional type of management seems to have died out, although it was recorded as recently as 1976 (van der Waal 1991*b*).

Not much aquaculture is presently carried out in the oshana region, although a hatchery at Mahanene provides catfish and three-spot barb fingerlings to about 50 part-time farmers who grow the fish in semi-permanent artificial ponds or deepened oshanas. The conflict of ownership of fish farms on communal land has yet to be resolved (Marsh & Seely 1992). Because of fears of introducing *Oreochromis mossambicus* into the Cuvelai, Kunene and Okavango Rivers, all the populations of this species at the Mahanene hatchery have been destroyed.

3.1.3 The Okavango and Zambezi drainages

The Okavango and eastern Caprivi rivers (Kwando, Linyati, Chobe and Zambezi) have extensive floodplains, and many of the species of fish found in these rivers rely on floodplains for breeding, feeding, or both. The total number of species of fish recorded from the Okavango River is about 79 (Hay 1995) or 80 (van Zyl & Hay 1994), and from those of the eastern Caprivi about 76 (Holtzhausen 1991). Several species are rare because of their specialised food requirements or habitat preferences. Lake Liambezi supported 43 species before it dried up in the late 1980s. The human populations of these regions rely heavily on fish as a source of protein in their daily diets. Of the two systems, the Okavango is under greater pressure because it is smaller and has a relatively larger population.

3.1.3.1 The Okavango

According to Tvedten *et al.* (1994), in 1994 the National Planning Commission (NPC) indicated that about 160 000 people were living in the Okavango Region, about 80% of them within 5 km of the river itself. The growth rate of the human population was >3% per year. Shortly before this time, van der Waal (1991*b*) had estimated that about 840 tons of fish were being caught per year on the Namibian side of the border; by 1995, the quantity had risen to nearly 1000 tons (Hay 1995). Because of the war, the quantity caught on the Angolan side is unknown, but is probably very small. Hay (1995) believes that the size of this catch comes close to, or even exceeds, the maximal sustainable yield for the system, since stocks seem to be declining, as are the sizes of individual fish caught, and the proportion of long-lived species in total catches.

According to Hay (1995), the favoured method of fishing is to use traps, sometimes baited, in shallow muddy areas. If the water is deeper, fish corrals are used, or rod and line. During the receding phase of the flood, fences may be placed to prevent the fish from returning to the main stream. These days, as well as scoop baskets, bows-and-arrows and spears, mosquito-nets and shadecloth may also be used. Some fishermen make use of cast-nets and gill-nets, many of which are in poor condition.

Hay (1995) recommends that, in order for fishing in the Okavango to be maintained at sustainable levels, the following steps must be taken:

- restrictions on the use of non-traditional gear, including specification of the allowable sizes of gill-nets;
- control over number and length of nets;
- a ban on fish poisons, explosives and drag-nets, and of any other gear that could span more than half the width of river;
- control of livestock grazing on the riverbanks;
- reduction in fishing effort during periods of low flow but increased intensity in peak flood season, when there are "excess" fish in the form of juveniles;
- proclamation of closed areas.

Hay stresses that these measures must be introduced on both sides of the border, and must be accompanied by education of the local communities.

According to Tvedten *et al.* (1994), most fishermen prefer traditional methods ("passive" traps), especially when they also have to spend time on agricultural pursuits: most farmers own about 4 ha of land, on which they grow a variety of crops, as well as fishing for a living. All use traditional gear, and many prefer it because it is easy to make and use, and cheap to produce. Farmers may use traditional, "passive" gear during winter, when they need to spend a lot of time cultivating their fields, but more active, "modern" methods at other times when they are not so busy. "Modern" gear includes mosquito nets, mostly used by women, and sometimes brought into country by the World Health Organisation. These very small-meshed nets trap fish of all sizes, including young fish that therefore never reach breeding age.

It is generally agreed that tribal fishing customs are breaking down, especially among the young. The effectiveness of traditional management is being eroded by pressure on natural resources, by increasing socio-economic stratification and commercialisation, and by the shift of political authority from traditional leaders to the central government. Furthermore, most fishermen also keep livestock as a form of wealth and most families have some money from wages earned elsewhere. Changes in ecosystems, including destruction of fish habitats, and reduced and inadequate floods, are altering the fishery. Grazing on and harvesting of reeds and grasses also contribute to the degradation of the riverine environment, as does stamping by large numbers of women attempting to attract fish.

Many residents agree that stocks appear to be declining and that careful management is needed. In fact, the local people seem to have a good understanding of the relationships between fish and environment, including the effects of reduction in flows and flooding, increased quantities of sand on the beds of rivers, and the loss of reeds (and their replacement with trees). Several people questioned by Tvedten *et al.* (1994) seemed to think that things were better on the Angolan side of the border, despite the activities of UNITA, because there are more reeds, better hiding spots for fish, and not so many trees, for instance. While local people seem to understand these effects, they tend not to see pollution as a problem. Many have no toilets, so they use the river for washing and the disposal of human excreta. They may also use "chemical" fertilisers, and DDT and related insecticides to combat mosquitoes and tsetse flies. According to P. Barnard (pers. comm.), DDT is still used officially by the Ministry of Health and Social Services for control of malaria vectors.

In general, people have some idea of management practices, but these are not very well defined. Many communities have agreed that a particular traditional poison is "bad" and most people, except for the old men, will not use it. Nets are generally seen as socially unacceptable and illegal, but are nonetheless often used: a successful catch is less and less attributed to skill or magic, and more and more to the possession of a net. Much confusion still exists about what is legal and what is not.

3.1.3.2 The Caprivi

Tvedten *et al.* (1994) show that 15% of households see fishing as an important source of income, that 20% of people are involved in fishing, and that 82% of fishermen market at least a portion of their catches. The annual value of the catch is approximately N$9 million and the average monthly income of households involved in fishing is N$474, of which fish represent about 40%. Fishing is not only a source of income, but also an important source of protein: most local people consume about 400 g of fish per week. The only freshwater fish market in Namibia is in Katima Mulilo, where some fish are kept on ice for tourist consumption.

Traditional management of fishing rights concerned the securing of access to fishing areas. Roughly, rivers were demarcated into zones, each belonging to a ward or village under the jurisdiction of a headman. In practice, subzones tended to belong to each village, and outsiders had to ask for permission to fish, so that rights were ward- and village-based. In floodplain depressions or *molapos*, individuals or households had territorial rights to plough and fish in specific plots. Access to fishing was free on the floodplain proper: for instance, people came from all over for the short, hectic fishing season at Katima Mulilo.

Although traditional methods and management are still practised in some areas, they no longer apply in the area of the Mamili National Park and are breaking down with the decrease in fish stocks in the Kwando/ Linyati system. Further, both traditional fishermen and traditional leaders are losing their authority in areas (near Katima Mulilo, for instance) where "progress" is most rapid and pressures are greatest. In the eastern floodplain, management systems are still mostly traditional, actively implemented and supported by local fishermen.

Tvedten *et al.* (1994) provide the following interesting and important analysis of the socio-economic situation in the Caprivi. People in the Caprivi are "better off" than in most of the rest of the country, in that traditional culture continues to be of importance, especially in the rural areas. But the fisheries are under severe pressure. After several years of inadequate floods, fish stocks are low and whole areas have become severely modified. For instance Lake Liambezi, which is 3.5 - 5 m deep and covers approximately 10 000 ha when full, has been entirely dry since 1985 (there is some argument as to whether the lake will ever fill again naturally). Long stretches of important rivers such as the Kwando and Linyati are choked with reeds, possibly as a result of a decline in the numbers of hippos. Overfishing has resulted from a combination of environmental changes and increased fishing pressure from modern gear. Traditional fisheries management practices have disintegrated in the larger centres. Political and other disputes with Zambia and Botswana exacerbate the problem. Local politics also play a role. Caprivi has three representatives on the National Assembly, two from the DTA, one from the UDF, and none from SWAPO. Relations with the central government are sometimes "strained". Further, Regional Councils are supposed to manage natural and other resources, but so far they have few economic resources with which to work and entirely inadequate data for managing the fishery.

The dichotomy between rich and poor continues to grow. Poorer households cannot allocate sufficient time to make fishing effective, certainly not unless they use (if they can afford to) modern gear like gill nets and drag nets. About 90% of the population now uses modern gear, whereas traditional gear was common in the mid-1970s. Further, women are not "supposed" to fish, even if they are, as frequently occurs, head of their household. Thus, a typical vicious cycle of poverty and unsustainable environmental exploitation has been set up.

3.1.4 **The Orange River**

Because of its temperate climate, and the vagaries of the evolutionary history of fish in southern Africa, the Orange River supports only 17 species of fish in the stretch that forms a common border between South Africa and Namibia. Few subsistence communities live along the Orange River, and so the use of fish for anything other than recreational angling is limited.

3.1.5 **Reservoirs**

The four State dams with greatest fish production seem to be the von Bach (19.1 t y^{-1}), Hardap (124 t y^{-1}), Naute (99.5 t y^{-1}) and Omatako (71.4 t y^{-1}) Dams (van Zyl & Hay 1994). Although van Zyl & Hay suggest that the fish resources in these systems are under-utilised, the few concessions to fish commercially seem not to have been successful in the past.

Small private dams are numerous, but virtually no information is available on their fish stocks or production.

3.1.6 **Fishing lodges**

Fishing lodges, which provide accommodation and opportunities for angling, are becoming common on the border rivers. Presently, according to the White Paper (1995), five are in Caprivi, three on the Kunene and eight on the Okavango. Sport fishing, an important tourist attraction, is organised by the Namibian Freshwater Angling Association. The authors of the White Paper suggest that all licence fees for boats, fishing permits, etc., should be directed to the traditional owners of the land.

3.1.7 **Aquaculture**

Little aquaculture is presently practised in Namibia. Indeed, aquaculture in all the SADC countries formed no more than 2.1% of production (1456 t) in 1988 (McCullum 1994), and is not very much greater now. As mentioned above, a hatchery at Mahanene provides fingerlings for a few local fishermen in the oshanas, and most reservoirs have been stocked with one or more species of fish. C.H. Hocutt (pers. comm.) has suggested that aquaculture in the Caprivi is unlikely to be particularly successful because of the sandy nature of the substrata and the low cost and availability of marine fish. van Zyl & Hay (1995) also indicate that "economically viable intensive aquaculture will probably not succeed unless high quality products are produced." Most aquacultural enterprises in the past have attempted to grow common "subsistence" fish, but without much success, not least because fish food is scarce and expensive.

The best bet seems to be small-scale, semi-intensive commercial fish culture, which would provide good social benefits and profits (Tvedten *et al.* 1994). B. van Zyl (pers. comm.) suggests that some of these high-quality products might include luxury items like prawns or freshwater oysters, a local species of each of which occurs in the Kunene River, or yabbies or marron (*Cherax* spp.) introduced from Australia. However, the introduction of *any* alien species could be extremely dangerous to aquatic ecosystems, and a careful environmental impact assessment would have to be done before any such introduction could be considered.

3.2 Threats

3.2.1 Trends in inland fisheries

There is a tendency for the individual fish that are caught to be significantly smaller than was the case a few years ago. Also, a greater proportion of fish now belong to "*r*-selected" species, which produce large numbers of small, short-lived individuals. This is because fishing gear has changed from traditional gear like baskets and traps to nets and, more recently, from relatively large-meshed (about 150 mm stretched mesh) gill nets to very fine gill nets (stretched mesh as little as 35 mm), or even mosquito-netting and shade-cloth.

Intensive grazing pressure, use of natural resources such as reeds and clay, pollution by pesticides, and physical damage to rivers and floodplains, are all having an effect on the habitats of fish. None has yet caused major damage, but the combined effects of these pressures are substantial cause for concern.

Ashley (1995) says of inland fisheries that

> "Both researchers and local people perceive a decline in fish stock sizes and diversity, attributable to a range of factors including siltation, changed flooding, heavy winter-season grazing, harvesting of reeds and grasses in floodplains, chemical pollution, overfishing ... Because the benefits of wetlands are often long-term, indirect and shared by many people rather than by individual owners or managers, they are often not appreciated."

3.2.2 Difficulties alluded to by MFMR staff

- ***Lack of trained staff***: presently only one biologist is employed by Inland Fisheries, housed at the Hardap Freshwater Fish Institute. Thus lack of staff for monitoring fish stocks and fishing practices, for carrying out research, and for communicating with local communities, is a major problem. It is unrealistic to expect progress in the sustainable exploitation of fisheries stocks if adequate personnel are not available for research and management, let alone for liaison with local communities.

- ***Difficulties in accurate estimations of fish populations*** because of their migratory behaviour and the dependence of some species on floodplains.

- ***The Inland Fisheries Division has been transferred*** from the Ministry for Environment and Tourism (MET) to the Ministry for Fisheries and Marine Resources (MFMR). The Inland Fisheries Division therefore still has to rely on MET policies, which are not always applicable to the northern areas, where most of the freshwater fishing takes place. They are waiting for the promulgation of the White Paper so that they can establish an Inland Fisheries Advisory Board. This can be involved in the licencing of all boats and other gear, and can ensure that the funds generated in this way can be given to local communities so that they will benefit from the sustained use of fish stocks.

- There is some suggestion that ***Inland Fisheries may be transferred back to MET***, but this is not supported by research staff, who recognise that research funds presently accrue from licences issued for exploitation of the much wealthier marine fisheries.

- ***Aquaculture is not strongly developed in Namibia***. B. van Zyl (pers. comm.) feels that this field would best be served if it were transferred to the Department of Agriculture and clear policies were developed. Aquaculture of various species of cichlids has been examined, and the freshwater Australian crayfish (*Cherax* spp.) has been introduced. Given the disastrous history of introductions of alien species in other parts of the world, the possibility of any such introductions must be treated with extreme caution (see Section 3.1.7 above).

- The ***increased abstraction of water***, particularly from the Okavango River, for rural water supply, especially during periods of low flow, is of concern to Inland Fisheries personnel. The perception is that massive central pivot irrigation schemes will cause a decline in fish catches, as will abstraction of water for the ENWC.

- ***Mass-fishing in the Cuvelai*** sometimes stirs up the water to the point that it is so muddy as to be undrinkable.

- ***Proposed production of irrigated and fertilised crops*** in the now-dry Lake Liambezi would likely result in eutrophication. It is also likely that attempts would be made to keep floodwaters out of the lake basin to prevent the lake from re-establishing itself.

3.2.2 Perceptions of the state of the inland fishery by MFMR staff

In general, staff of Inland Fisheries consider themselves to be very well organised; that water quality (including levels of heavy metals) is adequate to good; and that no species of fish have yet been lost. Fish are generally in good condition, the only significant pathogens (a species of the fungus *Saprolegnia*) becoming problematic only at Hardap Dam, and only at certain times of the year. The staff consider that the major problem is human population pressure on resources, both water and fish, within Namibia, and a lack of personnel to carry out the necessary research and monitoring.

3.3 Fisheries policies, laws and regulations

Regulations mostly concern issues such as the types of gear that may or may not be used, open and closed seasons, and bag limits for anglers.

3.3.1 The new Draft Inland Fisheries Act

Significant components of the policies contained in the draft Inland Fisheries Act are

a) to conserve and promote the sustainable use of the freshwater fisheries of Namibia;
b) to protect and conserve the ecosystems and habitats on which freshwater fish depend;
c) to ensure that the benefits deriving from freshwater fisheries are justly and equitably distributed, in particular that traditional and subsistence fisherpeople are not deprived from the resource on which they have historically depended;
d) to enter into co-operative agreements with neighbouring states whose freshwater catchments are shared with Namibia.

A White Paper on the "Responsible Management of the Inland Fisheries of Namibia" by the Section: Inland Fish, Directorate: Resource Management (DRM) of the MFMR was released in December 1995. In the introductory remarks, Minister Hifikepunye Pohamba states that the document has "benefited from inputs made by the communities with a vested interest in inland fish" and that the proposed new legislation would "discourage commercialisation of the resources in unfair competition with traditional fishers".

In summary, the White Paper aims

a) to allow sustainable use but to protect biodiversity, for instance by having closed seasons and closed areas (or breeding sanctuaries), by banning of certain fishing methods, by developing an appropriate licencing system, and by bag limits and size restrictions;
b) to develop different management approaches for different systems;
c) to protect the interests of subsistence households;
d) to control fishing by gear restrictions, giving preference to "passive" rather than "active" gear, and to traditional rather than to modern gear;
e) to police fishing activities using police officers and Ministry officials;
f) to allow local communities to share the income generated from fish;
g) to support research where this is needed;
h) to develop regional co-operation where this is needed.

Recognising that fish in the Okavango and Caprivi are an essential part of food security, the intention is to follow a policy of optimal, not maximal, yields in order to maintain fish stocks. MFMR also recognises, however, that some of most crucial factors involved in the degradation of ecosystems, including deterioration of floodplains through overgrazing, erosion, and siltation, are not under their control. They also recognise that the management of shared rivers is complicated but needs to be continually addressed.

3.3.2 Needs for foreign assistance

As stated in the White Paper, foreign assistance would be valuable for

- infrastructure for research on fisheries and floodplains, and technical assistance on a regional basis;
- training of enforcement officers as efficient extension and "attitude-creating" (sic) agents;
- help in putting into practice the proposals that result from research projects;
- legal advice in negotiations with neighbouring countries.

3.4 Research requirements

van Zyl (1992) stated that the most important research and monitoring needs are:

- a study of the fish of the Fish River;
- quantification of fish production on floodplains and rivers;
- the quantitative relationships between the hydrological cycle and fish production;
- the effects of grazing cattle on floodplains, which are the nursery grounds for some fish;
- the effects of deforestation on riverine ecosystems.

4. Trends and threats

4.1 Natural changes

In any very arid environment there are likely to be fairly rapid and noticeable changes in natural systems as a result of short- to medium-term climatic changes. In Namibia at present, two major changes of this nature are the reduction in the open water and associated wetlands at Sandwich Harbour, and the drying up of Lake Liambezi in 1985. The drying up of Lake Liambezi is related to a period of low rainfall over the last two decades or so. It is difficult to predict whether the lake will re-fill naturally during a wetter period, or whether it will remain dry, as Lake Ngami has since 1860. The floor of the presently dry lake is already being used for crop production and, should the lake be likely to be filled in future, barriers may well be erected to prevent flood waters from inundating croplands.

4.2 Land use

At present, about 45% of Namibia, mostly in the southern and central areas, is devoted to commercial farming. About 40%, mostly in the north where over 75% of Namibians live, is communal land. The rest is devoted to conservation and mining.

The communal land reflects the "tragedy of the commons", where degradation accompanies the over-exploitation of common resources. This is partly because of lack of tenure in these parts, partly because of the massive pressure of a burgeoning human population, and partly because of ignorance, a trait not confined to peasant farmers on communal land. As Ashley (1995) puts it, "Supply of environmental resources and services cannot simply be expanded to match population growth: water cannot be created; resources that are in principle renewable, such as forest, decline if over-harvested; and the most basic ecological functions, such as top soil formation, decomposition and water purification, occur slowly at nature's pace".

4.3 Anthropogenic degradation

The major human-induced changes that have taken place, or are taking place, in Namibia are summarised in Table 5. This indicates the kinds of change, the trends, and the proximal (immediate/ direct) and ultimate (indirect) causes of these changes. In summary, the environmental threats to Namibian wetlands can virtually all be put down to the over-use of finite resources in sensitive ecosystems as a result of a combination of the following:

- ***aridity*** over most of the country, resulting in massive concentration of the population on a very small part of the land;
- massive ***population growth*** resulting in rapidly increasing pressure on natural resources;
- ***loss of traditional resource management practices***, as a result of war; enforced removals of entire human communities; lack of adaptation of traditional practices to increased population densities; new, "high-tech" techniques for exploiting resources (e.g. fishing nets); and a decline in traditional values and social structures;
- ***poverty***: most of the population that uses wetland resources is poor and uneducated, relies almost entirely on natural resources such as wood, fish, crops and wildlife, and has little recourse to other ways of life.

In a sense, some of the trends listed in Table 5 are self-limiting. For instance, when water supplies or fish catches decrease to the point at which fewer people can be supported, then the population must decline, either by starvation or by emigration. The unknown factor is the extent to which wetland ecosystems will be irreversibly harmed before self-limiting degradation in resources reduces demand.

4.4 Human health

Bilharzia and malaria are two of the parasitic diseases intimately associated with wetlands. The larvae and pupae of the mosquito vectors of malaria, and the snails that are intermediate hosts of the bilharzia parasite, are aquatic. Malaria is the world's greatest killer: more than 250 million people suffer from the disease and more than 2 million people, mostly children, die each year in Africa alone. Bilharzia is less frequently fatal, but is debilitating. Anything that increases the area covered by shallow, slowly-flowing or still waters is likely to increase the presence of vectors or intermediate hosts, and therefore to encourage the spread of these diseases. In particular, bilharzia will spread if human hosts are not aware of the connection between human urine and/or faeces and the disease. Water-borne bacterial diseases, particularly cholera and diarrhoea, are usually associated with faecally-contaminated drinking or washing water. Overcrowded conditions, lack of sanitation, unprotected pit latrines and unhygienic habits all contribute to the likelihood of cholera epidemics occurring.

Table 5. Trends in environmental degradation in Namibia, and their proximal and ultimate causes.

Type of degradation	Trend	Proximate/immediate/ direct cause	Ultimate/indirect causes
drop in aquifer water tables	worsening	abstraction of groundwater	aridity: lack of surface waters; provision of water on demand; increased population/ increased water demand
decrease in surface waters	will worsen rapidly	damming, abstraction	aridity: lack of surface waters; provision of water on demand; increased population/ increased water demand
water pollution: pesticides	probably roughly constant	application of toxins to kill mosquitoes, tsetse flies	malaria, sleeping sickness
water pollution: fertilisers	minor but increasing	agricultural practices	sustained food production
water pollution: salinisation	worsening	irrigation, abstraction of water from surface aquifers	aridity: desire to produce food regardless of effects of irrigation
disruption of drainage in oshanas	has occurred	roads and canals	ignorance, lack of planning
decline in riparian vegetation	worsening	use of trees for fuel, construction, carving; grazing stock	overpopulation leading to increased use of resources; poverty leading to reliance on natural resources; loss of traditional management practices*; lack of education
decline in fish populations	worsening	inappropriate fishing gear, overfishing	overpopulation leading to increased use of resources; poverty leading to reliance on natural resources; loss of traditional management practices*; lack of education
degradation of floodplains	worsening	growth of crops; use of trees (construction, fuel, carving); grazing stock; trampling when fishing	overpopulation leading to increased use of resources; poverty leading to reliance on natural resources; loss of traditional management practices*; lack of education

* For instance, Oshiwambo-speaking people traditionally used very large quantities of wood in construction of homesteads.

4.5 Conflicts

Some major potential or actual conflicts include

- setting aside or managing land for nature conservation rather than human occupation in highly populated areas, raising the perception that conservators care more for elephants than people;

- the massive cultivation of cattle, a major form of wealth, even if unproductive, when the land could more productively be used for the cultivation of food for humans;
- the use of water for different purposes such as irrigation, mines, domestic purposes, and the generation of hydroelectric power.

4.6 Summary: environmental "hotspots"

A summary of the major environmental concerns identified in this document follows, in no particular order:

- ***species threatened with extinction***: for instance, the tiny populations of the Caprivi killifish, *Nothobranchius* sp., in gravel pits in the Caprivi;

- ***ignorant interference and lack of consultation*** by well-meaning aid agencies: for instance, the covering of waterbodies with oil by officials of the World Health Organisation, or the capping of wells in former Damaraland by the Red Cross (S. Bethune, pers. comm.);

- ***clearing of riparian vegetation*** on the northern floodplains;

- ***overgrazing by stock animals*** on the northern floodplains;

- the ***settlement of people in new areas*** each time there are good rains, or whenever any water becomes available;

- ***mining of water*** from aquifers;

- ***lowering of the water table*** as a result of exploitation of groundwater;

- ***overfishing***;

- ***poverty***, so that >95% of the population relies utterly on natural resources, mostly on the northern wetlands;

- the continued danger of the explosive growth of ***alien plants***;

- the threat that ***introduced alien fish*** pose to the populations of native fish that are already under pressure from habitat degradation and overfishing;

- ***increased likelihood of water-borne diseases***.

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